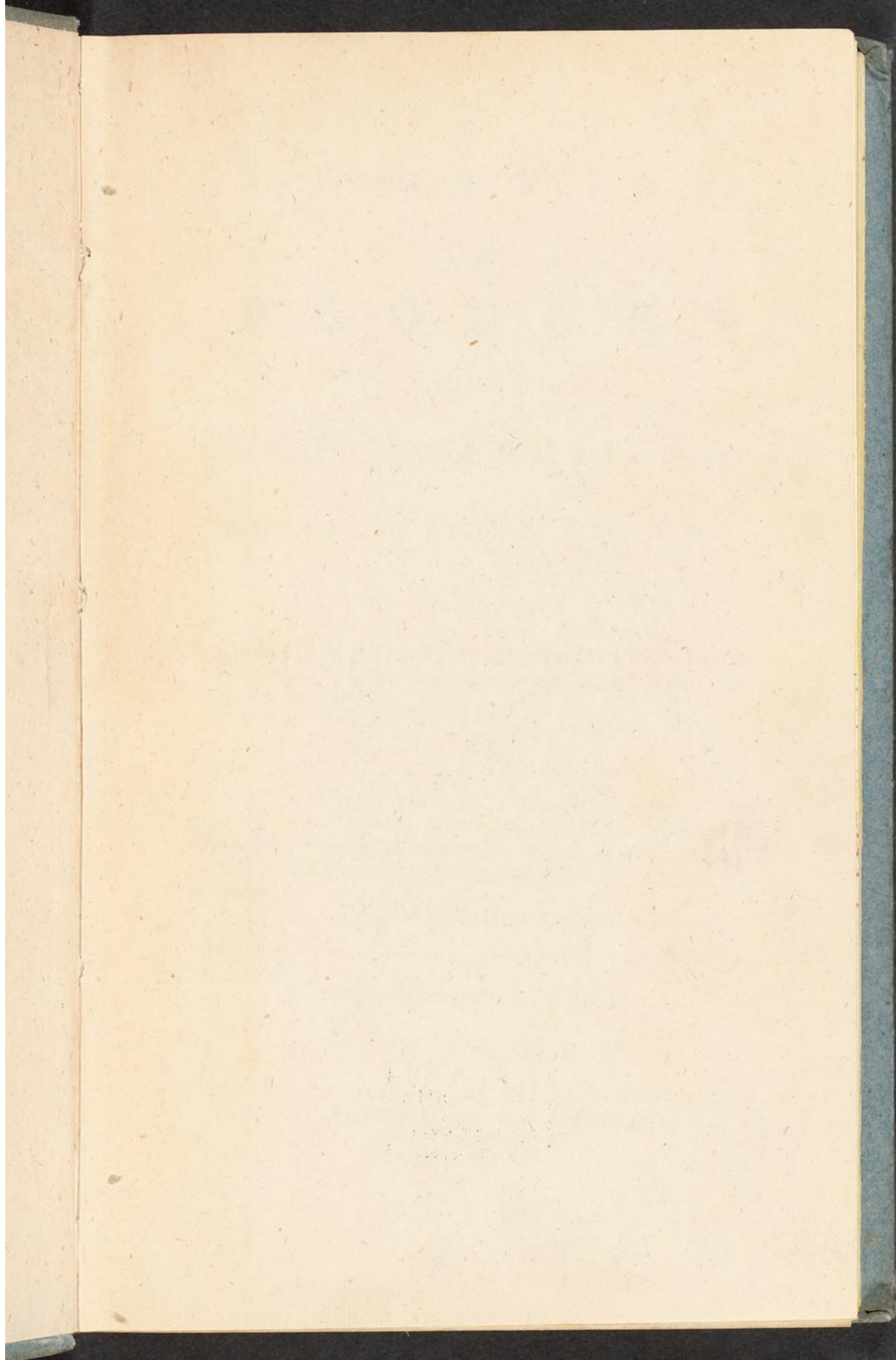


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 W H E E L C A R R I A G E S,
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B Y
 JAMES SMALL PLOUGH AND CART WRIGHT,
 formerly at Blackadder-mount, now at Rose-bank, near
 Foord, Mid Lothian.

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T O
ALEXANDER RENTON
OF LAMERTON, ESQ;
T H I S
T R E A T I S E
I S
MOST HUMBL Y AND RESPECTFULL Y
INSCRIBED,
AS A TESTIMONY OF RESPECT
AND GRATITUDE
F O R T H A T
COUNTENANCE AND PROTECTION
SO LONG AFFORDED

H I S
MUCH OBLIGED SERVANT

JAMES SMALL.

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I N T R O -

INTRODUCTION.

THE Plough is an instrument of such importance in agriculture, that, in all ages, it has held the first place among the implements of that art; nor is there any nation mentioned in history, who have attempted to cultivate the ground without it, excepting some Barbarians, destitute of every art and science. And even these have used something equivalent, some turning up the ground with the horns of oxen, and some with other things equally unfit. These rude and barbarous attempts only show the great usefulness of the instrument of which I propose to treat.

A

Though

ii INTRODUCTION.

Though many of the ancient nations understood agriculture very well, and had invented ploughs of different forms, all of them seem to be inferior to some of those lately introduced among us. Although the ancients had made great progress in the arts of life, their knowledge of mechanics was more imperfect, and less diffused, than among us, and therefore their improvements will not bear a comparison with those which have taken place within these two last centuries.

It is somewhat strange, that, amidst all the improvements which have been made during this period, the plough should have remained almost in the same state, till within these last fifty years. The truth is, that it has been
neglected

INTRODUCTION. iii

neglected by those persons who have turned their attention to machines, as a rude tool, unworthy of their attention. Such persons imagined that any thing could do for the clumsy operation of turning up the ground, and that there could be no nicety in a work which was successfully performed by the ignorant peasants. Other persons have imagined, that it is impossible to explain the principles by which the plough performs its work. If this be true, we must act at random in making this important instrument, without knowing whether we are right or wrong, except by the event; and if the plough should not answer our purpose, our attempts to amend it must be without rule, and as liable to error as before.

Both

iv INTRODUCTION.

Both these opinions are very erroneous, and the maintaining them would be productive of very bad consequences, by checking the improvement of agriculture: For, although our knowledge of the nature of plants, and of the manner of promoting their growth, should improve ever so much, and the husbandman should know, that, if his ground were so and so dressed, his crops would be improved, yet, if the imperfection of the plough be so great, that this dressing cannot be given without a very great expence, the knowledge of the husbandman is rendered almost useless.

The plough is so far from being a rude and despicable tool, that it is a machine of very ingenious contrivance, even in
the

INTRODUCTION. v

the rudest form in which it appears in this country. Several circumstances in the construction, even of our oldest ploughs, are far from being obvious, and yet the neglect of them would have rendered the ploughs much less fit for their work than they are. The circumstances, upon which the goodness of a plough depends, are both many, and difficult to be discovered; and it requires both great ingenuity and great experience to determine that form of a plough which will enable it to perform its work in the best manner, and with the least labour possible. So that, whether we consider the importance of the plough, or the great nicety of its construction, it is a subject very fit for exercising the genius of the most eminent mechanics

vi INTRODUCTION.

mechanics and philosophers in Europe.

On the other hand, this is not a task which exceeds the powers of our understanding; and it is not impossible to explain the principles upon which the plough acts in performing its work; and, consequently, to determine that form which shall do this in the best manner. Let the husbandmen once be agreed as to the state in which the ground should be left by the plough. The task which it is to perform is now a fixed thing, and there must be one manner of performing it, which is better than any other. Now, it is certain that a plough may be made which shall perform a task in any manner whatever, and therefore in this best manner.

It

INTRODUCTION. vii

It would be great presumption in me, if I should pretend to give perfect instruction in a subject which I have said is fit for exercising the greatest genius. My situation in life has deprived me of many advantages of theoretical learning.

But, on the other hand, it has given me a good deal of experience, both as a husbandman, and an artificer. This advantage appears to me considerable, and not very common, and has engaged me to turn my attention to the improvement of the plough more than many others of my profession. Some of my views were much approved of by gentlemen of great judgement and experience, which encouraged me to bestow still more attention upon the subject, and

viii INTRODUCTION.

and to put immediately in practice every alteration which I thought would be an improvement. It is to such encouragements, and the opportunities thereby given me for improving my ploughs, that I am indebted for the good character which they have given me, both in this neighbourhood and at a distance.

The same gentlemen who have encouraged my attempts to improve the plough, have also flattered me with the hopes that I would do a service to society, if I should make public my notions upon this subject. I have therefore set them forth, such as they are, with some degree of trust that my sentiments will be found pretty just, and with almost a certain confidence, that ploughs, made

ac-

INTRODUCTION. ix

according to the directions which I have given, will be found to perform their work in an agreeable manner. If any person of skill shall think it worth his while to correct any mistakes into which I have fallen, he will deserve well of the Public, and will have my particular thanks for the opportunity which he will thereby give me of improving in my profession. The chief merit which I claim in the following sheets is this, that I have given directions by which any sensible workman may be enabled to make a plough on my principles, without being reduced to the necessity of copying, and that those directions are such as will enable him to make a plough on any principles whatever. All that is necessary to be known

x INTRODUCTION.

is the state in which the ground is to be left by the plough. My directions enable the workman to make a plough which shall leave it in that state. So that, whether my principles are good or not, my directions for making a plough lose nothing of their value.

I hope that a candid and good natured Public will receive, with indulgence, my endeavours to be useful, and will pardon those defects which arise either from my situation, or from my want of talents. I am too sensible of the respect which is due to the Public, to be wanting in care and attention.

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Of the Action of a Plough in general.

IN ploughing three things are performed. A slice of earth is cut off from the general mass. This slice is removed some inches to one side. It is so turned, that it may expose a new surface to the air, and that what was formerly uppermost may now be buried. To the performance of these things, the construction of the plough must be adapted, and the work must be performed with as little labour to the cattle, and to the ploughman, as possible ; and the ploughman must have it in his power to vary at pleasure the depth, wideth, and position of the furrow.

row. The first of these actions is performed by the coulter, the second and third by the sock and mouldboard jointly. These are to be considered in order.

Of the Coulter.

The coulter must be considered as a cutting instrument, opposed to great and various resistances. It must be sharp, that it may cut the more easily, and strong, that it may not be broken or bent. These properties cannot be united, unless it is thin and broad. The giving it great strength, by means of great thickness, exposes it to more resistance than is necessary; whereas, increasing the breadth of the coulter diminishes the resistance; by making it a sharper wedge.

The

The dimensions of the coulter may be as follows: An eighth of an inch thickness at the edge, and an inch thick at the back, for a three horse plough, or seven-eighths for a two horse plough. The web may be three inches broad at the broadest, and taper from a foot down all the way to the point. The thickness of the back may taper also. The length is about twenty inches. It may have a little rounding on the furrow side, from the edge to the middle, and should be flat on the land side.

The operation of the coulter depends greatly upon its position. The plough may be considered as a sort of wedge, employed to remove the earth both from the land side and from the bottom of the furrow. The land side and bottom
of

of the furrow, are, each of them, to be kept straight. This circumstance, as we shall see more fully afterwards, require that the land side and sole of the plough be plane surfaces. The coulter therefore must be placed in the plane of the land side of the plough. By this means, the cut which it makes forms the land side of the furrow, to which the plough is afterwards pressed, by the resistance acting upon the furrow side of the sock and mouldboard. For the same reason, it appears proper to me, that the land side of the coulter should be in the plane of the land side of the plough, and that its whole thickness should be on the furrow side. When the plane of the coulter has any other position, there will always be a force acting

acting on the plough, tending to change its direction. This must be opposed by the continual influence of the ploughman, or by the form of some other part of the plough, which shall give it a contrary tendency. The first method is evidently improper. The second is no less so, because, though these contrary tendencies may balance each other, they both increase the labour of the cattle. It may be objected to this reasoning, that by making the land side of the coulter in the same plane with the land side of the plough, or parallel to it, the coulter itself will be pressed in towards the land, by the resistance of its furrow side. This is true, but is, in general, compensated by the firmness of the ground on the
land

land side. When the edge of the coulter strikes a stone directly, the stone, although driven straight forward, moves to the furrow side, where it is least resisted. But if the coulter has its edge exactly in the middle of its thickness, and strikes a stone with its land side, the plough must be thrown from the land, because the stone cannot be pressed much farther into the firm ground.

In fitting the coulter into the beam, the mortise must be made parallel to the plane in which the plough moves, and not pointing to the furrow side, as is much practised; for this practice always gives the plough a tendency to turn off from the land. The position which I here recommend for the edge of the coulter, causes it to co-operate
with

with the sock and mould-board, in removing the earth, which is an advantage not to be despised.

The loss sustained by the wrong position of the coulter, does not very sensibly appear in a plough which is drawn by the beam, projecting so much before it; but would be very distinctly felt, if the draft chain were fastened to the coulter itself. In this case, it would be found that it will be hardly possible to keep it in its proper direction.

Another thing to be taken notice of with respect to the position of the coulter, is its rake, or inclination forwards. It would seem, at first sight, that the edge of the coulter should be upright; but experience, perhaps without any principle, has directed us to point it

forward below. Some principles are, in this case, perfectly conformable to experience. In the first place, the inclination of the coulter makes it cut the earth more easily; for, it is well known, that, in all operations with cutting instruments, the work is more easily performed when the edge of the instrument is placed oblique to the direction of its motion. I cannot give a better instance, than the operation of shaving, where the resistances in the different positions of the edge of the razor are most easily distinguished. Some think, that a loss is sustained by the point of the coulter cutting the furrow so much below, before it is cut above. But it may be easily shown to such persons, that no loss is sustained; but, on the contrary,

a real advantage is gained. When the point of the coulter projects much below, it cuts the ground partly upwards, in which direction its cohesion is most easily overcome. Also, when the coulter comes to tough roots, which it does not cut at the first touch, it presses forward below them, strains, and tears them with the increased force of a wedge, and at last breaks them, with much greater ease than if its edge were upright. By this means too a very tough root is made to slide up along the coulter, till it comes to that part of its edge, which is not much employed in cutting the furrow, and is therefore sharper than the rest. Thus, the roots being cut by different parts of the coulter, as they differ in strength,

and

and being, in general, thrown up to its top, the coulter is cleared of them in that part chiefly employed in cutting the furrow.

But if the edge of the coulter were perpendicular, it would carry along with it the roots which it does not cut, which would greatly increase the resistance which it meets with, and would frequently choke the plough, and stop its motion. In like manner, when the coulter comes to a stone, it makes it rise upwards, in which direction it is more easily moved; whereas, if the edge were perpendicular, it behoved to force it straight forward.

Another advantage attending this inclination of the coulter, is, that it tends to keep the plough in the ground.

That

That some force is necessary for this purpose will easily appear. In the manner in which cattle are commonly yoked, the line of draught makes an angle of about 24 degrees with the sole of the plough, or bottom of the furrow. The tendency of the draught therefore, is always to pull the plough out of the ground; and if the edge of the coulter were upright, it would give no opposition to this tendency. Nay, even if the coulter were pointed 24 degrees forward, it would not have any effect. It must therefore project still more, in order that the resistance upon its upper edge may co-operate with the rest of the plough, in opposing this general effect of the ascent of the line of draught. This additional projection
of

of the coulter is the more necessary, for the purpose of keeping the plough in the ground; because, as we shall see afterwards, there are other circumstances which also tend to throw the plough out of the ground.

I would therefore recommend an inclination, or rake, of about 45 degrees, as the most proper, and the most conducive, to all the good purposes hitherto mentioned. The propriety of this position will be illustrated by considering figure 1st. Let A H represent the line of draught, making an angle of 24 degrees, with L M, the bottom of the furrow. This line of draught is supposed to pass through the centre of effort of the plough. Let it cut the edge of the coulter in N. This point
will

will be found to be about 4 or 5 inches from the bottom of the furrow, though N draw C D perpendicular to A H I. Then, if the edge E F of the coulter makes an angle of about 45 degrees with L M, it will make an angle of about 20 degrees with C D. There being nearly the same quantity of earth cut by the part below N, as there is cut by the part above N, the coulter will be equally pressed on each side of the line of draught, and will, in this respect, have no tendency to turn the plough out of the ground, nor into it. This position will therefore be the most proper, when the sock is at the longest, and will admit of being changed, so as to bring the point of the coulter near to the sock; when this is shorter, while
the

the sock is of such a length as to make the coulter more inclined than C D, the coulter will always help to keep the plough in the ground.

The next thing to be considered in the position of the coulter, respects its fitness for clearing, or freeing, the part of the plough which follows it in the furrow.

The defects of the common form of the land side of the plough, and of the position of the coulter corresponding to it, are very sensible, both when we use the long practised spear sock, and plain mouldboard; and also when we use the more modern feathered sock, and curved mouldboard. These defects have been distinctly seen by the actual comparison with a plough of a more
per-

perfect construction, and may be sufficiently understood, by attending to the description which will now be given of this improved plough.

The plough, as has been already observed, may be considered partly as a cutting instrument, of which the coulter forms the edge. It is not employed in cutting the earth, and separating it on both sides, in which case it would rather resemble a cleaving instrument; but it is employed in cutting a small slice from the firm ground, on the left hand, and removing it to a certain distance to the right hand. The chief resistance being therefore exerted on the furrow side of the plough, the plough is pressed to the firm ground on the left hand. By this means the land side of

D

the

the plough becomes the director of its motion, and therefore, in the perfect state of the instrument, should perform no other part of the work. This consideration shows at once that the land side of a plough should be a flat or plane surface. If it has any other form, being strongly pressed to the firm ground, its projecting parts must sink into it, and the plough cannot advance without continually tearing off the earth with its projecting parts; which earth must tumble in between the coulter and sheath, or into any hollow in the land side of the plough, and, collecting gradually there, will both obstruct its motion, and turn it from the land. Here, without any further argument, appears the great imperfection of the Scotch plough

plough, as usually made; and the advantage which must attend the covering the hollow between the head, sheath, and stilt, with boards, to reduce it to a flat surface.

In the next place, this flat surface, which forms the land side of the plough, must be in the direction of the plough's motion; that is to say, a straight line, drawn from the heel of the plough to the point to which the cattle are yoked, must touch the land side of the plough. If the surface of the land side of the plough, and the edge of the coulter, points to the right hand of the fore end of the beam, the plough will be thrown continually from the land, by the resistance which it meets with on that side, the contrary effect will be produced if
this

this surface points to the left of the fore end of the beam: but when the land side of the plough, and the line of draught are in the same plane, the plough will go smoothly and steadily, without any effort of the ploughman.

This consideration leads us to attend a little to the form of the beam. The mortise, for receiving the coulter, must be in the middle of the thickness of the beam, in order to give the greatest strength. The same may be said of the mortise in the stilt for receiving the beam. The coulter must be set to the left of the land side of the plough, nearly the thickness of its back, by which means the earth, which is pushed a little to the right hand by the thickness of the coulter, will be received on the edge
of

of the sheath and mould-board. These conditions cannot be obtained, if the beam is equally tapered on the land and furrow sides, as is usually practised. For, in this case, the coulter will have its upper part removed to the right hand of the land side of the plough by half the thickness of the beam. This is accordingly the case in the usual construction of the plough; and this defect is attempted to be remedied, by placing the plane of the coulter, not upright, but pointing with its lower end to the land, and projecting beyond the land side of the plough near five inches, as in fig. 3, 4, and 9. which represent a cross section of the plough at the heel, seen from the point of the beam. I shall first describe the construction, which

which appears to me to be the most proper, and then show its advantages, by comparing it with the common form.

The beam should be $4\frac{1}{4}$ or $4\frac{1}{2}$ thick between the coulter-hole, and the hindermost side of the sheath, and it should be $4\frac{3}{4}$ or 5 deep at the same place. At the fore end, the thickness should be $2\frac{1}{4}$, and the depth $3\frac{1}{2}$. It may have a curve of 6 inches up and down, which the ploughmen call the redde of the plough.

Instead of tapering the beam equally on both sides from the place of the coulter, as represented in fig. 2. No. 2. I make the beam straight on the furrow-side, as in fig. 2. No. 1. and taper it only on the land side, both ways from the place of the coulter. The taper
backwards

backwards to the hindermost side of the sheath, should be such, that, when a ruler is laid to the side in that place, it will project $2\frac{1}{2}$ inches to the left of the fore end of the beam. A B in this figure is the plane of the land side of the plough, which, by this way of tapering, passes very near the middle of the thickest part of the beam. By this method, the coulter-mortise is brought over to the land side, half of the taper given to the beam. But as this is not sufficient for bringing the coulter into the position formerly recommended, I give the coulter a knee, or set of 2 inches, as represented in fig. 5. Thus, the coulter may be set so as to make it cut in the best manner, and yet be in the middle of the beam. The sheath is also mortised

mortised nearly into the middle of the beam, but has a shoulder to the land side of $\frac{1}{2}$ an inch. This makes the land side of the sheath just touch the line A B (fig. 2. No. 1.) drawn from the land side of the fore end of the beam to the land side of its other end, and thus the land sides of the fore end of the beam, of the sheath, and of the stilt, are all in one plane surface. This causes the coulter to clear completely the part of the plough which follows it in the furrow. But when the beam is made in the usual manner, as in fig. 2. No. 2. the coulter does not clear the plough in all the parts of the land side. For, in this case, the line O K (fig. 4.) will represent the land side of the sheath, mortised into the middle of the beam, and NK will represent

sent

sent the land side of the stilt, (the point N of fig. 4. corresponding with V in fig. 2. No. 2.) and the angle OKN will be the twist of the land side of the plough, (the space ON being about $1\frac{1}{2}$ inches,) by which it appears, that the land side of this plough will point to the right of the fore end of the beam, which will give the plough a tendency to quit the land, or to turn into the furrow. In this construction, the coulter, being put flanting into the beam, so as to project to the land side about 5 inches below, does not clear the plough equally in all its parts. For the plane of the coulter intersects the plane of the sheath about $2\frac{1}{2}$ inches below the beam, and the plane of the stilt much lower. By this means, although the lower part of

E

the

the plough is more than sufficiently cleared, the upper part is not cleared at all. Accordingly, it may be observed, that in ploughs of this construction, the upper part of the plateing on the land side is more worn away than the lower, although it moves in looser earth. It is strongly pressed to the firm land, while the parts near the sole do not touch it, or touch it after the upper parts have been bruised together.

All these circumstances considered together, show that a plough of this construction is in a state of continual twisting, by the very unequal pressure of its different parts to the land. This must be varied by changing the position of the coulter, so as to point its lower end more or less to the land; whereas, by
making

making the land side of the plough in the direction of its motion, it is kept equally pressed in all its parts, and therefore sinks less in any one part, which makes it more steady in its motion, and more easily drawn, and the coulter, being kneed and placed as directed, frees the plough completely and equally in all its parts.

This may be further illustrated by fig. 6. which is adapted to a plough constructed as in fig. 4.

MN is a line drawn through the very point of the coulter, and hindermost end of the land side. HP is a line drawn through the edge of the coulter, and hindermost end of the land side, one foot up from the sole, and NR is the line which is parallel

to

to the direction of the plough's motion at a medium. The other two, HP and MN, are nearly equidistant on each side of NR. Now, although this is the line which ought to be in the direction of the plough's motion at all times, it cannot be so in this construction, except at one particular depth, because, with every different depth of furrow, the plough makes different degrees of land, on account of the coulter projecting obliquely to the land side.

These defects of the common construction are sometimes not observed, on account of other defects of the instrument, and they are thought to be compensated by the greater quantity of work which the plough *seems* to perform, by having the coulter turned so
much

much to the land. But this is a deceit, and the quantity of real work is not increased by this position of the coulter. For, by the point of the coulter being so much to the land side of the sock, a good part of the slice cut by the coulter is not raised by the sock, but is broken on the corner of the sock and sheath, and, falling in between the coulter and sock, obstructs the motion of the plough, and even throws it out of the ground. This obstruction is most distinctly perceived in the plough with a feathered sock. The furrow strikes on the land side of the sock, at its first rise, when it would, at any rate, press most upon what is below it. Also, by this pressing on the land side, both of the spear and feather sock, it tends to
turn

turn them to the furrow, and thus the plough is exposed to two contrary strains, the coulter turning it to the land, and the sock turning it to the furrow. Although these strains may be made to balance each other, they cause an additional resistance to the plough, and labour to the cattle. Also, when the space between the points of the coulter and sock is considerable, no roots which are between them can be cut by the feather, but they must be torn by the clod, or left behind. There is also a piece of the ground, at the corner of each furrow-slice, which, not being cut, is broken off, and not raised up, and this is the corner, which it is most necessary to raise, being the new soil. It frequently happens too, that, by not cutting

ting

ting this part of the ground, the furrow is not raised at all, nor turned over, but left jumbled in confusion. And, *lastly*, this position of the coulter and land side is very unfit for regulating the motion of the plough. When the soil is ploughed deep, this is not so distinctly perceived, by reason of the loose earth which tumbles in between the coulter and sock, and serves to fill up the vacancy between the corner of the sole and the firm ground. But, in ploughing a shallow soil, it is very evident. The only parts of the plough which press on the firm ground, are the coulter, and hindermost part of the land side; and the smallest resistance on the furrow side of the coulter is sufficient to turn it to the land.

All

All these inconveniencies seem to be removed in the construction here recommended. The point of the coulter is placed about two or three inches before the point of the sock, and within half an inch or an inch of the plane of the sole, and the edge, with the land side, projects about half an inch or an inch beyond the land side of the plough; so that the coulter is about as much beyond the plane of the land side, as the point of the sock is below the plane of the sole.

This construction was not relished by some persons who had been accustomed to the common form; but, when tried, appeared as much preferable as I have described it. In this construction, the advancing of the coulter so far
before

before the sock, causes it to cut the furrow so much the more forward, before it is raised by the back of the sock; but, by the great inclination of the coulter, the furrow is not so much cut above when it begins to rise on the sock, as its forward position would make one expect. The furrow is therefore soonest cut in the very place where it is to be soonest raised. If the coulter were placed as much behind the sock as it is here advanced before it, the ground would be raised before it is cut, which would increase the labour of the cattle, by causing a shorter, or more sudden turn of the furrow. But here, the furrow being cut at some distance before the sock, is more easily turned, or twisted by it.

F

It

It has been said, that the coulter thus far advanced before the sock, is more apt to strike on a stone, without having any support from the sock, which, in this case, receives no part of the shock, and then the coulter is more liable to be bent out of its position. But, in compensation of this, it may be observed, that although the coulter is thus more liable to be bent, it does not tend so much to break the plough, which will endure more strain from a stroke on the coulter than from a stroke on the sock. Besides, when the coulter is no more advanced than the sock, and placed at the usual distance on the land side, it is as liable to be hit by a stone, as in the construction now recommended, and has no support from the sock, and the
sock

shock may, at the same time, receive a shock from the same, or another stone. The chance of these shocks is therefore double; and if the stone is struck by both at once, it is not turned aside, as it would be if struck only by one of them, but must be carried forward before the plough, through the firm ground. For all these reasons, the construction is still preferable; but, as the coulter is liable to these shocks, I have strengthened it by a stay of iron, represented by H F, fig. 1. This is on the land side of the coulter, and turns on a bolt through the coulter at F, and passes through the eye of a bolt I, which passes through the beam. The upper part, H I of the stay is screwed, and the nut which turns on it supports the stay, and

enables us to raise or lower the coulter at pleasure. This itay also produces another good effect, by preventing the stubble from being pressed up into the angle formed by the coulter and beam, from which it is very troublesome to dislodge it. I may here observe, that it is not a good practice for the ploughman to push the stubble which gathers on the plough to the furrow side. It should be pushed to the land side, so that it would fall into the track of the plough, and be buried; whereas, by pushing it to the furrow side, it is apt to lye above. It is also easier for the ploughman, with his right hand, to push it to the land side.

On the whole, this position of the coulter, a little to the left of the land
side

side of the plough, and parallel to it, causes the coulter, by its thickness behind, to bring the furrow exactly on the edge of the sheath and mouldboard. No earth falls in between the plough and firm land in wet or loose soils; none strikes on the edge of the sheath and mouldboard in hard soils, but the furrow slice takes a regular rise, with its corner right with the land side of the sock. No roots can pass between the coulter and sock without being cut, and the corner is kept in the furrow, and turned up. And, *lastly*, the whole land side of the plough being equally pressed to the firm ground, the pressure on no part is very great, and the plough is prevented from running into the firm ground by any sudden strain on the opposite side.

The

This construction has also been used with the coulter no farther advanced than the sock; but in this case it has been thought an advantage to place it a very little more to the left, but still parallel to the side of the plough. But it has been found, on trial, that it was still better to advance the coulter before the sock.

It may be proper here to observe, that a plough constructed as above directed, makes a furrow considerably different from that made by a plough of which the lower point of the coulter projects so far to the land side. This will be illustrated by considering figures 8 and 9. In figure 8. A B represents the coulter of figure 5. E K is the section of the mouldboard, where it cuts
the

the furrow, and K B represents the sole of the plough. E F G H represents the slice cut off from the firm ground, removed to the right hand, and turned over. E H is the under surface of the slice, formerly joined to K B, and E is the corner which was formerly at B. This slice is made to stand upon one corner G, with its former upper surface E G leaning upon the next slice.

In this figure, the plough is supposed to be going perpendicular, this being the position which I would always recommend. The position also of the furrow slice, which I have here represented, is that which is approved of by the most intelligent farmers. Figure 9 represents the same thing, corresponding to a plough made according to fig.

4. In these two figures, it appears that the upper and under corners, E G, of the furrow slice, made by the plough, fig. 5. are square, whereas the two corners, R and N of the slice made by the plough of fig. 4. are about 13 degrees above the square. In order that the furrow may stand in this position, it must either lean upon the former furrow, or it must be supported by loose earth, which tumbles in below it, and fills up the vacancy represented by H G K of fig. 8. or P R S fig. 9. It is easy to see, that the vacancy of fig. 8. is easier made up than the other.

Although this position of the furrow slice is not always required, it being sometimes thought proper to leave it standing upon its edge G H, it is plain, that

that even in this case the plough of fig. 5. has the advantage ; for the furrow slice made by it will stand upright, whereas that made by the plough fig. 4. will lean to the space left by the plough, and it will hardly be possible to prevent it from falling back into its former position, especially in ploughing with a shallow and broad furrow.

Lastly, It appears that the plough of fig. 5. will leave the ploughed ground with a flatter topped furrow than the plough of fig. 4. which is also thought an advantage by the most intelligent farmers.

The reader will observe, that I have always supposed that the land side of the plough is kept perpendicular. It is a very usual practice to lean the plough

over to the left, or land side; but I do not approve of this practice, because it leaves the bottom of the furrow higher on the furrow side, and this leaves some of the earth not raised, and the furrow turned over has not so full a shoulder. It is in some degree to make amends for this, that the coulter is set so far to the land below. But the practice should be laid aside, and then this improper position of the coulter will not be necessary.

Thus it appears, that whether we consider the working of the plough, or the work which it performs, the plough of fig. 5. having its land side a plane surface, standing in the direction of the plough's motion, with the coulter parallel to it, is, in every respect, preferable

able to the plough fig. 4. which has its land side twisted, and the point of its coulter turned so far into the land.

Of the Sole and Sock of the Feather Sock Plough.

In the make of the sole of this plough, three things are to be considered.

First, The form of the land side sole, or head, and the position of the sock, for keeping the plough at the proper depth and breadth of the furrow, and solid in its motion.

Secondly, The breadth from the out land side sole, to the out side of the mouldboard sole behind, and the inclination and height of the mouldboard sole, with respect to the land side sole.

Thirdly,

Thirdly, The proper breadth and inclination of the feather, corresponding to the breadth and inclination of the sole.

First then, with respect to the form of the sole, and the position of the sock, which are most proper for keeping the plough at a proper depth, and solid in its motion. This is a point of the greatest difficulty in the construction of the plough, and therefore must be minutely considered.

Let L M, fig. 1. represent the bottom of the furrow. As the plough advances, its fore parts and furrow sides are exposed to resistances. The coulter is pressed down by the earth which it is cutting. The sock is pressed down, and also a little to the left
by

by the earth which it is raising. The fore part of the mouldboard is pressed down, and also to the left by the earth which it is partly raising, partly shifting to the right, and partly turning over. The hindermost part of the mouldboard is pressed to the left by the earth which it is forcing to the right, and is also pressed upwards by the earth which it is turning over. These resistances, taken together, give to the plough a tendency to thrust the point of the irons deeper into the ground, and to twist the point of the sock downwards to the right, and the hindermost part of the mouldboard upwards to the left.

If, therefore, the plough were drawn forward, by a rope fastened to the point of the sock, and level with the bottom
of

of the furrow, the plough would infallibly sink at the point, and rise at the heel; and, at the same time, twist over to the furrow side. With such a draught, therefore, the ploughman must continually press upon the left stilt. But the plough is not drawn in the manner here described, but in an oblique direction $K A$, from the bridle bolt K to the point A , where the draught ropes pass through the horses backband. This direction of the draught tends to pull the plough out of the ground. That this may not happen, the draught must be so placed as just to balance the plough's tendency to go deeper. Suppose $H A$ to be the direction of draught which is exactly proper for this purpose. Produce the line $A H$ backwards, till it meet

meet the coulter in N, the sock in O, and the sole in I. Every person skilled in the principles of mechanism knows, that the motion of the plough will be the same, whether the draught rope is fixed at H, N, O, or I, as the direction I H A is the direction of the draught, so A H I is the direction of the resistance, the labour of the cattle being the same as if the plough were not resisted by the earth at all, but were kept back by a rope fastened at H N O, or I, and pulling in the direction H I. There will, therefore, be some point in the plough, between H and I, where all the resistances may be supposed to be united. We shall, for the future, call this point the centre, or point of resistance. We may also call it the centre of action,

be-

because the action of every part of the plough is directly opposed, and is equal to the resistance which that part overcomes.

If we consider the pressure on the hindermost parts of the mouldboard, which tends to raise it up, we shall find that the plough will not swim fair, as the ploughmen express it, but will rise at the heel. This effect will be still farther increased, if the point of the coulter or sock meet with any uncommon obstacle. In such a case, if the draught rope is fixed at the centre of action, or any where behind it, the heel of the plough will always rise, and the plough will twist downward on the furrow side. But if the draught rope is fixed at H, this rise of the heel will stop in time,
be-

because, by this means, the point of the beam is depressed, and the line of draught comes to make a greater angle with the level of the furrow. When this happens, the draught again raises the point of the beam, and sinks the heel of the plough. It is evident, however, that the motion of a plough trimmed in this manner, will be very hobbling and irregular.

This defect is removed by a very simple contrivance; namely, by fixing the draught-rope to some point K, below the straight line A I, which passes thro' the centre of action. By this means, the plough becomes a sort of lever, of which the centre of action is the fulcrum. The lever is pulled upward at K, and, being supported at the fulcrum,

H

the

the hinder part of it is pressed down, and the heel of the plough M is kept firm in the bottom of the furrow. This makes the plough go solid, as the ploughmen express it, and neither go deeper into the ground, nor rise out of it. This the ploughmen call having a right hold of the ground.

It is easy to see, that this circumstance in the trim of a plough is of the utmost consequence to the perfection of the instrument. We see also, in general, that the plough may get more or less hold, by raising or lowering the point K, to which the draught-rope is fixed. This is the use of the shifting pieces of the bridle fixed to the fore end of the beam, which put it in the power of the ploughman, to trim

or temper the plough to his mind. Making the bridle bolt too low, both causes the plough to rise out of the ground before, and causes the heel to press more on the bottom of the furrow than is necessary, and also causes the hindermost and upper part of the mouldboard to press too hard on the earth, at quitting it, which is productive of bad effects in moist clay soils, by casting the earth into a solid clod. No more should be done than what is just necessary to make the plough go steady, by keeping the heel gently pressing on the bottom of the furrow.

From the account here given of the operation of the plough, and the various resistances to which it is exposed, it is easy to infer, that the proper place
of

of the point of draught at the fore end of the beam, must depend on the form of the plough, both with respect to its sock and mouldboard. A plough, of which the sheath has little inclination or rake forwards, being less pressed down before, will require the point of draught to be higher than a plough of another make. Thus it appears, that when a plough is already made, its hold may be regulated by the place of the point of draught.

On the other hand, a plough, whose point of draught is fixed, or cannot be sufficiently changed, may have its hold regulated by the make of its sock and mouldboard; for these two things, the place of the point of draught, and the make of the plough, have a mutual dependence,

pendence, and necessary connection with each other. This last method of regulating the hold of a plough depends on the form and position both of the sock and mouldboard. Pointing the sock downward will increase the hold of the plough, and raising its point will diminish it. Also, by inclining the sheath much forward below, we increase the hold of the plough, and by making the sheath more upright, we diminish it. Thus a plough may have hold both by the sock, and by the make of the plough. It is plain, therefore, that these may be so adjusted as to give the plough a proper hold on the whole, and a plough, which has too much or too little hold by its make, may be brought to a right temper, by giving it less or
more

more hold by the sock. But it is plain, that although the excess or want of hold by the make, may be balanced or corrected by a want or excess of hold by the sock, and thus the plough be made to have, on the whole, a proper hold; yet this exposes the plough to opposite strains, and increases the labour of the cattle, and that the plough will be more perfect, when the hold by the sock and by the make both agree. This will also be attended with the advantage of making the upper part of the sock and the mouldboard of one regular twist, which will give the easiest turn to the furrow, and leave it in the best state.

It would appear, that the best position of the sock is to have its under
surface

surface even with the plane of the sole. But experience teaches us, that a plough goes more steadily when the sock projects a little below. The reason seems to be this: When the sock and sole are in one plane, and the point of the sock meets a small stone, it cannot get below it, because the sole is then on the firm ground. The plough must therefore pass over this stone, and lose part of its hold. Or, if the resistance of the stone against the upper part of the sock forces down the point, the heel must immediately rise; whereas, when there is a small projection downward of the sock, a little hollow is left under the fore part of the sole of the plough, which allows it to sink a little deeper, and thus throw up the stone, and, at the same time,

time, does not necessarily force up the heel. All this may be done with a sock of a regular twist, and proper length and shape on its upper side, by making the point of the sock about five eighths of an inch below the plane of the sole, and bringing forward the plane of the sole as much as possible, so as to leave no considerable hollow between it and the sock.

This being done, the tempering of the plough for its hold must always be produced by means of the shifting parts of the bridle, which the ploughman can vary in an instant, agreeably to the nature of the soil in which he is working. A well-conditioned plough will always allow this, and if a plough cannot be tempered in this way, it must be tempered

pered by the sock. But, as was said before, such a plough is not perfect, but has an excess of hold in one part, balanced by a want of it in another. It may be known when a plough is perfect in these respects. Let the point of draught be fixed as high as the bridle will admit, and let the plough be worked in even light soil, free of stones, and take a good furrow. The heel of the plough should not press on the ground at all, but should even rise a little. Then let the point of draught be fixed as low as possible. The heel of the plough should then press hard on the ground, and the plough should even show some tendency to come out of the ground. If these things do not happen, we may be certain that the position of the beam is not properly adjusted to the make of the plough, and

the position of the sock, and we can now temper the plough by the sock, so as to bring it into the condition described above.

It may be observed in general, that the point of draught must be fixed a little below the straight line drawn from the lower end of the backband to the lower end of the sheath behind, because, in most ploughs, the centre of action is not far from this part of the sheath. The distance of the points H and K, should never exceed four inches. But this matter, together with another method of tempering the plough for the hold, by yoking the cattle more or less forward, will be considered afterwards, when we come to speak more particularly of the framing and putting the
plough

plough together, and of the manner of yoking.

It may, however, be added here, that the length of the beam has a great effect in making the plough go more steady, even when, in every thing, it is adjusted as above described. Directions will also be given afterwards for adjusting all ploughs to the same hold, whatever is the length of the beam.

Besides the adapting the fock in the manner now described, for giving the plough a proper hold of the ground, we must also consider its position, which is most proper for keeping the plough in the straight direction forward. It appears to me, that the most proper method for obtaining this end, is to make the land side of the fock even with the
rest

rest of the land side of the plough, and to make the whole of its taper on the furrow side. It is, however, a very usual practice to set the point of the sock a little to the right. The reason given for this is, that the resistance may be diminished by sharing it between the two sides. But this reason is insufficient, when the sock is of the proper form, and this position of the land side of the sock produces very bad effects. It is very true, that if a sock of the form in figure 10. were drawn in the direction of A H, instead of being drawn in the direction of I L, and if it had a part on both sides of the point I, equally formed for cutting, the resistance to its motion would be diminished. But, in the first place, this resistance is but a small
part

part of the whole resistance of the plough. In the next place, this form of the sock at the point, will not agree with the good property, which a sock should have, of making a fair surface with the mould-board, and thus beginning the operation of the plough, in turning over the soil, as well as cutting and raising it. Now, if the sock is made of the proper form for those purposes, that is to say, thick or perpendicular on the land side, and without a cutting edge, the resistance will be increased, instead of being diminished, by thus turning the point of it to the furrow side, because, then the land side of the sock would meet the firm ground with a perpendicular surface, unfit for cutting, and would be pushed by it to the right hand, causing

sing the plough to lose land, as the ploughmen express it.

The bad consequences of this position of the sock, even if the land side were made fit for cutting, are many and great. When the sock strikes on a stone with its land side, it must be turned off to the furrow side, because it cannot force the stone further into the firm unploughed ground, whereas a stone which is struck by the furrow side of the sock, is very easily forced into the open furrow. This position therefore of the sock, even when cutting on both sides, causes the plough to lose land, and this bad effect must be balanced by giving the plough a greater tendency to the land by the form of its other parts, which must increase the resistance

to

to its motion, or it must be balanced, by fixing the point of draught more to the right, which occasions a strain on the beam, across it, where it is weakest, by the coulter-hole and mortise for the sheath. All these reasons, taken together, give a plain preference to the position of the land side of the sock which I have here recommended.

We come next to consider the breadth of the sole, reckoned from outside to outside at the heel. With respect to which there is great difference of opinion. But an attentive consideration of the operation of ploughing will fix our sentiments on this matter. The sice which the plough cuts off from the firm ground must be turned over to a certain degree, or must, at least, be set on its edge. This
can

can never be done unless we remove the slice its whole breadth to the right hand, as may be seen by inspecting figure 9. where A C D B represents the firm ground from which the slice is to be cut. Suppose the breadth of this to be nine inches from A to H, the coulter must come perpendicularly down thro' H I, and the slice A H I B must be turned over upon the corner B, so that the bottom B I of the slice may at least stand upright, fronting the unploughed ground, and the furrow slice stand on its side A B. Now, it is plain, that when this is done, the whole slice is shifted nine inches to the right hand. It is evident, that this can be done by no other means, than by giving the sole of the plough this breadth behind,

when

when it leaves the earth, for there is nothing else to press the earth to the right. When the sole has this breadth, it will shift the earth completely, and the turning over the slice into the desired position may then be performed by a proper shape of the mouldboard. If the soil is of loose mould, which will not remove by turning over, or will not turn over like close earth, it will still be removed completely from its former bed by a sole, which is as broad as the furrow taken by the plough.

I now add, that no greater breadth of the sole is necessary. I know that a contrary opinion prevails, and that it is supposed, that when the sole is much broader than the furrow taken by the plough, and by this means removed

K

farther

farther to the right hand, there is the more room made for the next furrow slice to stand on. But that this is a mistake, will easily appear, by comparing two ploughs, one of which has a sole of nine inches, and the other of 18 inches, both employed in cutting off a slice of nine inches broad, and nine inches deep. The narrow plough removes the first slice nine inches to the right hand, and sets it, as we shall suppose, on its edge. When it cuts off a second slice, it also removes it nine inches, and sets it on its edge. Therefore the second slice is set close to the first, because its thickness across, as it now stands, is also nine inches. The broad plough removes the first slice 18 inches to the right hand, and sets it on its edge. It
removes

removes the second slice 18 inches to the right hand, and sets it on its edge. Therefore, in this case also, the second slice is set close to the first, and it has no more room to stand on than the first.

It is not the breadth of the sole, or the removal of the earth to the right, which gives room for the furrow slice to stand on. This depends on the proportion between the breadth of the slice and its depth. When the slice is as deep as it is broad, it is pressed close to the former slice, whatever is the breadth of the sole of the plough, because there is no more space than its thickness will fill up. If the slice is still deeper, it is squeezed still closer to the former slice, and so bruised, that part of it is forced up to a greater height than

than it would rise to if it had room. When the slice is broader than it is deep, which is the common case, then it has more room, when raised on its edge, than it can fill up, and by this means it does not press so much on the hindermost end of the mouldboard, but falls more freely away. But when the slice is much broader than deep, it falls much over, and is made to lye on its back, which is reckoned a defect in the work. This has been frequently charged as a great fault of the plough with a feathered sock, and curved mouldboard; and it is true, that this has been oftner seen in working with this plough than with the plough having a spear sock and plane mouldboard. But this is not a defect of the plough, but a fault
of

of the ploughman. The feather sock can raise a greater breadth of furrow than the spear sock, and this gives an opportunity, and temptation to the ploughman to make the furrow very broad, in proportion to its depth, and this will necessarily lay the sledge on its back. But the feather sock plough, with the twisted mouldboard may, and should be so constructed, as to turn the furrow no farther over than will allow it to stand on edge, by giving the mouldboard the proper twist, and by not giving the feather too great breadth.

As the different soils, and the different number of cattle in the yoke, must require different breadths of furrow, no rule can be given for the breadth

breadth of the sole, which will fit all cases. The furrow should always be adapted to the strength of the draught. For a draught of two or three horses, the breadth of the sole ought not to be less than eight inches, nor greater than ten, reckoned from outside to outside behind, square over from the land side. The only advantage attending a greater breadth of the sole, is the giving more room for the horse and ploughman to walk on in the bottom of the furrow. But it is very improper to increase this beyond what is absolutely necessary, because the removing the earth so much farther to the right hand requires nearly as much more power, or labour of the cattle.

It

It must be observed, that what has been now said concerning the breadth of the sole, relates only to the feather sock plough. The spear sock plough differs in its manner of raising the furrow, and requires a different form and position, both of the sole and mouldboard, as will be shown afterwards.

The form of the mouldboard sole, and its inclination to the land side sole, come next to be considered.

This has been very frequently formed circular, or convex, outward, like the upper part of the mouldboard. But this shape does not agree with the best manner of turning over the furrow slice, which should be done by equal degrees, as the plough advances thro' equal spaces. As the plough advances
equally

equally, the earth should be moved equally to the right hand, as well as be equally twisted over. This maxim, therefore, directs us to make the mould-board sole a straight line from the point of the sock, to its hindermost end, as is represented in fig. 10. where I L is the straight line of the land side, and I K is the straight line of the furrow side, intersecting each other at the point of the sock.

The breadth of the feather is the next point of importance to be considered. This must be in a certain proportion to the breadth of the sole, and of the furrow slice taken off by the plough. It also depends on the nature of the soil. A soil free from stones, and full of tough roots, requires a broad feather; and a stoney

stoney soil, with few roots, requires a narrower one. We can only mention the breadth proper for a middle kind of soil, and soils of very different qualities must have the feather changed on purpose for them.

When the sole of the plough is nine inches broad, which will suit extremely well a furrow of eight inches, more or less, the breadth of the feather should be about six inches. It is very usual to make the feather of such a plough eight inches broad; and this has been thought by some to be an improvement in the plough, because it makes it to cut off all the earth from the bottom of the furrow. But this great breadth of the feather is attended with two bad effects. The slice being completely cut

L

off

off from its bottom, sometimes breaks from the firm ground, before it begins to rise on the sock and mouldboard. By this means, it frequently happens that it is not turned over by it, but is merely shifted away to the right hand, retaining its former position, with the same surface uppermost which was uppermost before. But when the feather is two or three inches narrower than the furrow slice, a part of the slice on the corner next the furrow is not cut. This keeps that corner of the slice fast till the rest of it rises on the sock and mouldboard; and, by the time that it is almost on edge, this corner breaks off itself, or is very easily broken off by the wider part of the mouldboard sole, and then the slice does not slide to the right,
but

but is properly turned over. The tearing of this little part occasions no resistance that is worth minding. The resistance is perhaps even less than what would happen on cutting it with the feather, because this great breadth of feather would make it cut the earth almost perpendicularly, which is the second inconvenience arising from too great breadth of the feather.

On the other hand, I do not think that the feather should be much narrower than six inches, because, when too great a portion of the furrow slice is left uncut, it requires more force to tear it, and the work is not so neatly performed, and the mouldboard is pressed up, which throws the plough to the left above, and spoils the shape intended to be given to the furrow.

The

The length of the feather should be in proportion to its breadth. Ten inches along the land side of the sock, or 12 inches along the edge of the feather, appears to me to be a very proper length for a breadth of six inches. The making it much longer will leave too little room for bending the sock plate for fixing into the plough. It is plain, however, that the longer we make the feather it will cut more obliquely, and meet with less resistance.

The height of the sock feather, or its position with respect to the land side, is of some importance. The outer corner of the feather should be square with the land side of the plough, and on a level with it. It is true, that by this position the cut made by the feather
will

will not be exactly level with the sole of the plough, because the point of the feather is a little lower. But it is found, that when the whole feather is as much lower than the sole as the point is, the plough is very apt to run out of the ground to the left side. The reason of which seems to be this: The right corner of the feather, and the right side of the sock, are most strongly pressed down by the furrow, which is a raising. This twists the plough to the right above. If, now, the feather should meet with any considerable resistance, when the point of the sock is higher than the right corner of the feather, the plough is apt to run upon the edge of the feather, and be thrown out of the ground to the left. On the other hand,

hand, if the right corner of the feather is higher than the sole, it leaves a part of the furrow uncut, which the sole must pass over, and the plough is turned over to the left above, unless the mouldboard sole be made higher than the land side sole; in which case the work is not performed as it ought to be, with a square bottomed furrow.

I must here observe, that as the point of the sock cuts five eighths of an inch below the sole, for the reasons given above, it is necessary to raise the mouldboard sole as much higher than the land side sole, that it may be cleared by the feather cutting before it. But if it be any higher than this, it will not remove all the earth which is cut by the feather.

Of

Of the Mouldboard.

This forms the furrow side of the plough, by which the furrow slice is removed from that place and position which it has when cut by the coulter and sock, to the place and position which it has when finally left on the ploughed land. This part of the plough has been long neglected, the whole instrument having been considered as unworthy of the attention of persons skilled in machinery, who were apt to imagine that no rule was necessary for the construction of so simple an instrument. Thus it has been left in the hands of unskilful country artists, who, having no just principles to guide them, could

neither

neither judge of its defects, nor of the means of its improvement. But it may be affirmed, that the construction of the plough, especially of its mouldboard, is of a very nice and complex nature, and requires considerable skill to make it in such a manner as to perform its work to the wish of the ploughman, and with as little labour as possible to the cattle. I may also affirm, that with respect to the propriety of the work, ploughs of the most approved construction, and which have a great character, fall short of what a plough may be made to perform, in a proportion not less than that of three to four. And, with respect to the resistance, I may also venture to affirm, that with the same size of furrow, and the same finish of the work, these

these ploughs will give as much labour to three horses as a better adapted plough will give to two.

The form of the mouldboard must have three properties. It must keep the plough to a proper hold of the ground; it must remove the earth to the furrow side, and it must turn it over.

1st, It is by the back of the sock, and the fore part of the mouldboard, having the furrow slice lying upon them, that the fore part of the plough is kept in the ground. Therefore, the weight of the furrow will have the more power to keep the plough in the ground, in proportion as the back of the sock, and fore part of the mouldboard, are more below it. The plough will also keep the ground so much the better, in proportion

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portion as the earth ceases more gradually to press down the mouldboard, as it is turned over.

In the next place, as it is by the back of the sock, and by the mouldboard, that the earth is removed from its first position, it is plain, that the higher that the back of the sock can come to a plane parallel to the surface of the ground, and the greater breadth of furrow that can be lying on the back of the sock at once, the better will the under surface of the furrow slice be raised. It is plain too, that in proportion as we make the twist of the sock and mouldboard more gradual, from the point and edge backwards, the furrow will be raised with less risk of crumbling, and with less labour to the
cattle.

cattle. The more direct that the surface of the back of the sock and mouldboard is for leading the earth from the one position to the other, it must be so much the better for taking the quantity of furrow which is cut by the coulter and sock all together, whereby there is a greater quantity of earth brought up from below, and made part of the new surface: But when the sock and mouldboard are of such a make as to have little breadth below the furrow, and that little of an abrupt, or irregular form, there is but little of the lower part of the furrow made to become part of the surface of the ploughed land. In land where the soil is neither clay, nor free in rising, but loose, or bound with deep roots, the plough of such a
make

make cannot raise above half of the furrow which is cut off by the coulter and sock; but, instead of this, pushes a quantity of earth to the right, leaving the former surface still uppermost, and covering that part of the furrow which should have been raised. There is a plough made with an iron head, and spear sock, without a feather; and made with such a degree of land, or tendency to the left, as to require the being held over to the land side above, in order not to run into it. In this position of the plough, the sole of the mouldboard behind is nearly as high as the surface of the ground; the back of the sock being very narrow, raises so very little breadth of furrow, that the mouldboard could not follow it, if it were not so high.

high. Such a plough can only make a triangular rut, and raises no more earth than what lyes in the angle between the coulter and mouldboard sole, in the position in which the plough is going, and this earth is turned over upon the firm ground left to the right hand untouched, and covers it, so that the whole appears to be turned up.

In the next place, the earth is to be removed to the right hand. If this were all that is to be done, the most proper form of the plough would be a half wedge, with its fore edge perpendicular, moving in the cut made by the coulter, and having its land side applied close to the firm ground. Such a plough would remove all the earth to the right hand, keeping the same surface uppermost which was uppermost before.

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The power requisite to draw this plough forward diminishes as the thickness of the wedge is less in proportion to its length, or as the plough is longer in proportion to its width. It is true, that Mr Baron, in his treatise on the plough, denies this, and says, on the contrary, that a short wedge is more easily drawn than a long one. He also says, that when he made experiments with different wedges drawn through sand, he found the resistances to be proportioned to the length of the wedges, and he ascribes this to the greater time which the ground has for pressing on the longer wedge. It is very true, that when the wedge is longer than another of the same thickness, it is at any one time employed in

removing more earth, in proportion to its length. If, therefore, a plough were working in mere sand, or in soil as loose as sand, and had nothing to do but to shift this to the right, little advantage would be gained by making it longer: But, in soils which have any considerable cohesion, the furrow slice must be cut and bent aside. In the performance of which, there is an advantage attending a very long and thin wedge, as well as in all cases of cutting and cleaving instruments. It is very difficult to say what is the proportion in which the advantage will increase; but I may venture to assert, that it will at least extend to that length of wedge which is necessary for giving steadiness to the plough's motion.

It has been supposed, that by making the wedge round on the furrow side, it would require less power to draw it forward; and this supposition has been justified by observing the advantage which a ship has by being of this form. But there is very little resemblance between the resistance of the water to a ship, and the resistance of the earth to a plough. A ship moves more easily, by being rounded in behind, because, by this means, the water falls in more easily to fill up the space left by the ship. This, with other reasons, renders that form the most proper for a ship.

But, in ploughing, the earth is not to fall in behind the plough, and, if it did, it could not help the plough's motion. It is true, by rounding the wedge backwards,

wards, the resistance of its hindermost part is diminished; but its use in removing the earth is diminished in the very same proportion; for the wedge will not remove the earth but in proportion as it widens behind. If, therefore, the wideness of the wedge behind is specified, it will remove the earth to the same distance, whatever is the round of its furrow side; and the only effect of rounding this side, is to make it remove the earth more suddenly with its fore parts. This shape, therefore, so far from diminishing the resistance to the plough's motion, seems rather to increase it, because it makes the fore part of the plough act like a wedge of a more sudden taper. Each part of the plough would act like a wedge, tapered in the

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same direction in which a plane board would lye when it touches the plough in that part. Besides the increase of resistance, the wedge of this rounded form would be more apt to break the furrow, without removing it regularly, than if it were straight in the side. It is plain that these inconveniences must be so much the greater as the round of the sock is more forward.

On the whole, therefore, a straight surface is the most proper shape for the furrow side of a wedge, whose only office is to remove the earth to the right hand.

But, as the earth must be raised up, as well as shifted to the right hand, the form of the wedge must be different from that now described, and must resemble

semble fig. 7. No. 2. Suppose a triangular block of wood, $G F D E$, of which the hindermost and back edge $G F$ is perpendicular, and whose lower back edge $F E$ lies in the angle formed by the land side of the plough and the sole, and whose base $F D E$ is a triangle, square at F , and sharp at E , and whose breadth $F D$ is the breadth of the sole behind. Suppose now, that this block were cut through level at the height $A B$, the lower part of it will form a sort of wedge $A C B E D F$. When this wedge is drawn forwards, in the direction $F E$, with its back surface $A F E B$ pressed close to the firm land, the fore surface $B E D C$, will shift the earth to the right, and at the same time raise it. Accordingly this is very nearly the form of

of the mouldboard of the Scotch plough,

But there remains another office for the mouldboard to perform, namely, to turn over the furrow slice. This will not be performed by either of the wedges above described. It may be here said, that the Scotch plough does really turn over the furrow. It does so, but for the following improper reason. The plough is kept over to the land above, and the wrest, or mouldboard sole, rises considerably above the land side sole. By this means the plough leaves a small ridge of untouched earth between the bottom of the furrow in which it is going, and the bottom of the next. When the straight mouldboard has shifted the earth to the top of this ridge, it cannot remain there,

but

but falls over on the next furrow. The plough, by this, appears to make good work, but this is only an appearance, because there remains under every furrow a ridge of earth which is not turned up.

Since then it appears that the three fold motion which must be given to the earth, namely rising, shifting to the right hand, and twisting over, cannot be performed by means of a straight sided mouldboard, whatever position we give it, we must have recourse to a twisted mouldboard, or one of a curved form. Accordingly mouldboards have long been made with a curve or twist. These have differed very much in their shape, as they came from the hands of different artists. Such persons, being
guided

guided by no principle, could not be expected to follow any one rule. But the operation of the plough is a certain thing. The earth is found by it in one place, and in one position, and must be left by it in another place, and in another position. If the farmers are once agreed as to the place and position in which the earth must be left, there is surely but one way in which this can be best done, and therefore, when all ploughs are made so as to do this, their mouldboards will be of one form.

With respect to the first, it seems to be the opinion of the most sensible farmers, that the earth should be shifted about nine inches to the furrow side, and that the furrow slice should stand
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with that side which was formerly undermost now fronting the land side, and leaning back to the furrow side about forty degrees; so that the furrow slice must be twisted from its former position about 130 degrees. This plainly fixes the position of the hindermost part of the mouldboard, where it quits the furrow. If any other position of the earth is found by experience to be preferable to this, it is easy to vary the mouldboard accordingly. My business is not to instruct the farmers what should be the position of the earth when left by the plough, but to make a plough which will leave it in the position which their best judgements approve. The directions which I shall now give on this head, will show that

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my principles will apply equally well to any opinion which they may have in this important matter.

The principle which should direct us is the following very simple one. As the best way of shifting the earth to one side, or of raising it, is to shift it, or raise it, by equal degrees for every inch that the plough advances, so the best way of turning it over, is to give it equal degrees of twist for every inch that the plough advances. If it is more suddenly twisted in any one part than another, more force is required at that part, and the furrow slice is more exposed to the chance of breaking in that part, by which the regular position in which we wish to leave it is destroyed.

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This being the principle, I proceed to give directions, by which any workman, of common understanding, may infallibly make a mouldboard which shall perform its work as desired, without ever having seen one before, or being obliged to copy. The directions will also help him to make a mouldboard which shall differ from the one to be here described in any manner he pleases, so as to perform the work with certainty, in any manner which a farmer shall desire.

It follows, from the principle now laid down, that the moment the furrow is cut by the sock, and begins to rise on its back, it should also begin to shift and twist to the right hand. From this it follows, that the back of the sock

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and mouldboard should make one continued fair surface, without any interruption, or sudden change. The twist, therefore, must begin from nothing, at the point of the sock, and the sock and mouldboard must be formed by the very same rule.

In the next place, there must be some certain line of the furrow, on which we must always reckon the twist. This must certainly be reckoned on a line drawn straight across the furrow, square with the land side. Let us suppose, that the plough has just entered on a ridge, which has been cut square across, and has advanced till the heel has just entered the ridge. Then *R I D* in fig. 13. will represent the sod as it then lies on the sock and part of the
mould-

mouldboard. RI is the side of the sod which was cut by the coulter, and RD will represent the end of the sod as it was cut across, while lying in the ridge. Therefore the angle R is exactly square, and the angle D is within the square about 16 degrees, when the length from the point of the sock to the heel is 33 inches, and the breadth of the sole is nine inches, which is nearly the usual dimensions. This angle D continues the same from the time that the point of the sock begins to raise and turn the sod, till the heel passes the end of it at DR . As the plough advances, the angle approaches nearer to the square; but, we may, without any material error, suppose, that it never changes from the time that the plough begins to raise the sod till it quits it. This supposition

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tion is very near the truth, and will give us very easy methods of forming the mouldboard. I shall point out two methods for this purpose.

The first is by means of a protractor and scale.

The protractor is a semicircle, divided as usual into 180 degrees. It is represented in figure 11. and has an index or pointer BOA moveable round the centre O . One of the radiuses OC is made to project to a convenient distance beyond the circumference. The use of this instrument is similar to that of the common suit-stock, used by carpenters and joiners. If the pointer A be set to any number of degrees, suppose 50, then the angle made by the edges CO, BO , will also be 50 degrees, and

and a piece of wood may be worked to this bevel, by applying it square over to the edge of the piece of wood. The piece of wood may also be worked to any twist. Suppose, that it is required to be twisted, in such a manner, that it may be square at one end, and half square at the other. Let one side of the piece of wood be planed flat, and with a straight edge. Let it be divided along this edge into 45 equal parts, make the mark 90 at that end, where the wood is to be square. Mark the first division 89, the second 88, the third 87, and so on, till you come to the end, which will be marked 45. Now, set the index of the protractor at 90, and apply the angle C O B to the piece of wood at the mark 90, square with its edge,

edge. Let the wood be worked off at that place till it just fits the angle of the protractor. In like manner, set the index at 89, and apply the angle C O B to the mark 89 upon the piece of wood, square over its edge, and let the wood be worked away till it fits the angle in that place also. Proceed in this manner with all the different degrees of the protractor between 90 and 45, and the corresponding points on the edge of the piece of wood. It is evident, that by this means the piece of wood will be formed, so that the wrought surface shall have a twist, from the square to the half-square, increasing gradually from one end to the other, and every part of its length has a gradual increase of twist. We may also vary this twist in
any

any manner we please, making it more sudden in one part than another. This will be done by making the spaces along the edge unequal, namely, smaller where the twist it intended to be more sudden, and wider where it is intended to be more gentle.

The other instrument is the scale, represented in figure 12. which is nothing else than a piece of hard wood, planed flat, and straight, and divided into any number of parts, equal or unequal, according to the nature of the twist which the piece of wood is to have. The only use of this scale is to save the trouble of dividing the edge of the piece of wood to be twisted. It is of use, therefore, only in these cases where we have occasion to make several

ral pieces of wood of the same dimensions, and of the same twist.

To use this scale, the edge of the piece of wood must be worked flat and straight, and in such a position that there may be wood enough every where to complete the twist. The scale must now be fixed to the piece of wood with pins or screws, in such a manner that its different divisions may correspond to those parts of the edge where the twist is to be, of that number of degrees which is expressed by the divisions.

In order to apply these instruments to the purpose of forming the mouldboard, another circumstance must be attended to. It was observed before, that when the plough has advanced the whole length of its sole, a line drawn
square

square across the furrow slice, as it then lyes upon the mouldboard, does not make a square angle with the mouldboard sole, but falls about 16 degrees within the square, making an angle of about 74 degrees. For this reason, it is necessary, that when the edge B O of the protractor's index is applied square to the edge of the mouldboard sole, the plane surface of the protractor shall not be square with that edge, but make an angle R D I of 74 degrees. (see fig. 13.) For this purpose, the tail of the index B O must not be a square piece, but bevelled to 74 degrees, as is represented in figure 11. No. 2. where B E F G is the index seen endways, having its two angles G and E of 74 degrees. The protractor A C goes slanting through it,

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and turns round the pin H O, which is square with the sides B G and E F. By this means the protractor A C will make an angle of 74 degrees with the upper edge of the index B E.

The protractor, with this change being applied as above directed, with its index square with the outer edge of the mouldboard sole, will always give the proper twist for the furrow, reckoned directly across it.

Now, let C, fig. 13. be the hindermost point of the mouldboard above, and let I D E be the straight edge of the mouldboard sole, or rather of the scale fixed to it, and let E be the point, to which the index of the protractor is applied square, when the side C O (fig. 11.) being opened to 130 degrees, just touches

touches the point C of the mouldboard. (fig. 13.) Measure the length from E to the point of the sock, and make this the length of the scale, (fig. 12.) Divide this scale into 130 equal parts, and number the tens as in the figure 12. Now, let this scale be applied to the straight edge of the mouldboard sole, and there fixed with screws, so that the beginning of the divisions may be at the point of the sock, and the division 130 will then project a good way behind the mouldboard. This is represented in fig. 14. where CI is the land side sole, C is the point of the sock, and CB is the scale. The protractor being applied to this scale, in the manner above directed, will regulate the mouldboard to one uniform twist, from its
hinder-

hindermost point to the very point of the sock, forming at once the mouldboard itself, the fore edge of the sheath, and the back of the sock.

In using these instruments, we must always be careful to apply the edge of the index square with the edge of the mouldboard sole; and the part of the scale which projects behind the sole must be supported, so that it may not be pressed out of the straight by applying the scale to it. Neglect in either of these particulars, may produce great errors in the form of the mouldboard.

It must now be observed, that the directions here given require a correction, on account of the plating with which the mouldboard is to be covered. This may be done by altering the divisions
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of the scale in the following manner :
The scale being four feet long, it is divided into 130 parts, which answers to the 130 degrees of twist, and it is marked at every five. This makes 26 principal divisions, each foot having $6\frac{1}{2}$. Set off the first 20 divisions from C to H, (fig. 14.) the same as if the whole scale were divided equally, and put the mark 20 at H. Set off $2\frac{3}{4}$ inches from H to A, and put the mark 20 again at A. Set off $8\frac{3}{4}$ inches from A to D, and put the mark 50 at D, and divide the space AD equally. Set off $5\frac{1}{8}$ inches from D to E, and put the mark 65 at E. Let the divisions between 50 and 65 gradually increase, being smallest at D, and biggest at E. The distance from E to B will now be two feet, and is to be divided

vided equally, in the same manner as the whole scale would have been without this correction. The blank between H and A is to make up for the difference between the inner and outer side of the sock; and the inequalities of the other divisions is to make up for the different thickness of the plating. Although the mouldboard made by this corrected scale has not the regular twisting of its parts, yet the surface of the iron will have that regular twist which is intended.

From this description of the instruments, and of the manner of using them, it is plain, that whatever opinion farmers may have concerning the gradual variation of the twist which the plough must give the furrow, a mouldboard

board may be made by these instruments, which shall produce the twist which is desired. Accordingly the following division of the scale gives a form of mouldboard which is much approved of. The numbers in the first column are those which are to be placed on the divisions of the scale, and the numbers in the second column are the distances from the hindermost end of the sock.

			Feet.	Inches.
20	-	-	0	0
30	-	-	0	$3\frac{4}{5}$
40	-	-	0	$7\frac{2}{5}$
50	-	-	0	$9\frac{1}{5}$
60	-	-	1	$3\frac{1}{5}$
70	-	-	1	$6\frac{7}{8}$
80	-	-	1	11
90	-	-	2	$3\frac{1}{2}$
100	-	-	2	$7\frac{7}{8}$
110	-	-	3	$0\frac{1}{5}$
120	-	-	3	$4\frac{2}{3}$
130	-	-	3	9

The following division of the scale also produces a mouldboard which has given great satisfaction.

			<i>Feet.</i>	<i>Inches.</i>
20	-	-	0	0
30	-	-	0	3 $\frac{1}{2}$
40	-	-	0	7
50	-	-	0	10 $\frac{1}{2}$
60	-	-	1	2
70	-	-	1	6
80	-	-	1	10
90	-	-	2	2 $\frac{1}{3}$
100	-	-	2	7
110	-	-	3	0
120	-	-	3	6
130	-	-	4	1

I have already observed, that this method also forms the back of the sock, and the fore edge of the sheath. But

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as it is convenient to know pretty nearly the inclination and curve of the sheath, before it is framed into the beam, I shall here give directions, illustrated by *fig. 15.* The perpendicular height *AC* of the sheath, reckoned from the sole to the under side of the beam, at the fore side of the tenon of the sheath, is $13\frac{1}{4}$ inches, and its inclination forward *CD* is $14\frac{1}{4}$ inches. The fore side of the sheath may be formed to a circle *ID*, having the radius *DO* of 18 inches, the centre *O* being in a perpendicular above *E*, which is 19 inches from *C*. This will leave a small space between *AC*, which is not made up by the sheath, but this is of no detriment, for if the sheath were so far forward, working it to the twist would weaken its tenon.

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The part of the scale before 20 is of no use in making the mouldboard, as it is before the point of the sheath. It serves to show the point C, fig. 14. where the land and furrow sides intersect each other. The scale must be fixed so, that 20 at A is equally forward with the point of the sheath, and the edge which is used for forming the mouldboard must be $2\frac{1}{2}$ inches from the land side at the point of the sheath, and $3\frac{1}{2}$ at I. When the shoeing is put on the wood at this size, it makes the sole to be above nine inches, which is abundance of breadth for general purposes.

The other method which I shall give for forming the mouldboard, is by an instrument represented in fig. 17. which we call a bevel. It consists of a straight
piece

piece of wood K M, which may be called its handle, and a rod N P, fixed into it at an angle equal to that which the cross line R D of the furrow, fig. 13. makes with the mouldboard sole, namely, an angle of about 74 degrees. The lath A B is fastened to its upper side, parallel with its edge, so as to form a shoulder, which can be applied to the edge of the mouldboard sole. This instrument is represented endways in No. 2. by which the angle or shoulder may be better seen.

In order to see the manner of using this instrument, consider fig. 16. where G is the point of the sock, G L the land side of the plough, C R E a line drawn parallel to it, along the furrow side of the sheath, and C I the furrow side of
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the mouldboard sole. R A is the upper mould of the mouldboard, drawn to its proper thickness and position. This upper mould must be taken from a pattern made by the protractor and scale: Or we may come extremely near the equal twist, by making R A a straight line, set on at R, opposite to the point Y, which is two feet distant from the point of the sock. R A must make an angle A R E of $46\frac{1}{2}$ degrees.

Now, let a piece of wood be chosen for the mouldboard. This must be at least eight inches thick, and of the shape represented in fig. 16. No. 2. The lower edge C H must be about $22\frac{1}{2}$ inches, the height O P 12 inches, the inclination forward C P of its fore side must be 11 inches, and the upper edge

O A

OA must be about 24 inches. When this piece is joined to the plough, in such a manner that the mouldboard can be worked out of it, it will stand in the position, fig. 16. A O R B being its upper edge, and H C D I its under edge. For this purpose, it must be hewed away with a perpendicular face on the land side, in such a manner that the lowest point forward C of figure 16. No. 2. may be at C in figure 16. No. 1. which is the intersection of the furrow side AI, with the furrow side of the sheath CR; and the highest point A, behind figure 16. No. 2. must fall on A No. 1. The perpendicular face abovementioned must now apply close to the furrow side of the sheath, all the way from C to S. Now, let the mould

CI

C I be drawn on the under edge of the piece of wood, and the mould R A on its upper edge, in their proper position, or inclination to each other, as in the figure, and let the fore edge of the sheath on the land side be formed according to figure 15. Every thing is now ready for applying the bevel.

Lay the stock or handle of the bevel along the line G C, the end M of the stock being towards G, and the check or angle of the stock being applied close to G C, slide it back along G C, till the rod P N of the bevel comes to touch the sheath, which it will do at first on the furrow side. Let the wood be hewed away till the rod now touches the fore edge of the sheath on the land side. In this manner proceed backwards, always

ways sliding the stock along the draught CI, and hewing away the wood till the rod can touch the fore edge of the sheath on the land side. This will form the mouldboard as far as the top of the sheath. Proceed in the same manner, always applying the stock to the draught CI, and hewing away the wood till the rod can touch the mould draught RA, drawn on the upper edge of the mouldboard in its different parts. When this is done, if the stock be gradually drawn along CI, and the rod applied to the fore edge of the sheath CR, and the upper mould draught, the rod itself will slide along the surface of the mouldboard, and will, in every situation, be perfectly similar to the edge of the protractor, and perform the same office.

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The mouldboard made in this manner will hardly differ from that made by the scale and protractor, and may, like it, be varied at pleasure, by varying the form of the fore edge of the sheath, and the form of the upper mould draught R A.

A gentleman, who has been so good as to look over this performance before it was put to the press, has favoured me with the following observations on these two methods.

“ The method with the scale and pro-
“ tractor does not give an equable twist
“ of the mouldboard in any part, ex-
“ cept just at the point I. The me-
“ thod with the bevel is exact all the
“ way from the point of the sock to I.
“ Both the methods give too much in-

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“clination to the furrow after it passes
“I, and leave it turned farther than
“130 degrees.”

As I make no pretension to mathematical knowledge, I will not dispute the truth of this observation, especially as I am informed by my friend, that the deviation from a regular twist is not so great as to affect the performance of the plough very materially. Besides, the reader sees by this time, that this method of forming the mouldboard, whether by the protractor, or by the bevel, will enable us to give it a regular twist, or any twist we please. We have only to vary the divisions of the scale for the protractor, in such a manner as a mathematician shall direct for the twist required. If we use the bevel, the mathematician

thematician can inform us what shape of the upper edge of the mouldboard will form the whole surface to the desired twist. And I reckon it a matter of some consequence to have pointed out a rule, by which workmen may make mouldboards with absolute certainty, according to any given principle, whereas at present they are made at random, or by the eye.

The last circumstance to be taken notice of with respect to the mouldboard, is the form of its hindermost end. This has been greatly varied by different workmen, although there is only one way of making it proper for its work, which is, that all the parts of it shall leave the furrow in one inclined plane. This may be very nearly done
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in the mouldboard now described, by making the hindermost end of the same curve with the fore end, the curve cutting the mouldboard, all at one length, as in fig. 13. When the mouldboard is of any other form, its hindermost end may be formed so as to leave the furrow in one regular inclined line, by the following easy method. Let two parallel lines be drawn upon an even floor, at the distance of the extreme point of the heel of the mouldboard sole, from the land side of the plough, as is represented in fig. 16. by the lines G L and Q T. Let the plough be set with its land side along G L, so that the heel of its mouldboard sole may be at I. Now, let a straight plank, of the same breadth with the mouldboard, be set
with

with its straight edge along the line Q T, but leaning over to the furrow side. Let it now be turned round upon the line Q T, like a door on its hinges, till it touch the hindermost end of the mouldboard, which must be cut away till the plank touches it from the heel to the top, and stands at the proper inclination to the furrow side. After this description of the mouldboard, and this account of the principle which leads to the construction, it seems unnecessary to draw any comparisons between this mouldboard and those of other forms; and I doubt not but that the reader will agree with me in thinking that this merits the preference.

As the description hitherto given of the plough, has all along related to the
plough

plough which has the feather sock on the sheath, it may be thought that this construction is proper for that kind of sock, and that manner of framing, only. But it will correspond equally well with other socks and methods of framing.

When land is stoney, the spear-sock is thought to be the most proper, and, in this case, a plough framed with a head is thought better than one framed in the manner already described. Such a framing is represented in fig. 18. In this framing, the land side of the sheath must be even with the land side of the head, and with the land side of the fore and hinder end of the beam. This is done, by giving the sheath a shoulder upon the land side, both above
and

and below, and not making its tenon on the land side, as is usually practised. In this manner, the upper tenon of the sheath may be through the middle of the beam, which will give it the greater strength. Thus the land sides of the head and sheath, and stilt, are in one plane.

The curve of the sheath and its inclination forward, are to be the same as in fig. 15. as far down as the upper side of the head. The plough however will not be materially hurt, although the sheath has not so much curve below, which would perhaps weaken the lower tenon of the sheath, which, in this construction, is more over to the furrow side than usual.

The

The stilt may be either of such a mould as is represented by the dotted lines in fig. 18. so as to frame into the hindermost part of the head, or it may be of the shape expressed by the shaded part of the figure, with a chock of wood between it and the heel, and an iron bolt through it, as C D. This is a much stronger form, and less liable to rack. This framing of the plough may be used either with a spear sock, or with a feather sock. The spear sock is represented in fig. 19. which shows the sole of the head and furrow side, inclined as they should be, when the mouldboard is made according to fig. 14. A cross section of the hindermost part of the sock is seen at N I, where E B A C is the iron work of the sock, B A

its

its back, B E its land side, and A C its furrow side, and C D the sole of the head. The back of this sock behind will have very nearly the same inclination with the mouldboard of fig. 14. at that place.

The greatest difference between this and the feather sock plough is in the height of the mouldboard sole. As the spear sock does not cut the furrow so low before the mouldboard sole as the feather sock does, the sole must be $1\frac{1}{4}$ inch higher all its length. Different soils require a variety in this respect.

Another difference is, that the point of the sock must not be straight with the land side, because, in this case, it would be too much to the left, and would not raise up all the furrow, when

S

the

the coulter is placed as before directed, which is its most proper position in this plough, as well as in the feather sock plough.

When the feather sock is put on this head, as is represented in fig. 20. the hindermost end of the sock is as N 2. C A B being its back, and C E its land side. This sock has nearly the same inclination behind with the mouldboard of fig. 14. at that place. As this sock has a feather, the mouldboard sole may be made as low as when the sock is in the sheath. The point of the sock must also be straight with the land side of the plough.

A feathered sock plough with a head, will admit the sock to be flatter above than when the sock is on the sheath, by
which

which means there is more length of the plough below the furrow before it is turned up, and the plough keeps better in the ground, and seems, in this respect, preferable to the other, in soils where obstacles frequently occur, which are apt to put the plough out of the ground.

When the iron head, with the feather sock, is employed, the twist of the mouldboard is formed in the same manner, but is extended more forward, because the hindermost end of the sock is smaller.

Directions for making Sock Maundrels.

It is best to have these of cast metal.

This requires a wooden pattern. This, for the feather sock on the sheath, must be formed to the regular twist by the same instruments which are used for forming the mouldboard. For the sock on the head, the pattern is made proportionably flatter, because, in this case, the twist is extended further forward.

Directions for framing the Plough, fig. 1.

When the fundry parts of the plough are to be marked for the tenons and mortises, they must be laid in the position which they are to have when the
 plough

plough is made. The position of the beam for giving the proper hold depends on two things, 1st, the different length of the beam, and the height of its fore end from the plane of the sole. 2^d, The inclination of the line of draught. If all ploughs were of one length, from the part which turns the furrow, to the part of the beam by which the cattle draw, the rule for giving them all the same hold is very short and simple; namely, to place the fore end of the beam at the same height above the plane of the sole. But this rule will not apply when the beams are of different lengths. The following method may therefore be practised.

A B (fig. 22.) is a straight batten about 10 feet long. Let there be a notch, stud, or other mark C, about 3 feet,

6 inches from the end A. Make the point H about 4 inches farther from A, which, in most good ploughs, is nearly the distance between the point of the sheath, and the interfection of the line of draught with the sole of the plough. Draw a line H L, making an angle L H A, equal to the inclination of the draught. This inclination is to be found by directions which will be given afterwards. Make H M nine feet, and draw the perpendicular M L, meeting the draught line in L. Make L G about five or six inches, and draw the line G H. Take a straight batten E F, and lay it on the line G H, so that its middle K may be about four feet from H. Let the battens E F and A B be connected by a batten A K nailed to both, which

which will keep E F in its proper place and inclination.

Now, let the sheath be cut by a mould to its proper curve forward, and a draught made for the sole, or let it be also formed on the end which is to be the sole. Let it also be marked at the height, where its tenon is to begin. Let the stilt also be cut to its proper mould. Now, place the sheath with its sole draught on the edge of the batten A B, and its point at the noth c. Place also the stilt in its proper position. Then lay the beam, with the under part of its fore end, on the edge of the batten E F, and its under side on the tenon mark of the sheath. Slide the point of the beam backwards or forwards along the edge E F, always keeping its under side

side to the tenon mark of the sheath, till the other end of the beam projects sufficiently behind the stilt, for giving a proper length of tenon. The mortises and tenons must now be marked, while the parts are in this position, and the plough will have its proper hold for the inclination of the draught, and when the bridle is added, the plough will keep its heel well to the ground.

If the plough is to be worked with a bridle and chain, a piece must be fixed to the fore end of the beam, when it is laid down for marking, which will make the part which touches the batten E F to correspond with the situation of the point of draught in the going plough.

The part of the batten A B, which is behind the heel of the plough is for adjusting

justing the height of the stilt handles.

This must be the same whatever is the length of the stilt, and for ordinary men, must be about three feet two inches from P to B.

The ascent or inclination of the line of draught depends both on the height of the cattle, and the distance from the plough at which they are yoked. When the horses are standing in the draught, let a plumb line be applied to that point of the chain or draught rope which goes through the backband. Measure the height from the ground, and the distance of the point of the ground where the plummet falls from the point H, three inches behind the point of the sheath. When two horses are going abreast, as one of them is on the un-

T

ploughed

ploughed ground, we must add half the depth of the furrow to the measure taken as above directed. When one horse is yoked before another, in such a manner as to make two ascents of draught, a middle between these may be taken, if both are of equal strength. If they are not equal in strength, the medium line of draught will be nearer to the draught line of the strongest. Thus, if HN be the draught line of the hindermost horse, and HO the draught line of the foremost; and if the draught of the first is stronger than that of the last, in the proportion of five to four, for instance, make HN five parts of any scale, and HO four parts of the same scale. Make NP parallel to HO , and OP parallel to HN . These two lines

will

will meet in P, and H P will be the direction of the medium line of draught.

The framing on the sheath requires only this farther direction in addition to what has been already said, namely, that in order to make its land side on the same plane with the land side of the sole, and, at the same time, its tenon near the middle of the beam, it must have a shoulder on the land side. This will seldom need to exceed $\frac{3}{8}$ of an inch. The land side of the stilt must also be in the same plane with the sheath and sole.

In fixing on the furrow side of the plough, the inside of the mouldboard must be hewed till it is reduced to the thickness of 2, or $2\frac{1}{2}$ inches in the middle, where the little stilt is to be fixed.

fixed. The upper side and hindermost end may be made thinner, because they are exposed to less strain. The mouldboard is then fitted on to the sheath, at its proper inclination with the land side of the plough, and the proper width behind. The little stilt is then fitted to, and marked for its proper height. The mouldboard being now taken away again, the little stilt is nailed to its proper place. The mouldboard being again put on as before, the stilts are bored for the rungs, and marked for the length.

Of the Use of a Chain on the Plough.

When a plough is made with such a degree of hold as in fig. 24. the point C of the bridle, to which the draught is applied, is kept in its position by means of a chain CD, which is hooked to a staple at D, at some distance behind on the beam. The chain may be made shorter or longer by means of the click in the staple D; and by this means, the point of the bridle C is kept in a circle round the centre bolt B, and the plough gets more or less hold, according as the chain is made longer or shorter. When the plough is mounted in this manner, the point of the beam is set higher than when no chain is used, although the
 height

height of the sheath be the same, as has been already observed in the directions for framing. The ploughmen call this giving the plough greater redd or freedom. This form of the plough enables us to give it greater changes of hold than when a bridle is used without a chain, because the bridle may be made longer from the bolt, without any danger of breaking, being supported by the chain. The part of the beam also between the bridle and staple is somewhat secured from breaking upwards; and if the staple could be conveniently placed at the very stilt, it would be still more secure. This bridle is made with notches on each side of the middle, in order to give the plough more or less land.

When

When two horses go a-breast, the draught line falls in with the direction of the plough, or is right along the beam. But when the horses go all in the furrow, the draught line is then removed to the right, something more than half the breadth of the furrow, (see fig. 25.) where $A D B$ represents the draught line, when the horses are all in the furrow, and $A E C$ is the draught line when the horses are a-breast. D is the point where the line $A D B$ falls in with the furrow, and A is the point where it falls in with the centre draught. DE will then be the distance of the notch of the bridle, upon which the chain should be placed, from the other draught line $A E C$. It may be observed of this manner of drawing, that the draught

draught line can never fall parallel with the direction of the plough. Indeed, even where the horses are a-breast, the draught line is not exactly in the direction of the plough, because the land horse generally keeps more than nine inches from the edge of the furrow.

Of the Use of Wheels to a Plough.

From the description which has already been given of the various parts of a plough, and the reasons which have been offered for giving to each of them the form which I have recommended, the reader will see what part of the work is performed by each, and will be able to judge of any alteration which may be proposed by way of improvement, whether

whether or not they tend to make a plough perform better work, be more easily drawn, more regular in the draught, or more easily managed. Care has been taken of each of these things in the foregoing constructions, and experience shows that a plough may be so made, as that, when working in even and well dressed ground, the plough will perform the work almost of itself, requiring very little attention from the ploughman.

But ploughs have been used which are of a very different construction, having many parts which are not in the plain plough, the subject of the foregoing sheets. As these ploughs are now in great vogue, and much used both in England and other countries, and as

the parts added are intended for producing some of the good effects just now mentioned, it will be improper to pass them over without notice in this treatise. The chief of these proposed improvements is the addition of wheels to a plough, which shall therefore be particularly considered in this place.

It has been a very general opinion, that the addition of wheels is an improvement of the plough, but artists have differed exceedingly, both as to the manner of applying them, and the parts to which they should be applied. Since these parts are only subservient to the part of the plough which really performs the work, and as the manner of acting of a wheeled plough differs considerably from that of a plough without
wheels

wheels, we must consider particularly their action, at the different parts to which they may be applied, in order to judge of their advantages or disadvantages. The reader also will easily see, that the form of that part of the plough which is in the ground, and really performing the work, must be regulated by the same principles in both cases, and that what is most proper for the one will also be most proper for the other.

One manner in which wheels have been used, is to have two wheels applied to the beam, by a carriage. Wheels applied in this manner have their principal effect in regulating the plough, by giving it a certain quantity of furrow, either in breadth or depth. While one
wheel

wheel continues in the furrow, and the plough is set to take any given breadth, it must keep that breadth very regularly, and not be liable to make any sudden bend, and is therefore very proper for keeping ground straight that is already laid out in straight ridges. Also, when the beam is fixed to any height of the wheel carriage, the plough must be kept at a fixed depth, and, by shifting the beam higher or lower, the plough may be made to go deeper or shallower, as occasion may require. When, therefore, the soil is equally deep, and free from obstacles of stones or roots, this plough must require little labour in managing it.

But,

But, on the other hand, when the surface is not a plane, either level or inclined, but has a number of heights and hollows, as is frequently the case, especially in cross ploughing, the wheeled plough cannot be so proper as the one without wheels, which the ploughman can regulate to his mind, whereas the wheeled plough is out of his power. In like manner, when the soil is not equally deep in the length of a furrow, or would require to be ploughed to different depths at different places, it cannot be proper to have the plough fixed to one certain depth. It is known that, in general, the crown of the ridge will admit of being deeper ploughed than what is near the furrow.

It

It must also be observed, that in making the first furrow of the ridge, the wheel which, at all other times, goes in the furrow, must now be as high before the furrow is made, as the one on the unploughed ground. This requires the plough to be altered every time we make the first furrow of a ridge. On the other hand, when a plough is making the last furrow of a ridge, the wheel, which, at all other times, goes on the unploughed land, is now in the furrow of the former ploughed ridge, or on the opposite side of the same ridge. This will, in like manner, require an alteration of the plough.

From these observations, it appears that inconveniencies arise from keeping the plough in one uniform depth, and
that

that by the frequent alterations here specified, very little labour is saved to the ploughman upon the whole. It must also be observed, that the part of the wheeled plough in the furrow must be the same as that of the plain plough, when the centre draught is the same. But, in this plough, the draught line has often two different ascents, one from the part of the plough acting in the furrow, to the wheel carriage, and the other from the carriage to the cattle. To this is added the draught of the wheels and carriage.

In finding the draught line of this plough, we must consider the parts upon which the pressures are exerted. With respect to the part of the plough which is in the furrow, the pressure is exerted

on

on that point which we have called the centre of action. This will vary a little, by a change in the depth of the furrow, and by any difference in the length and position of the sock and coulter. But, in general, when the distance between the point of the sock and the heel is two feet nine inches, the draught line will intersect the sole about 14 inches back from the point of the sock.

With respect to the carriage, the pressure of the draught is always exerted on that point to which the draught is applied. Some may think, that the pressure of the work is exerted on that point where the beam rests upon the carriage. But, in whatever way the carriage draws the plough, or beam, or
in

in whatever way the carriage is made, it has all one effect, and the draught line will never follow any elevation of the beam, nor the various turnings of the different parts which connect the centre of action with the part of the carriage to which the draught of the horses is immediately applied, but makes a straight line through them all. Thus, then, there are two ascents of draught, one from the centre of action to the draught point of the carriage, and the other from thence to the horses. If these two ascents make but one straight line, the plough will, in this respect, differ very little from the plough without wheels, because then there is no pressure upon the wheels. It is true, that the plough will not go

deeper, but it will be easily thrown out. If the first ascent of draught is greater than the second, so as that they make an angle below, at the part of the carriage which is drawn by, there will then be a pressure upon the wheels, and the plough will be regulated in its depth, and will go steady. This pressure upon the wheels will be so much the greater, as the two ascents of draught differ more from each other.

It is thought that power is gained by thus raising the line of draught upon the carriage, because, in the common way, the draught is partly employed in pulling the plough out of the ground, and the remainder only is employed in pulling the plough forwards. In the wheeled plough, the draught of the
cattle

cattle may be made parallel with the bottom of the furrow; but it must be here observed, that by giving this direction to the draught of the horses, we increase the pressure of the wheels; and while power is gained by lessening the ascent of draught, power is also lost by increasing the pressure upon the wheels. I am of opinion, that, when these circumstances are duly attended to, and when we consider the uneven and compressible surface upon which the wheels must move, we shall find that no power will be gained by placing the draught higher upon the carriage than the straight line which joins the centre of action of the plough with the height of draught, as it comes from the lower end of the horses backband. With respect, there-

therefore, to the easiness of draught, the wheeled plough does not seem to possess any advantages, and it is loaded with the additional weight of the carriage and wheels.

There is a wheeled plough of a much more artificial construction than the one now described, having wheels or rollers applied to that part of it which is in the furrow.

In order that the furrow side of a plough may shift and turn the earth in the manner desired, the plough must be supported against the resistance which it meets with from the earth. As the earth is raised and pressed to the right, the plough is pressed downwards, and to the left, and must be supported by the bottom of the furrow, and by the
firm

firm ground to the left. The sole and land side of the plough are therefore strongly pressed, and exposed to great friction, in the same manner as the sole of a sledge drawn along a soft road. In the plough now under consideration, a wheel has been substituted in place of the sole, and another wheel, or rather roller, with a perpendicular axle and horizontal motion, has been substituted in place of the land side. This plough differing from a common plough in the same manner as a wheeled carriage differs from a sledge, it has been called a carriage plough, while the common ploughs are called sledge ploughs. It is also commonly known by the name of Moore's patent plough. As these wheels are placed in the most proper manner

manner for producing the effect that is desired, this plough is very fit for enabling us to judge of the value of this improvement. The improvement is supposed to be the same upon the plough that wheels are supposed to be upon a sledge. The superiority of the wheel-carriage above the sledge is well known. Now it is thought, that as the wheel, which, in this plough, performs the office of the sole, is 16 inches in diameter, while its gudgeon is but one inch, the resistance to the plough's motion arising from the friction of the sole is diminished 16 times.

Granting this, the improvement is not so great as is commonly imagined. For a wheel of 16 inches diameter cannot be placed so near the point of the sock, as

to perform the office of the sole. It only performs the office of the heel of a plough. Now, we have seen, that the pressure upon the heel of a plough, and consequently its friction, is not considerable, if the plough is constructed according to good principles, being nothing more than what is necessary for making the plough steady in its motion. In Moore's patent plough, the pressure of the heel may be reduced to nothing, because it has wheels under the beam. But in the way in which it is commonly made, the pressure at the heel is very considerable, and the friction may be greatly diminished by means of the wheel at the heel of the plough. This advantage however is much more than balanced by other inconveniencies. The sole

sole of a common plough being made smooth and even, and in the direction of the plough's motion, it suffers no resistance, but what arises from friction alone. Pressing upon the furrow with its whole surface, no part of it can sink deeper than another. It is also well known, that its friction is the same whether its whole surface is pressing, or only some parts of it. By experiments which I have made with great care, I have reason to conclude, that the friction of a plough sole does not much exceed the fourth part of the pressure which is acting on it. I have also made experiments with a wheel placed in the manner of Mr Moore's. I have found its resistance to be very irregular, according as the soil was uniform or not. A
wheel

wheel of 16 inches diameter requires near $\frac{1}{4}$ of its weight or pressure to draw it over an obstacle one inch high, and near one half of its weight to draw it over an obstacle two inches high. Many such obstacles occur in the bottom of a furrow, from hollows, eminencies, stones, soft places, and loose mould, which tumbles in, and it would be but a moderate estimation to reckon them equivalent to an obstacle of two inches high. The resistance therefore to such a wheel is nearly double the resistance to a common sole plate. I do not by this mean to assert, that the resistance to Moore's plough is double of that of a common plough, because I have observed already that the resistance at the heel is but a small part of the whole resistance to

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which

which the plough is exposed, and it is this resistance alone upon which the wheel makes any change.

I will now add, that using of this wheel in place of a common sole, greatly hurts that steadiness of motion, which we have been at so much pains to procure, and which is one of the greatest properties of a plough. For, as the wheel sinks into a hollow, or goes over an eminence, the point of the sock must be raised or depressed. Accordingly it is found, that when it is used without a carriage under the beam, the plough goes with a very hobbling motion, and although the beam-carriage prevents this in Mr Moore's plough, it must be acknowledged, that the labour of the cattle must be increased on this account.

With

With respect to the wheel which performs the office of the land side, the same inconveniencies must attend it in a greater degree, because, from its situation, it cannot be above nine inches diameter. Indeed, it cannot be nearly so big, without projecting too much to the right: it is, therefore, much more affected by any inequality of surface than the other wheel. The bad effects of these inequalities are more considerable on this wheel, for this additional reason, that the wheel itself is placed in a part of the plough where there is really a greater pressure.

A plough of this construction, but without wheels under the beam, has been tried in company with other ploughs of the common form, and it

was

was found to require at least a third more power to draw it. I did not, however, attribute the whole of this to the wheels, because the plough was defective in the construction of its other parts.

There is another wheeled plough which deserves to be taken notice of, because it has met with the approbation of the society in London, for the encouragement of arts and manufactures, and has a very great name, as the plough which is drawn by the least force possible. The make of the body of this plough is not very different from that of the Rotherham plough, from the point of the coulter and the sock backwards. It differs a little in the manner of framing, the left stilt being extended

ed

ed forward, so as to serve in place of the sheath. The mouldboard also is so contrived, that it may be set at different widths.

This plough has three wheels. One of them is placed under the fore end of the beam, which has a bend upwards at the place of the coulter, on purpose to give room for a wheel of two feet three inches high. The other two wheels are on an axle-tree fixed to the beam, a little behind the point of the coulter and sock. One of these wheels treads upon the unploughed ground. The other is let down by means of a crank upon the axle, so as to go at the bottom of the furrow on the right side. The third wheel is fixed to the beam by a frame, which comes back as far as the
point

point of the coulter, where it is fixed to the beam. A part of the frame comes perpendicularly up from the centre of the wheel, and goes through the beam like a slider, so that it can be set at different heights. By this means the plough is tempered to any particular depth. Thus the plough becomes a sort of wheel carriage.

The view of the society in making experiments with this plough, was to discover whether the whole amount of friction on a well constructed plough was an inconvenience which was worth regarding. The result of the experiments was, that it was not. The result could not be otherwise; for the effect of these wheels was little more than carrying the weight of the plough itself.

One

One of the wheels, indeed, acts a little like the wheel in the sole of Mr Moore's plough, and has all its inconveniencies.

This disposition of the wheels is attended with other great inconveniencies. As two of the wheels are very near the point of the coulter and sock, whenever both, or one of them, are raised upon any eminence, the point of the plough must immediately rise, and the connecting parts are exposed to very great strains. When the wheels have got over the eminence, and would come down again, they are prevented, because the sock is now at a less depth than before, and must advance some space before it can regain its former depth. By this means the wheels are often kept from pressing on the surface, while

while, at other times, they are most violently squeezed to it, so that the plough is neither regular in its depth, nor in the labour which it gives to the horses, unless the ground be a smooth plane. Even in this case, the labour of the cattle is considerably increased, because the two wheels, being so near the coulter and sock, are violently squeezed into the ground. By thus sinking into the soft earth, they require a force to draw them forward, nearly equal to what would draw them over an obstacle half as high as the depth to which they sink.

I have given this account of the wheeled plough, in order to show, that besides the other inconveniencies to which they are exposed, they are not adapted

adapted for procuring the very advantages for which they are intended. The advantages also are but inconsiderable, and by no means equivalent to the great additional expence, to the risque of going out of repair, and the trouble of keeping them in order. I might have said, that they possess no advantages over the sledge plough; for they cannot be used except in well dressed ground, free from stones. In such soils, there is no use for them; for it appears that the principles upon which a plough operates, while it is performing its work in the manner required by the farmer, are so certain, that a plough may be made which will perform the work with hardly any attention on the part of the ploughman. Whether I

have succeeded in giving a construction of a plough which is perfect in this respect, the reader must judge, or experience must determine. The intelligent reader must see that the thing is possible; and if ever it is done, the plough constructed in this manner must be preferable to all others, for cheapness, simplicity, easiness of being kept in repair, and its capableness of being adapted in an instant to every change of soil which the ploughman can observe.

Here follows the description of a plough which can turn the furrow to either side at pleasure, and is therefore useful for ploughing along the sides of steep hills, where the furrow must always be turned to the lower side. See fig. 23. Nos. 1. 2. 3. 4. 5.

No. 1.

No. 1. is a view of the frame part of the plough before the mouldboard is put on. The redd or curve of the beam cannot be less than is represented in the figure, otherwise it would not leave room from the motion of the coulter, which is all below it, as is represented in fig. 2. A much greater curve is hurtful, by reason of the weight of the plough being too high, because this plough must always be leaning considerably to the land side.

The stilts may be made in four different ways. 1st. A half length of a stilt may be framed to the beam, and fixed to the sheath and head, and the whole kept together by a bolt E F, as is represented in No. 1. To the part above the beam, two handles may be fixed by
three

180 *Of turning the furrow to either side.*

three rungs. *2dly*, A piece of wood may be taken, which has a cast to the left hand, so that it will answer for the left handle, when it is framed to the beam, as already mentioned. To this may be spliced a handle of an equal cast to the opposite side. *3dly*, A piece of wood may be formed which has a natural fork, suited to this purpose. *4thly*, A piece of wood may be taken which has a proper cast for a stilt up and down, and of such toughness, that when it is fawn along the middle, near to the beam mortise, it will bear to be bent aside to the necessary width.

The sheath is about $1\frac{1}{8}$ inch thick by five inches broad. The head is three inches deep, by four inches broad. In framing of these parts together, they
are

Of turning the furrow to either side. 181

are all placed in the direction of a line along the middle of the head and beam.

The left mouldboard is seen sideways in No. 2. *QR* being the fore edge, where the two mouldboards meet, and *ST* is the hindermost edge. The two mouldboards are seen from above in No. 3. which shows the angle which their upper edges make with each other. The fore edge of the mouldboard is also seen in No. 1. being represented by the dotted line *GH*. These mouldboards are mitred together before. The inside of the mitre is represented by *KL* in No. 1. They turn round an iron bolt *DC* No. 1. which goes through the beam and head. The bolt has a head at *C*, which is sunk into the head of the
plough

plough, and it is screwed at D, where there is a nut. This bolt passes through the solid wood of the mouldboard, through the mitre: therefore, before the mouldboards are fastened together, a half round groove is made in each, and when they are joined, these grooves make a round hole, as if made by an augre. The angle which the under-side of the mouldboard makes with the upper side, is about 18 degrees, both being straight, see No. 6. where A C is the lower edge of the right hand mouldboard, and A B its upper side. The mouldboards may be formed to the regular twist, by means of the bevel, fig. 17. The angle between them at the sole should be the same with that made by the land side and mouldboard sole

of

Of turning the furrow to either side. 183

of a common plough, which is about 15 degrees. Then the mouldboards will make an angle of about 15 degrees below, and 52 degrees above. In order to keep them at their proper angle, and to strengthen them against the pressure of the earth, which tends to force them together, they are secured below by a forked strap of iron of the proper angle, which has a hole through it for the mouldboard bolt D C No. 1. to pass through. This strap is nailed to the lower edge or sole of the mouldboards. They may also be secured by a rung between them, so placed as to pass free between the sheath and stilt. They are secured above by what I call the iron beam, represented separately in No. 5. and seen sideways at E Q T, No. 2.

This

This beam, No. 5. is formed to the proper angle E A F of 51 degrees, and has a hole at G, through which the upper part of the mouldboard bolt passes. The part A N projects forward, right with the middle of the angle E A F, formed by its sides, and has a square mortise at H, for receiving the upper part of the coulter, as is more distinctly seen in No. 2. The fore part N of this iron beam is formed into a point, for being received into the catch F E of No. 2. This iron beam between the coulter hole and the point of the mouldboards is two inches thick, and the end of the coulter which goes into the hole H is two inches by $\frac{7}{8}$.

There is also fixed on the upper edge of the mouldboards behind, an arch of
iron

Of turning the furrow to either side, 185
iron, represented by L M, No. 3. in
the middle of which, at K, there is a
socket, for receiving the handle K T N.

A B C of No. 3. and E F of No. 2.
represent the catch which keeps the
mouldboards in their proper position.
This catch goes over the beam like an
arch, and has a bolt D E through it,
and through the beam, round which it
turns upward and downward. The
holes at A and C are for receiving the
point of the iron beam, represented by
E in No. 2. and by N in No. 5. The
catch is made very strong between these
two holes and the bolt holes D and E
No. 1. namely, about $\frac{7}{8}$ square. The
catch is made to keep its hold of the
iron beam by means of a long spring,
represented by C D in No. 2. and by

A a

F B

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F B in No. 3. Its fore part is nailed to the beam; and as the spring acts upwards, it presses the arch of the catch upwards, and this keeps the hole A or C on the point of the iron beam. This catch is loosened from its hold by means of a string or rope, which is fastened to the top of the arch F, No. 2. and comes backward, through a staple M on the beam, to the part L of the jointed handle. By raising the end of the handle, the rope is drawn tight, and it pulls down the top of the arch of the catch, by which the other end E of the catch is drawn off from the point of the iron beam. The mouldboard being now shifted to either side, by pushing the handle to the opposite side, the rope is then allowed to slacken, and the other

ther

the hole of the catch immediately falls on the point of the iron beam, and keeps it fast.

In order that these mouldboards may be able to shift to the proper angle, it is necessary that the lower part of the stilt, and the heel-piece at B, No 1. be reduced to the thickness of the sheath. In order to make this more effectual, and also to give that mouldboard, which is at the firm ground, some support from the head of the plough, the upper side of the head is sloped off for an inch down, as is represented by the line A B, No. 1. The lower edge of the mouldboard is equally sloped off on the inside, so that when the plough is set, the land side mouldboard claps close with its chamfered edge to the chamfer of the
upper

upper side of the head, and is then supported by it, and all dirt or small stones is by this means prevented from getting between them, and the mouldboard and head make one uniform surface, without any projection on that side for about six inches up.

The edge of the coulter must be set right in the middle of its thickness, but the back of the coulter must have a thickness equal to $\frac{1}{4}$ of its breadth. By this means, when the mouldboard is shifted to one side, that face of the coulter which is next the firm ground, will be flush with that side of the head, or will lie in the direction in which the plough is going, agreeable to the principles formerly laid down.

The

The lower part R, No. 2. of the fore edge of the mouldboard must always be kept close to the upper side of the sock. If it projects to either side, and a stone gets into the angle, the plough will be broken, or its motion will be prodigiously retarded: therefore, the upper side of the sock must be made of a breadth proportioned to the shift of the mouldboard, at the place where the lower point of the mouldboard traverses over it. This is represented in No. 4. where D is the centre of the motion of the mouldboards, and A is the fore point of them when the plough is turning the furrow to the left hand, and F is the place of it when the plough turns the furrow to the right hand. The breadth of the sock A F will therefore depend

190 *Of turning the furrow to either side.*

depend on the width of the shift of the plough, and on the distance from the bolt D. In the dimensions represented in the figures, A F must be four inches, because the point of the mouldboard shifts two inches on each side of the middle line of the plough.

If the bolt, round which the mouldboards turn, were placed perpendicular, as at I C, No. 1. the upper surface of the sock, No. 4. should be quite flat. But when the bolt D C, No. 1. leans back above, the upper surface of the sock between A and F, and behind it a little, must be rounded a little above. Thus the point of the mouldboards will keep close to the back of the sock as the plough shifts.

While

Of turning the furrow to either side. 198

While the point A, No. 4. shifts over to F 4 inches, the point G of the coulter shifts over to H 6 inches, so that in both positions of the plough, it is an inch without the point of the mouldboard, and better than half an inch without the land side of the head, which is a very proper position. If the fore edge of the coulter is parallel to the bolt D C, the upper end of the coulter will shift as much as the lower. If the edge of the coulter and bolt are narrower above than below, which is the case in the figures, the upper end of the coulter will shift less. This shift of the upper end of the coulter is represented in No. 5. where the line M G N is the middle line of the plough, I is the upper end of the coulter, when the plough turns
the

192 *Of turning the furrow to either side.*

the furrow to the left hand, and K is its place when the plough is turning the furrow to the right. This shift in the figures is $2\frac{1}{2}$ inches on each side of the middle line, or 5 inches in all. At the same time, the upper point A of the fore edge of the mouldboard shifts 3 inches from A to L. This shifting of the upper and under parts both of the coulter and of the mouldboard edge depends, as has been already said, on the position of the bolt DC, and on the distance of these parts of the coulter and mouldboard from the corresponding parts of the bolt. Attention must be paid to these circumstances, in order that they may have always a proper position. The shifting of the fore point of the iron beam must regulate the distance

tance

tance between the two holes of the catch.

It is necessary in this plough, that the horses go all in the furrow. For, in ploughing along the side of a steep hill, a horse cannot find footing on the unploughed land, but will be always sliding into the furrow.

This circumstance requires a bridle of a particular construction, to allow the draught to be shifted at every turning of the plough. See No. 3.

QP is the bridle, 10 inches within from Q to P. It is straight before, and without any notches. The horse tree has a ring, which slides from side to side on the bridle. At Q and P are two rollers or sheaves. A rope has its middle fixed to the sliding ring, and the two ends are made to pass through the

B b

roller

194 *Of turning the furrow to either side.*

roller Q and P, and the two staples on the upper side of the beam, just before the catch bolt DE, and through another staple in the stilt G, just by the beam mortise. They then are made to pass through two other rollers on the upper side of the stilt handles at R and S, and then their ends are brought together, drawn tight, and tied together.

From this description of the plough, it is easy to see, without repeating what has been already said, how all the parts are shifted.

Figures 7 8 and 9 represent the parts of another shifting plough, which has been a good deal employed. P M, fig. 7. is a side view of the beam, A C D is the bridle, having holes in its fore part, for giving more or less hold. The bridle
dle

the wheel turns in a bolt B C, which passes down through the beam. The tail C D comes a good way back, and has, on its upper side at D, a pin with a broad head, which takes hold of the end H of the iron beam H I L, which turns on a bolt K L, in the same manner with the iron beam of the other shifting plough.

A catch bolt G H goes down through the beam at G, and serves to fix the iron beam to the wooden beam, when the plough is shifted. This bolt is kept down by a spring F G. It is drawn up by G R N, which turns round a joint at R, and has a rope reaching from N to the ploughman's hand. When he pulls the rope N O, the point G of the catch rises, and raises the spring and bolt G H, and loosens the iron beam from the wooden beam.

Fig.

196 *Of turning the furrow to either side.*

Fig. 8. is a view of the upper side of the same parts, C E D is the bridle, turning on the bolt at E L. M F G is the iron beam, turning on the bolt at G. In the fore part of this iron beam at D, there is a hole for receiving the broad headed pin, which is in the tail of the bridle at D. This hole is made oblong, to allow the pin to shift along it as the plough is shifted. The part L M is formed into the arch of a circle, of which the centre is G, and it has a hole at each extremity L and M for receiving the catch bolt. It has also a hole in the middle between L and M for the same purpose. In order to keep the arch L M close to the beam, so that the bolt G H, No. 7. may fall truly into the holes in the arch which are made

to receive it, there is a support for the iron beam, represented in fig. 9. B D C is this piece. The part B D goes thro' the beam, and is screwed or rivetted above at B. A tail sticks out at H, which is nailed to the under side of the beam. It passes thro' between the arch L M of fig. 8. and the arms. The part D C projects forward below the arch, and it has a hole at C, exactly below the hole thro' the beam, through which the catch bolt comes. When, therefore, the catch bolt has been drawn up, and the arch L M comes into such a position, that any of its holes comes exactly between the hole in the beam and the hole in the piece B D C, the catch bolt being let down, it goes through all the three holes, and keeps all fast together. When the plough
throws

198 *Of turning the furrow to either side.*

throws the furrow to the left, the catch bolt is in the hole at N, and when it throws the furrow to the right, it is in the hole at L. The plough may also be employed to throw the furrow both ways, by putting the catch bolt into the middle hole of the arch L M.

The iron beam cannot shift any more than the open space which is within the arch L M, because, when it is put so much to one side, it is stopped from going farther by the pin B D of No. 9. striking against one of the arms.

The hind part of this iron beam has got two tails, in the same manner as in the other shifting plough, by which it is fixed to the mouldboards, and all the other parts are made in the same manner.

Of

I. Of Wheels in general:

To attempt to prove that a carriage is more easily drawn upon wheels than upon sledges, would be an affront to the understanding of the reader.

But whether high or low wheels are fittest for the purpose has been a subject of dispute, even among persons of skill. Reason and experience, however, seem perfectly to agree in this, that wheels, whose centres are on a level with the moving power, will be easiest drawn along a level plane, and that the higher a wheel is, it will more easily get over any obstacle, if the moving power is not below its centre. It seems
to

to follow therefore, that carriages drawn by horses or oxen should have wheels whose centres have the height of the draught line, that is, of the shoulders of the horses, or the yokes of the oxen. This is true, however, only in the case of a horizontal road. In going up a hill, the distance of the line of draught from the road is somewhat less, because, when a man, or any other animal, is standing upon the side of a slope, his height is inclined to the slope, although it is perpendicular to the horizon. As this is the situation in which it is of the greatest importance to diminish the labour of the cattle, it follows, that the height of a wheel's centre should be somewhat less than the height of the line of draught. But what the difference

difference should be depends upon a great number of circumstances, which those who make use of wheel carriages should be best acquainted with. Four feet eight inches is reckoned a very good height for a cart wheel, and has been thought preferable to any other. But the great loads which are drawn in the coal carts at Glasgow, which go upon wheels above six feet high, and other instances of a like kind, show that great advantages are to be gained by using the high wheels, and that the disadvantage arising from the greater weight of the wheels may be disregarded. The great inconvenience which attends the high wheels is the greater pressure upon the cattle on going down hill, because the support which

the cattle can give in this case, is very low placed. But, even in this case, the instances above mentioned, show that the height of wheels may be increased beyond the ordinary practice.

II. *Of the Dish or Cavity of Wheels.*

Suppose that a person totally unacquainted with the practice, were employed to make a cart. He would naturally make the axle straight, and the arms of it without taper. He would set the spokes of the wheels at right angles to the axle, by which means they would also be perpendicular to a level road, and thereby give the most perfect support to the carriage and its load. Such wheels would be flat, and their sole or head would be parallel to the axle.

But

But experience has shown, that such wheels are liable to great inconveniences. When going in wet and dirty roads, all the mud taken up by the wheel comes down again upon the nave, and gets between it and the axle, and soon wears it prodigiously. Such a form of wheels also requires a great distance between them, and consequently a great breadth of road, in order to give room for the cart body and loading. It is also found, that such wheels bear hard upon the inner end of the axle arm below; and also, that the spokes are forced back in the mortices, and the wheels in time get a dish or hollow on the side next the cart.

The reason of these two last inconveniences is this: It is very seldom that
the

the two wheels are exactly on the same level. When one of them is lower than the other, either by getting into a rut, or being on the lower side of the road, the greatest part of the load is upon that wheel. In this situation, the head of the wheel is not perpendicularly below the point of the nave, which is supported by the spoke. The spoke itself leans over, and if not of sufficient strength, would break inwards. It therefore bears hard upon the inner side of the mortice, and causes the nave to bear hard upon the inner end of the axle arm.

Experience has shown, that these inconveniencies may be greatly removed, by setting the spokes into the nave, so as to point outward a little. By this means the wheel gets what is called a
dish,

dish, and the spokes no longer form a flat surface. Let us now suppose, that two such wheels are put upon an axle, whose arms have no taper. The wheels would be as wide above as below, and the spokes would never be perpendicular to the ground. Suppose now, that the two axle arms are bent downwards. This would make the wheels closer below, and wider above, and the bend of the axle may be such, as that the spoke which rests upon the ground will be perpendicular. This form of the wheels will remove some of the above mentioned inconveniencies.

The wheels being wide above, the mud which is carried up by them will not fall so much upon the nave, and there will be greater room for the body
of

of the carriage and its loading. But one of the great inconveniencies still remains. When one of the wheels is in a rut, the spoke which is then supporting the carriage is leaning outwards, and bears hard upon the inner end of its mortice, and causes the nave to bear hard upon the inner end of the axle arm. It is, therefore, found more expedient not to bend the axle so much as to bring the two spokes, whose ends are on the road, to be perpendicular to the horizon, or parallel to each other. They are made to be a little wider below than at the centre; by which means, when one wheel is in a rut, the spoke which is then supporting the carriage, may be perpendicular. It is even found necessary, that when the wheel is in this situation,

tion,

tion, the spoke should be a little without the perpendicular below; for the chief jolts which the wheel receives are from the outside, and when the spoke is set a little against the jolts, it is better able to resist them. Experience shows, that, notwithstanding all the dish which has been given to wheels, they still go from the face, or loose their cavity when they fail. It might, therefore, be supposed, that it would be an advantage to give the wheels a still greater dish. But this is limited by other considerations. The spokes must be very hard driven into the nave, in order to have sufficient strength. They must not be very much tapered at the foot, otherways they would be apt to work loose. This being the case, the spokes cannot be set
very

very obliquely into the nave, because the wood of the nave would then start up at the heel of the spoke, when it is properly driven.

A dish or cavity of $3\frac{1}{2}$ inches may be given with safety to wheels of 4 feet 8 inches diameter, and in general $\frac{3}{4}$ inch of dish may be allowed for every foot of diameter.

The spokes should be set so far from the outer end of the nave, that a perpendicular from the sole to the under side of the axle, may fall between an inch and two inches without the middle point between the bushes. By this the pressure on the outer bush will be somewhat greater than on the inner, when the wheels are on a level. This should be so. For the inner part of the axle

arm

arm being much bigger than the outer, it has more friction, and therefore should have less pressure. Also, every sinking of the wheel below the level of the other, causes it to press harder on the inner bush. This position of the spokes remedies both these inconveniencies.

There are still some persons of experience, who have proposed that the wheel should be made without any dish, and they propose to remedy the inconvenience which arises from an unequal pressure upon the outer and inner ends of the axle arm, by placing the spokes, not in the middle of the nave, but towards the outer extremity. This will only remove the inconveniency to a certain degree, and it still leaves the other defects which have been already

mentioned without any remedy. The experiment has been tried, and it has been found, that the axle arm is still much worn at the inner end, and that the wheels are much weaker, and sooner fail, getting a dish inwards. In short, the dishing of wheels, which was not a natural thought, has either been found by accident, or has been invented by some person of great ingenuity, and the course of uniform experience has fully confirmed its advantages.

III. *Of the Length of the Naves.*

Too short an axle arm has too little power to guide the wheel in a steady direction, unless very tightly fitted into the bushes, and too long a nave is inconvenient,

convenient, both on account of its bulk, and of the dirt which it is apt to carry. 12 inches or thereabouts seems a very convenient length for a nave, exclusive of the depth of the pan in the ends.

IV. Of the Taper of the Bushes.

It is found necessary to line the inside of the nave hole with iron. This is done by driving two iron rings, called bushes, into the opposite ends of the hole. The axle arm is made to fit exactly the inside of the bushes. The wideness of a bush therefore always determines the size of the axle upon which it turns, and the smaller the bush is, the less will be the friction. The wideness must be such as suits the axle required

red for the carriage. The strain upon the axle arm is chiefly at the inside bush, and wooden axles generally require an inner bush of $5\frac{1}{4}$ or $5\frac{1}{2}$ inches for ordinary carriages.

When speaking of the dish of wheels in the second section, we supposed the axle arm to be without any taper. In order, therefore, that the supporting spokes may stand perpendicular to the ground, or nearly so, it is necessary to bend the axle arms downwards. But this would be attended with a very great inconvenience. When the carriage is going upon a level road, the wheel would be continually sliding in upon the axle, and would press hard upon the shoulder. As this is the place where dirt is most apt to get in, the friction would

would be prodigiously increased, and the bushes and axle would be very much heated and worn. This inconvenience would be still more sensibly felt upon that wheel which gets into a rut, and bears the greatest part of the load.

This inconvenience is remedied by the very simple contrivance of tapering the axle arm. The intention, therefore, of this contrivance being to hinder the dished wheels from pressing in upon the shoulder of the axle, the manner of executing it must be taken from these principles. In the *first* place then, the under surface of the axle arm, which rests on the bushes, must be level. If it be higher at the inner end, they will slide in and press on the shoulders. If it be higher at the outer end, they will
slide

slide out, and press on the linch pins. In the *second* place, the spoke which touches the ground, or which is supporting the carriage, must either be perpendicular, or must lean a little inward above, and outward below. These two conditions will determine the quantity of taper which must be given to the axle and bushes.

In the *first* place, let us suppose, that the supporting spoke must stand perpendicular. In fig. 1. let $L K B A$ represent the taper hole through the nave. The lower side $A B$ must be level. Let E be the point of the sole which touches the ground. Draw $E D$ perpendicular to $A B$. Let $Q O$ be the centre line of the hole. This will be the line round which the wheel really turns. $E D$ will

will cut this line in C. Let G be the uppermost point of the wheel, exactly opposite to E. Draw GC. For the same reason, that ED is perpendicular to AB, GF will be perpendicular to LK, the upper side of the nave hole. Draw GE, cutting the line of the centre in H. Then CH is the true dish of the wheel. Let the lines LK and AB meet in I. Then, because the two triangles ECH and ICD have a common angle at C, and equal angles at H and D, the angles at E and I are equal. Therefore the half taper of the axle and bushes is just the same *per foot* as the real dish of the wheels, and we may use the following proportion. As the half diameter of the wheel is to its real dish, so is the length of the nave to
half

half the taper of the bushes, or to half the difference of the width of the inner and outer bushes.

On the other hand, the real dish of the wheels may be gathered from the taper of the axle and bushes. For if we draw BR parallel to the centre line OQ , then QR will be equal to OB , the half width of the outer bush, and RA will be half the difference of the width of the inner and outer bushes, or will be half the taper of the bushes corresponding to the length of the nave, which must be counted on the centre line QO . Now BR is equal to OQ . Also, BR is to RA as EH is to HC . That is, the length of the nave is to the half taper of the bushes, as the half diameter of the wheel is to the real dish.

Then

Thus, from the dish of a wheel already made, we can chuse a pair of bushes which shall answer it, and taper the axle accordingly; and from the bushes already cast, we can give the wheel the proper dish. A pair of bushes, of which the inner is $5\frac{1}{4}$ inches diameter, and the outer $3\frac{1}{4}$, are found to answer very well, and require a real dish of $2\frac{1}{3}$ inches for a wheel of four feet eight inches diameter.

In the *next* place, let it be supposed, that the standing spokes should spread out a little below, which is thought most proper. This may be done either by increasing the dish of the wheel, or diminishing the taper of the bushes. Thus, if the taper of the bushes be what we have now recommended, that is two

E e inches,

inches, and also the dish of the wheels be $3\frac{1}{2}$ inches, the spokes will spread $1\frac{1}{2}$ inch on each side below.

The spokes may spread still more, by setting them more obliquely.

It is most convenient to have both bushes made to one taper. This will make the axle arm of one taper both at the inner and outer end. This however is not absolutely necessary, provided that the taper of each part of the axle arm is made to suit the bush which is to turn on it.

V. *Of fitting in the Bushes.*

This must be very exactly done, otherwise the wheels can never run well.

The

The first circumstance to be attended to, is the setting them fair, that is, so that the centre line of the two bushes may make one straight line, which should be the centre line of the whole eye of the wheel, or nave hole.

In fig. 2. let A B be the centre line of the eye of a wheel. It is plain, that if the inner bush c d e f be set more down at C than at e, it will be nearer the centre line at d than at f, and will grate upon the axle arm at d, which will both obstruct the motion, and exhaust the grease; and if the outer bush be more set down at k than at h, it will be nearer the centre line at i than at g, which will have the same effect. Their centre lines will not, in this case, fall in with A B, but will stand at A a
and

and B b. Great care must therefore be taken to avoid this, and make them stand fair. If both the bushes have one taper, their inside should run straight with the lines c h and e k.

The *second* thing to be taken care of is, that the centre line of the bushes may be perpendicular to the face of the wheel, without which the wheel cannot turn true on the axle arm. This may be discovered by turning the wheel round an axle arm which fits it, and holding a steady mark to some place to the face of the ring or felloes. This will touch the face all round as it turns, if the centre line is perpendicular to the face. If it does not, there is an error, which, if not helped, will cause a false motion of the wheel, and make
crooked

crooked ruts in the road, equal to the distance of the different parts of the face from the steady mark above mentioned.

VI. *Of the Sole of a Wheel.*

This should be so made as to press fair on the road, especially if the sole or tread of the wheel is broad. When the axle is straight or level on its under side, the sole should make the same angle with the face which the taper of the bushes makes with their centre line, except what is to be allowed for the declivity of the road. Therefore use this proportion. As the length of the nave is to half the taper of the bushes, so is the breadth of the sole to the quantity
which

which it should be above the square. Thus, if the length of the nave be 12 inches, the taper of the bushes two inches, and the breadth of the sole three inches, $12 : 2 = 3 : \frac{1}{4}$, and the inner edge of the sole should be $\frac{1}{4}$ of an inch above the square with the face of the wheel.

VII. *Of fitting in the Axles.*

In order to do this properly, we must know, 1st, what is called by the workman the dish of the wheels, which is very different from what I have called the real dish, and the methods for finding it. 2^{dly}, The way of finding the length of axle beds, which will answer to any given wideness on the road, the axle being straight below, in order

to

to find what length will answer for any given hollow, and what hollow will answer to any given length of an axle bed. When every thing needful has been calculated, the wood for the axle must be prepared, and set out (as the workmen call it) with great exactness, that is, the lines must be truly drawn, which direct us for working the axle, so as to make the arms fit the bushes, and the wheels run right on the road, and the work must be truly executed according to these lines. When nearly done, it will be proper for the workman to try whether the wheels gather inwards equally on both sides, both below and before. This he may do, by applying a line or ruler diagonal wise, across from the under part of the
right

right wheel to the upper part of the left wheel, and then from the under part of the left wheel to the upper part of the right wheel. If the wheels are properly set, these two trials should give the same distance on the line or ruler.

Thus, supposing a c, fig. 3. and b d two wheels gathering below, between c and d. If b c is found shorter than a d, then either b is too far in, or a is too far out. Then the distance a b and c d should be measured, to know if the gather is as much as is required.

N. B. This gather will always be equal to twice the real dish of the wheels. If it is too little, a must be brought a little in. If it is too much, throw out b. If just right, a must be brought in, and b thrown out equally.

Of

VIII. *Of finding the Dish of the Wheel.*

What the workmen find most convenient to consider as the dish of a wheel is considerably different from what I have called the real dish.

Figure 4. represents a wheel seen edge-ways, and standing on the level ground, with its sole $o a$. The line $h i$, which is the lower side of the axle arm, is supposed to be level, or parallel to $o a$. The line $m h f$ is parallel to the face of the wheel $b a$, and $i k$ is parallel to the centre line $A B$. $H e$ is perpendicular to the ground. Now, $e o$, the distance of this perpendicular from the inner side of the sole o , is called the dish of the wheel by the workmen. It

$F f$ is

is plain, that the distance of the point e , from the like point corresponding to the other wheel, is the distance between the shoulders of the axle, or the length of the axle bed.

This being attended to, the two following methods may be taken for finding the dish of a wheel.

1. By a square and rule.

Let $a b c d$ (fig. 3. No. 2.) represent the ring of a wheel, $g h i$ a square. The stock $h i$ is applied through the eye of the wheel to the bushes. The blade is applied to the inner end of the nave, and reaches as far up as the ring of the wheel. Then a rule, $d e f$, being held square over it, will show the distance
between

between the inside of the square and the sole of the wheel, which is the dish sought, allowance being made for the distance of the square from the bush, occasioned by the depth of the inner pan, if there be any.

2. By calculation.

Let a straight ruler $c d$ (fig. 4.) be applied to the face of a wheel, as near the nave as possible. Let a straight rod, $l m n$, be put thro' between the spokes, square on $c d$. This will show the distance $m n$ between the face of the wheel and the inner end of the nave. Then say, as this distance is to half the taper of the bushes, so is the height of the lower side of the axle arm (supposed level)

level) to a fourth quantity. This must be added to the breadth of the sole, and the sum must be taken from $m n$. The remainder is the dish required; for it is plain, that $f a$ is very nearly equal to $i k$, which is equal to $m n$; and that $i k : k h :: h e : e f$; and also, that $e o$ is the difference between $f a$ and the sum of $f e$ and $o a$.

Thus, if the distance of the lower side of the axle from the ground be two feet, or 24 inches, and the taper of the bushes two inches, and the distance of the inner end of the nave, from the face of the wheel, be 12 inches, and the breadth of the tread be $2\frac{1}{2}$ inches, we have $12 : 1 :: 24 : 2$, which is $f e$. Then $f e$ and $o a$ make $4\frac{1}{2}$ inches. This taken from 12 inches, leaves $7\frac{1}{2}$ for the
dish

dish of the wheel, or one foot three inches for two wheels.

This calculation may be done by the sliding rule, which is much used by cart wrights. Set 12 to 24, and then 1 will stand opposite to 2 for f e, and proceed as before.

IX. To find the Length of the Axle Bed.

This is the distance between the inner ends of the two naves.

1. When the axle arms are straight below, from the proposed wideness between the wheels within on the road, take the dish of both wheels, the remainder is the length of the axle bed.

Example.

Example.

Wideness on the road within, c f,		
(fig. 5.)	- -	4 6
Dish of both wheels, c d + e f		1 3
		<hr style="width: 100px; margin: 0 auto;"/>
Length of axle bed		3 3

The truth of this rule is plain, by inspecting fig. 5. where A B is the axle, c f the wideness within on the road, c d and e f the dish of the wheel, and a b the length of the axle bed.

2. When the axle is hollow below.

This is often the case, because the bed of an axle is sometimes confined

to

to a certain length, especially such as have iron arms, whether they are fixed to waggons or carts. In such cases, they must be made hollow below, or the arm must be laid into the bed, with a bend downwards, in order to bring the wheels to a right gather, or make them run at a right distance on the road. This is also sometimes necessary, in order to make the tread of the wheel press fair on the road. These circumstances give rise to two questions or problems.

1. Having given a certain length of axle bed, and a certain wideness on the road, to find the degree of hollow, that is to say, how far the under side of the axle arm should be below the straight, at the out end of the nave.

Rule.

Rule.

Find the length of the bed, which will give the wheels the required width of the road, when the arms are straight below. Take half the difference between the given length of bed, and the length then found. Then say, as the height of the under side of the straight axle from the ground is to this half difference, so is the length of the arm to the hollow required.

Example.

Suppose the given length of bed is three feet six inches, and the given width on the road four feet six inches,

and

and the wheels to have the dimensions of the last example, namely, one foot three inches of dish, &c. and the height of the under side of the axle from the ground two feet, or 24 inches, and the length of the arm 12 inches, then the length of the bed will be three feet three inches by the last rule. The difference is three inches, half of which is $1\frac{1}{2}$ inches. Then 24 is to $1\frac{1}{2}$ as 12 to $\frac{3}{4}$ of an inch, which is the hollow required.

The reason of this operation is very easily understood.

Let A B (fig. 6.) be the given length of bed, F K the given wideness on the road, and let C D be the length of bed which would give the wheels that wideness on the road, when the axle is

G g straight

straight below. Let CE be the length of the arm. Draw CL perpendicular to the horizon. Then LF is the distance of the wheels. Now, suppose the axle bent down to the position CM . The line CF will take the position CG , in such a manner, that the angle ECF will be equal to the angle MCG , and therefore the angle ECM will be equal to the angle FCG . Draw EM perpendicular to EC , and FG perpendicular to CF , and GH perpendicular to FK . It is easy to see that $CE : EM :: CF : FG$, and that $CE : EM :: CL : FH$. Now, FH is half the quantity by which the distance between the wheels is diminished, by bending down the axle from CE to CM . If, therefore, AC be made equal to FH ,
and

and $A O$ be made parallel to $C M$, the wheel placed on the bent arm, $P B A O$, will have the same wideness on the road as when on the straight axle $Q E$. Therefore $A C$ is really the half difference between the two axle beds, when $E M$ is the hollow or bend of the axle. Therefore the rule given is just.

N. B. It is not strictly just, because $C G$ is not equal to $C F$, but the difference of $A C$ or $E M$ from the truth does not amount to the 500th part of an inch.

Quest. Given a certain hollow $E M$, and a certain wideness $F K$ on the road, to find $A B$ the length of the axle bed.

Rule.

Rule.

Find, as before, the length of bed CD for an axle straight below. Then say, as the length of arm CE is to the given hollow EM, so is the height of the lower side of the straight axle from the ground CL to a fourth number, which will be AC. Twice this, added to the straight axle bed, will give the hollow axle bed.

Example.

Suppose $\frac{3}{4}$ of hollow, and four feet six inches on the road are given for the wheels, which we have so often mentioned, then $12 : \frac{3}{4} :: 24 : 1\frac{1}{2} = AC$.

Now,

Now, the double of this is three inches, and C D is three feet three inches, therefore A B is three feet six inches.

The reason of this is evident from what has been said already.

In the foregoing calculation, the height of the under side of a straight axle from the ground was always one of the numbers to be worked with. In order to find this, consider figure 4. Thus it is plain that h f is equal to i a, which is half the breadth of the face of the wheel, deducting half the width of the bush at i, even with the face of the wheel. Measure i h along the bush. i k was found in the way formerly directed. Then we have $i h : i k :: h f : h e$, the height from the ground. I may here observe, that h e will hardly ever differ

$\frac{1}{8}$ of

$\frac{1}{8}$ of an inch from h f or i a, so that it is hardly necessary to make a calculation for it.

I conclude this part of the subject by observing, that if the taper of one axle be less than that of another, the axle whose taper is smallest will require to be farther bent down, in order to give the same pair of wheels the same gathar below, or to put the wheels in the same position; and the additional bend that must be given for this purpose is just equal to one half of the difference of the two tapers.

Let the axle A B D C, (fig. 7.) be straight below, and have two inches of taper. Let L I be the centre line, and K I a horizontal line. Let A P be the face of the wheel, and L Q a perpendicular

cular from the centre of the outer bush.
It is plain that KL is equal to half the taper, or difference between the width of the bushes. It is also plain, that IL is to LK as LQ to QP , which is half the girth of that wheel. Again, let $EFGH$ (fig. 8.) be another axle, straight below, with only one inch of taper. MO will, in like manner, be half the taper, and half of KL . SR will therefore be half of PQ . If, now, we make ST equal to PQ , we must bend the arm to the position HV with its lower side, so that GV may be equal to MO . This will bring down the centre O as much further as it is already below the level MN , and then the position of the face OT will be the same with that of the face LP , and, consequently,

quently, both wheels will have the same gather below.

X. *Of the gathering of the Wheels forward.*

It is found, by experience, that wheels run better when they are gathered a little forward, or incline a little inward towards the foreside of the axle.

The taper of the axle arm is the cause of this. The wheel being pressed forward by the arm, it must be forced outward by the taper, unless it be balanced by an inclination inward. The more, therefore, that the arm is tapered, and the less that the wheels are gathered below, the more gather forward will be required. About an inch and

ces, the following proportions will answer to every case.

As the half height of the wheel is to the fourth part of the intended gather, so make the length of the arm to the distance sought.

This proportion may be thus demonstrated from fig. 9.

Let $a b c d$ represent the under side of an axle, $n e f r$ a line drawn along the middle of it, $n o$ the distance set forward at one out head, and $r o$ the distance set forward at the other. Then, since the centre line of the axle must correspond with the centre line of the bushes, and the face of the wheel cuts these lines at right angles, if the centres of the out heads were continued in the straight line in n and r , the face of the
wheels

wheels would cut that line at right angles, at the lines ht and mu . But when the centre of the out heads are placed in o and o , the faces of the wheels will cut the lines eo and fo at right angles, and therefore the angle oen and hik are equal; so also the angles fit and uiv are equal, and ofr and lim are equal. Therefore, as ih , the half height of the wheel, is to hk , a fourth of the gather, (that is a fourth of the difference between hl and fv) so is en , the length of the arm, to no , the distance sought, and so of the other end, because $il : lm :: fr : ro$.

XI. *Of the Manner of placing the Carriage on
the Wheels.*

Let a b c d (fig. 10.) represent the body of a carriage, and suppose it placed on a pair of wheels, which require no packing, the half height of the wheel being n p. Suppose it again placed on a pair of wheels, whose half height is o p, so as to require a packing to raise it to the same height with the other. The height of the packing will then be equal to n o. In a level road this will make no difference of weight on the horse's back. But if the carriage should be going down a road, making an angle with the horizon of about 15 degrees, it will make a considerable difference, as
may

may be seen by the figure. For suppose *i k* to represent such a declining road. Then, if a perpendicular to the horizon is raised to the centre of the high wheel, it will cut the carriage at *e g*, whereas a perpendicular passing through the centre of the low wheels will cut it at *f h*. From this it is evident, that the higher that any carriage is raised above the centre of the wheels, the greater weight will, in such a case, be thrown on the back of the horse. And, in going down, the horse will have too much weight, and, in going up, too little.

The higher any carriage is thus raised, and the more any road declines, the greater will be the inconveniency, arising from the additional weight which
is

is thrown upon the horse's back, when going down hill, and his having too little weight on his back, when going up hill. It will be some remedy if the shafts or limbers of the cart be raised in going down hill, and lowered in going up hill, which may be done by altering some links of the back band.

Of fixing the Axle on the Carriage.

After an axle has been properly fitted into the wheels, special care must be taken, that it be not turned out of its right position by the manner in which it is fixed to the carriage. Axles are sometimes fixed to the body of the carriage, and sometimes to the shafts or limbers, the body lying loose above them. In whatever manner the axle is
fixed,

fixed, it must be kept, while working, in the position for which it was drawn. Therefore when the axle is fixed to the body of the carriage, and that body is so placed as to be level when going upon level ground, the axle must be fixed with the plane of its upper side parallel to the body of the carriage.

When the axle is fitted to the shafts, it must be considered how much higher the shafts will be at the back band than at the axle, when the carriage is going upon level ground. This may be known from the height of the wheels, and the height of the horse, (see fig. 10.) Let $a c e$ represent one of the shafts, $a f$ the height at the back band, and $b c d$ a level line passing through the upper side of the axle. It is plain, that to
keep

keep the axle in the right position, its upper face must be kept in the line $b c d$. If it be merely applied to the outer side of the shaft $a c e$, the wheels will be made to have too much gather forward.

The right slope to be given to the axle or shaft, where they are fitted together, may be found by the following proportion. As the length of the shaft from the fore side of the axle to the back band, is to the difference between the height at the axle, and at the back band, so is the breadth of the axle on its upper side, to the depth to which it must be let into the shaft, at the hind side more than at the fore side. For $a c$ is to $a b$, as $c d$ is to $d e$.

From

From this it is also plain, that the gather forward may easily be either increased or diminished, by the manner in which the axle is fixed on, and that a proportionable difference will, at the same time be made on the gather below, or wideness on the road.

Masters and drivers should be careful to keep the shafts always about the same height, by the manner of yoking the horses, because some alteration will be made by every change. The buyer of a cart should get from the maker a note of the difference between the height of the wheels, and the height of the back band, to which the cart was adjusted, or the workman should be enjoined to adjust the cart in this respect in the manner which the buyer may think

most suitable to his horses. Any alteration occasioned by the change of horses, must be corrected by altering the length of the back band, so as to bring the shafts to that height to which they were adjusted by the maker.

XIII. *Some Remarks on the Observations made by Mr Jacob on the bending of the Axle-arms downward.*

He says, that the universality of this practice would make one apt to suspect, that there must have been some better reason for it than seems at present readily to be given by artificers.

It must be allowed, that experience and facts are always superior to theoretical reasonings, and that every theory

con-

contradicted by these is to be rejected, however plausible it may appear. But, in this case, theory and experience perfectly agree, as will appear by considering a little the necessary consequences of the conical form of the axle arms.

Let $a b c$, (fig. 11.) represent any heavy body pressing upon $d e f$, $d f$ being parallel to the horizon. Then it is plain, that $d e f$ will be pressed from d to f . Therefore an axle, tapered off on the under side, presses the bush in this manner, and must cause the wheel to fly out.

Suppose again a heavy body, as $A B$ (fig. 12.) pressing on another $C D$, and that the surface, by which they join is horizontal, it is plain, that $C D$ will be pressed straight downwards, without
any

any tendency towards C or D. Therefore an axle which is straight below will not press the wheel either outward or inward, in so far as it is acted on by no other cause than the downward pressure.

Again, suppose a b (fig. 13.) to be an axle arm bending downwards, and c d to be the part of the bush on which it presses. It is plain, that the wheels will be pressed inwards by this form of the axle.

I must now observe, that the axle arm exerts another pressure upon the bushes, besides that which is directly downwards. For, by the draught of the horses, it must also press upon the fore part of the bush. This forward pressure is but very small in comparison with the downward pressure, when
the

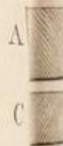


Fig. 11.

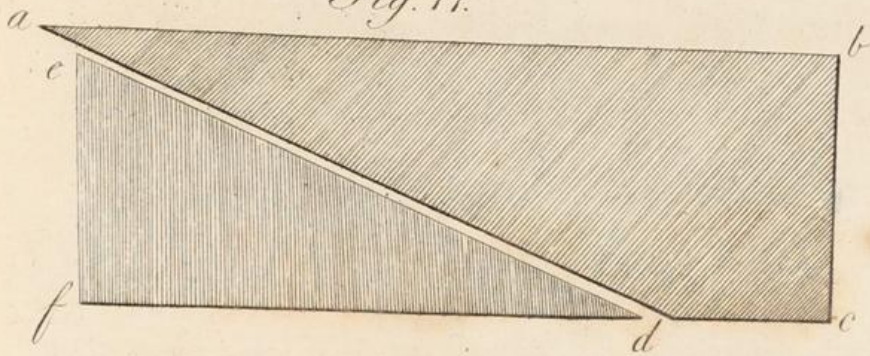


Fig. 12.

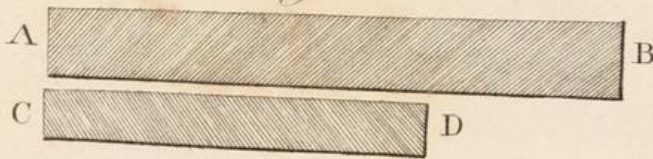
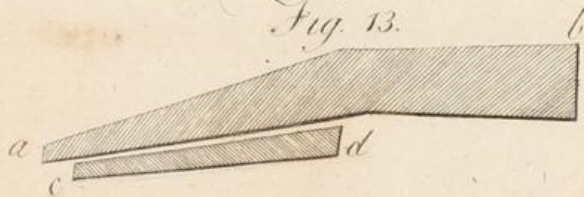
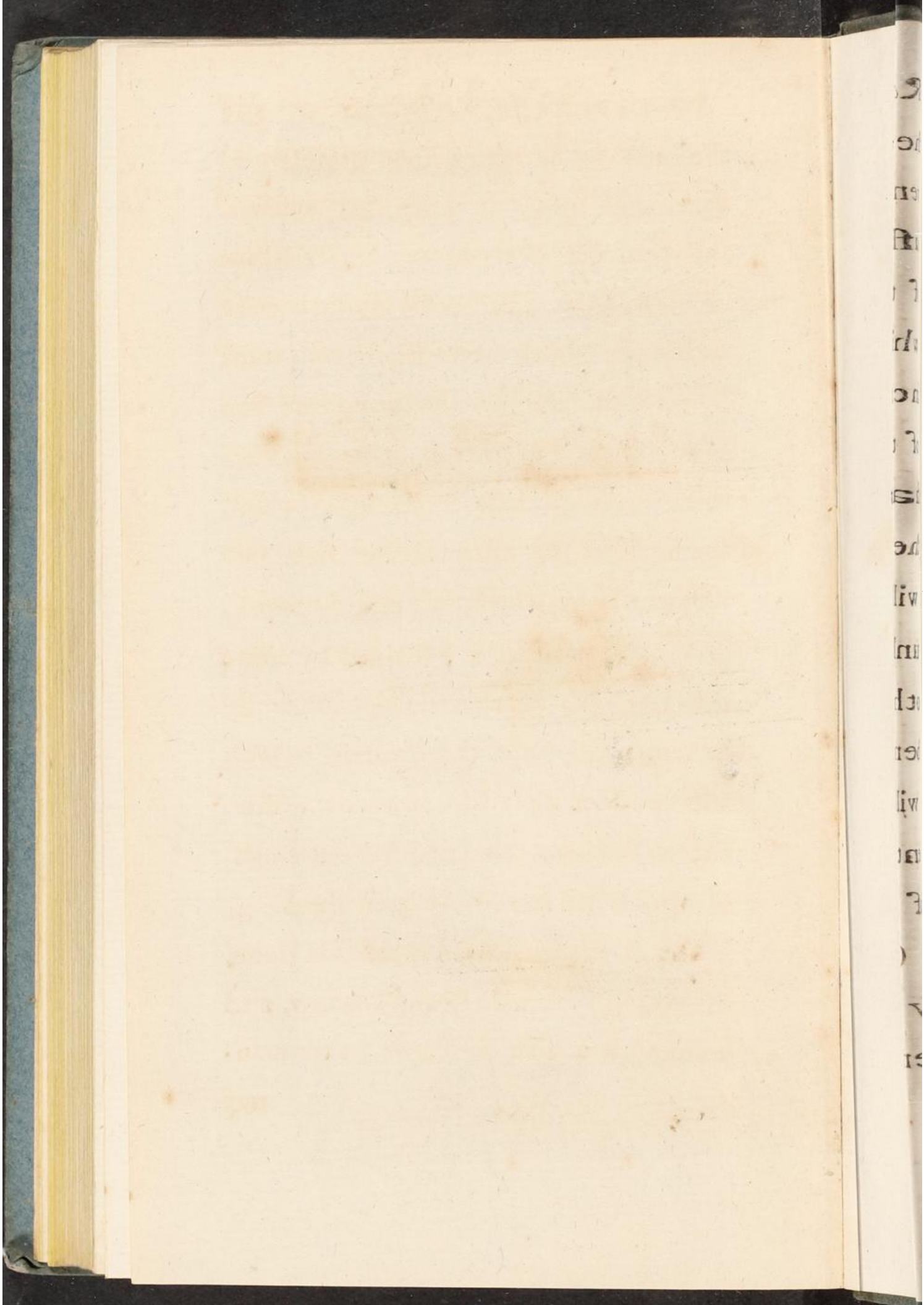


Fig. 13.





the carriage is going upon perfectly even road, being no more than what is sufficient for overcoming the friction of the wheels. But every obstacle over which the wheels are to be driven, must increase this pressure upon the fore side of the bush. From this it is evident, that when an axle is straight below, the taper of the arms on the fore side will cause the wheels to press outwards, unless this pressure is balanced by some other. This may be done, either by bending the axle downwards, which will produce a pressure inwards, sufficient to balance this pressure outwards, of which we have now been speaking.

Or, it may be more perfectly done, by keeping the axle straight below, and bending it a little forwards, in the man-

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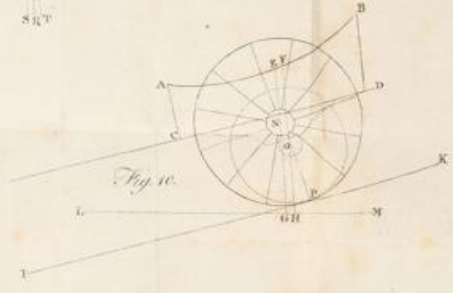
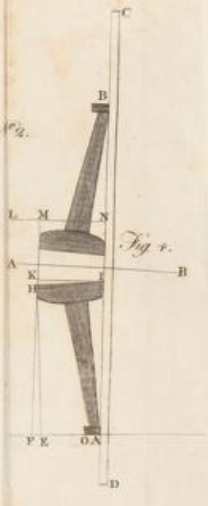
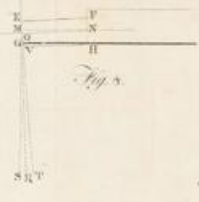
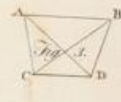
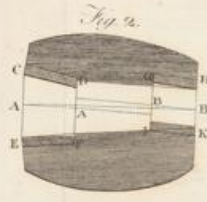
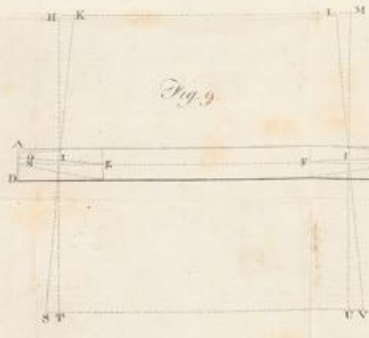
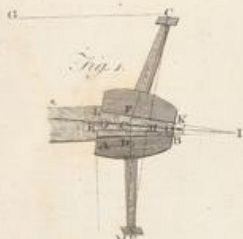
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ner directed in sect. X. It is this circumstance which gives occasion to the gather of the wheels forward; and Mr Jacob is mistaken, when he makes the bend of the arms, or gather of the wheels, to depend wholly upon, or be regulated by, the dish or cavity of the wheels; and when he alledges that the dish of a wheel necessarily requires a bend in the axle arm, to give it a motion straight forward. Whatever the dish of a wheel is, the face of it will always be perpendicularly cut by the centre line of the bushes, if the wheel be truly made, and truly bushed. It is therefore the taper of the arm, and not the cavity of the wheels, which is the immediate cause of that outward pressure, which makes it necessary to bend
the

the arms either downward or forward. Mr Jacob is indeed so far in the right in his assertion, as a dish of the wheel requires a taper of the arm, in order to gain those advantages which are proposed by the dish.

But dished wheels *may* be used with cylindrical arms, and in this case the arms must neither be bent downwards nor forwards; for, if they were, the wheels would press violently inwards.

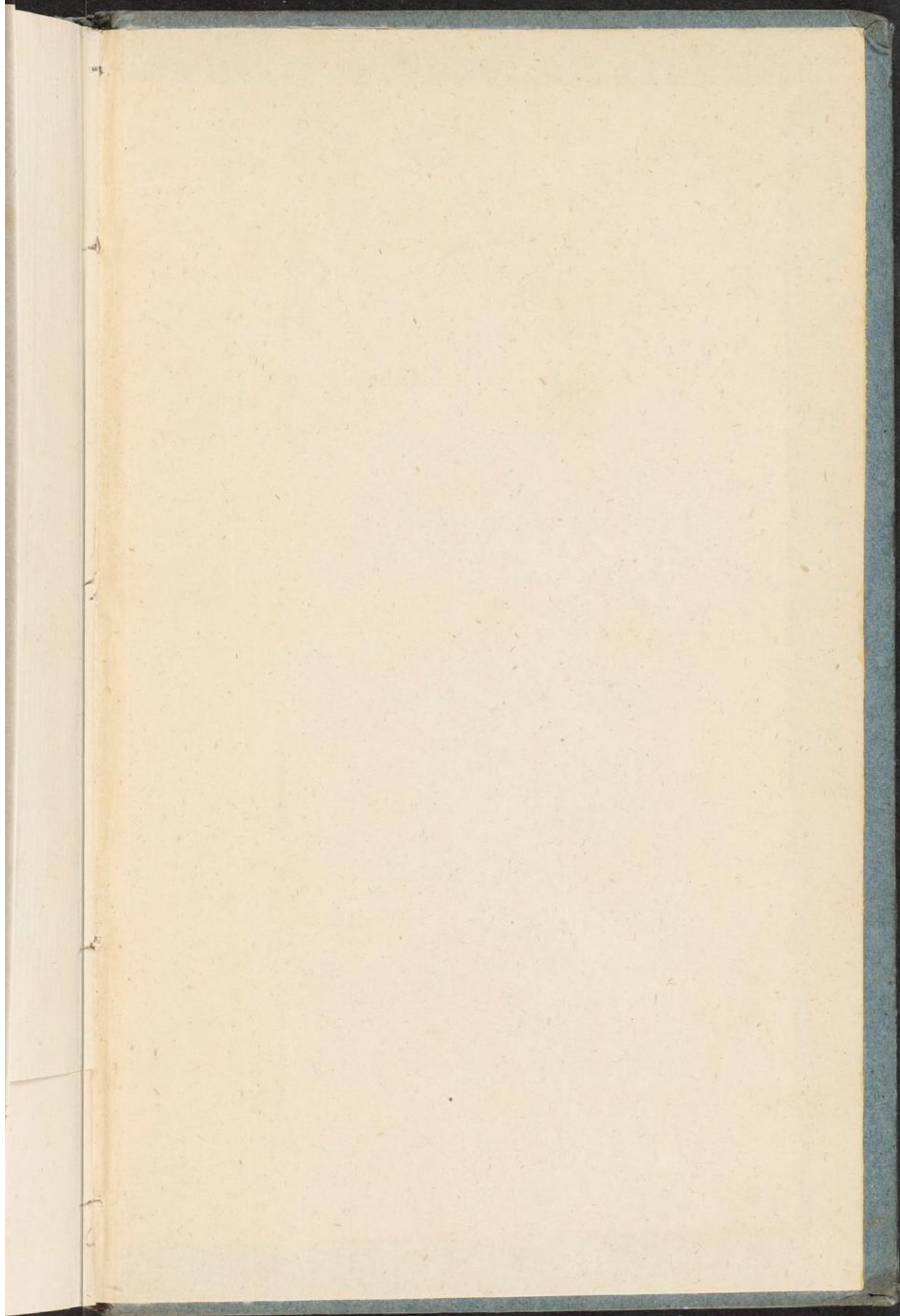
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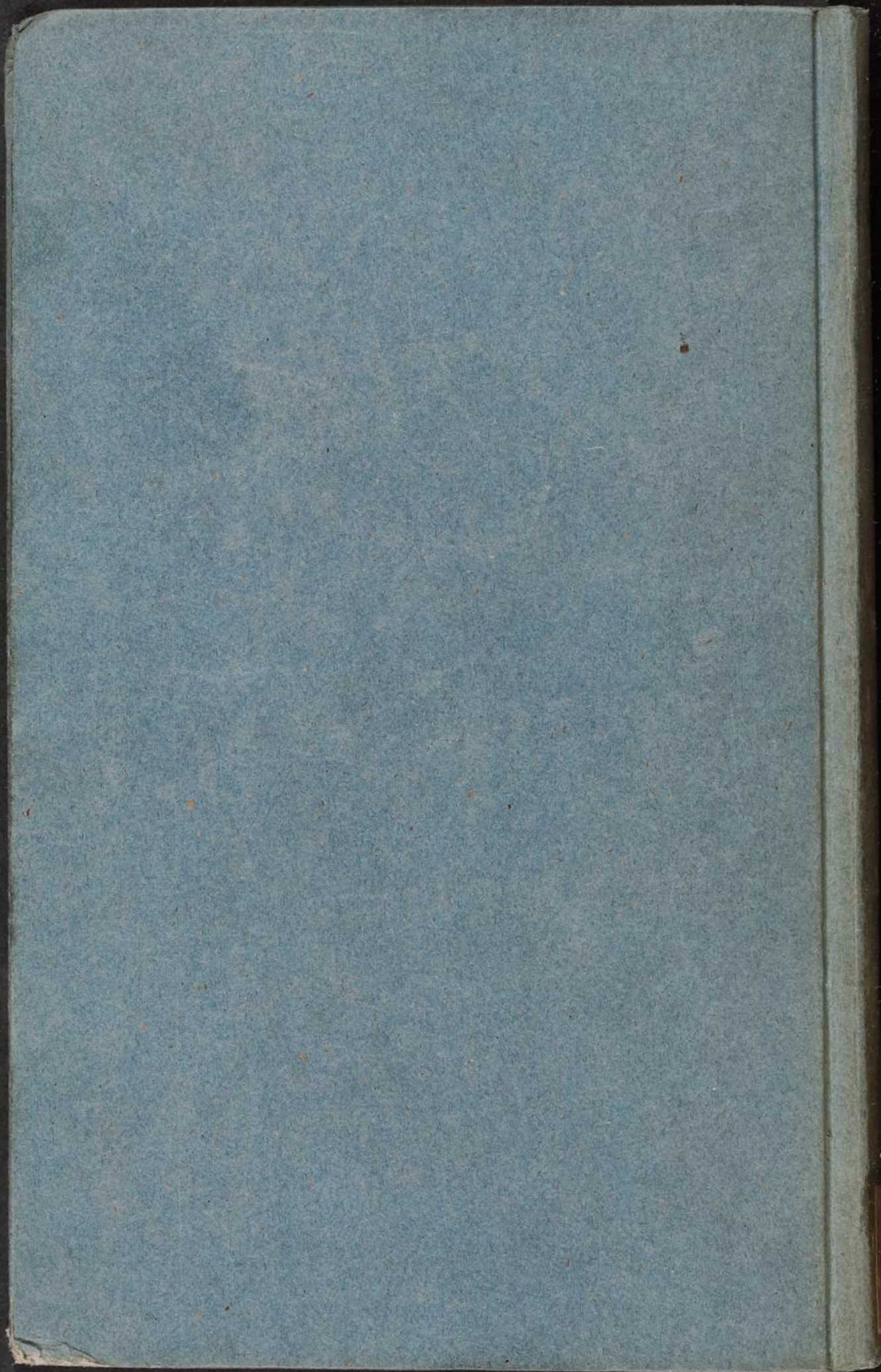
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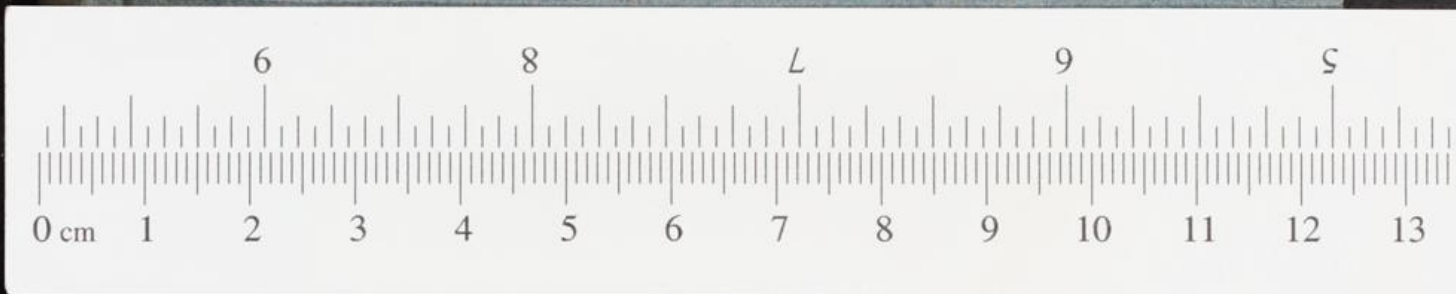
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Colour & Grey Control Chart

Danes Picta 

Blue	Cyan	Green	Yellow	Red	Magenta
White	Grey 1	Grey 2	Grey 3	Grey 4	Black
