Painted by I. Verkolje. *Engrav'd by Anker Smith A.R.A.*

ANTONY VAN LEEUWENHOEK,

Fellow of the Royal Society,

Wyen konnen den Heeren maker van het geheel All, niet meer verheerlyken, als dat wy in alle zaken, hoe klein die ook in onse bloote oogen mogen zyn, als ze maar leven en wasdom hebben ontfangen, zyn al-wysheit en volmaaktheit, met de uiterste verwondering sien uit steken.

ANTONI van LEEUWENHOEK *Brieven 99ste missive 't Druk 16[illegible]*

THE

SELECT WORKS

OF

ANTONY VAN LEEUWENHOEK,

CONTAINING HIS

MISCROSCOPICAL DISCOVERIES

IN MANY OF THE WORKS OF NATURE.

TRANSLATED FROM THE DUTCH AND LATIN EDITIONS PUBLISHED BY THE AUTHOR,

BY SAMUEL HOOLE.

PART THE FIRST.

Wanneerje ſchoone dingen ſiet,
Vergaept u aen het ſchepſel niet ;
Oock wilt daer op niet blyven ſtaen,
Maer laet uw' ſinnen verder gaen ?
Ey klimt ! o lieve, klimt om hoog,
En metten geeſt, en mettet oog;
En ſiet, dat gy tot hem genaeckt,
Die al wat ſchoon is heeft gemaeckt.

Jac. Cats werken, tweede deel pag. 400, *'tDruk*, 1726.

Inde hominum pecudumque genus, vitæque volantum,
Et quæ marmoreo fert monſtra ſub æquore pontus.

Virg. Æn. vi. 728, 729.

" Lo, theſe are parts of his ways : but how
little a portion is heard of him ?

Job. xxvi. 14.

LONDON:
PRINTED BY HENRY FRY, FOR THE TRANSLATOR,
And Sold by GEORGE NICOL, Bookſeller to His Majeſty, Pall-Mall ; J. WHITE, Fleet-Street ; J. & A. ARCH, Gracechurch Street ; and J. WRIGHT, Piccadilly.

M,DCC,XCVIII.

ADVERTISEMENT.

THE following tranſlation was begun from the Latin Edition publiſhed in Holland, but after the tranſlator had proceeded in the work as far as the concluſion of the ſubjects deſcribed in the two firſt plates, he obtained from Holland the original Dutch Edition. He has carefully compared the two verſions, and finds that the Dutch is faithfully rendered in the Latin, and conſequently that the ſenſe of the author is not injured by the Engliſh being ſo far taken from thence. The learned reader may himſelf form a judgment of this, by the following paragraphs, taken from the Dutch and Latin Editions, whereto an Engliſh tranſlation is ſubjoined, and in which care has been taken to follow the Dutch original as literally as poſſible.

" Wy willen dan hoopen, dat de onderſoekers der natuurlyke " zaken, die tot nog toe verborgentheden dieper en dieper ſullen " op delven, om alſoo meer en meer de waarheid voor de oogen " geſtelt hebbende, van veele oude dwalingen, een afkeer te doen " krygen, waar na alle die de waarheid lief hebben behooren te " tragten. Want *wy en konnen den Heer en Maaker van het geheel " Al, niet meer verheerlyken, als dat wy in alle zaken, hoe klein die ook " in onſe bloote oogen mogen zyn, als ze maar levenen wasdom hebben " ontfangen, zyn Al-wyſheit en Volmaaktheit, met de uiterſte verwondering ſien uit ſteken.*"

Leeuwenhoeks Brieven, 99ſte miſſive.

" Speramus ergo naturæ indagatores omnem in poſterum in id " impenſuros operam, ut ea, quæ adhuc in ejus ſinu occulta latent " ulterius in propatulo ponant, atque ita in hominibus, veritatis " lumine illuſtratis, antiquorum errorum ingenerent faſtidium; " quod omnium veritatem amantium ſtudium eſſe decet. *Non enim " hujus univerſi Dominum atque Opificem melius nos glorificare poſſe*

INTRODUCTION.

TO thoſe who are acquainted with the works of Mr. Leeuwenhoek, or who have been much converſant in Microſcopical Studies, this Introduction may appear unneceſſary: but thoſe to whom the ſubject is new, will find ſo many wonders laid open to their view, as perhaps to induce a doubt of the Author's accuracy in his obſervations, or his veracity in his narrations. Indeed, the extreme minuteneſs of many of the ſubjects on which he treats, is in ſome inſtances beyond the reach of our capacities to comprehend*,

* The Spectator, in one of his papers on the Pleaſures of the Imagination, has a paſſage full to the preſent purpoſe, which is as follows:

' Nothing is more pleaſant to the fancy, than to enlarge itſelf by degrees, in its con-' templation of the various proportions which its ſeveral objects bear to each other, when ' it compares the body of man to the bulk of the whole earth, the earth to the circle it ' deſcribes round the ſun, that circle to the ſphere of the fix'd ſtars, the ſphere of the ' fix'd ſtars to the circuit of the whole creation, the whole creation itſelf to the infinite ' ſpace that is every where diffuſed about it: or when the imagination works downward, ' and conſiders the bulk of a human body, in reſpect of an animal a hundred times leſs ' than a mite, the particular limbs of ſuch an animal, the different ſprings which actuate ' the limbs, the ſpirits which ſet theſe ſprings a going, and the proportionable minute-' neſs of theſe ſeveral parts, before they have arrived at their full growth and perfection. ' But if, after all this, we take the leaſt particle of theſe animal ſpirits, and conſider its ' capacity of being wrought into a world, that ſhall contain within thoſe narrow dimen-' ſions a heaven and earth, ſtars and planets, and every different ſpecies of living creaalthough we may be fully aſſured of their exiſtence. In fact, it appears by Mr. Leeuwenhoek's writings, that the difficulty now ſtated, was made a matter of objection by ſeveral of his co-temporaries, therefore the following paſſage in his own words, will ſerve to ſtate the objection, and the manner in which it was anſwered by the Author himſelf.

'I have often heard, that many perſons diſpute the truth of 'what I advance in my writings, ſaying that my narrations con-'cerning animalcules, or minute living creatures, are merely of 'my own invention. And, it ſeems, ſome perſons in France have 'even ventured to aſſert, that thoſe are not in truth living 'creatures, which I deſcribe as diſcoverable to our ſight, and al-'ledge, that after water has been boiled, thoſe particles in it

'tures, in the ſame analogy and proportion they bear to each other in our own univerſe; 'ſuch a ſpeculation, by reaſon of its nicety, appears ridiculous to thoſe who have not 'turned their thoughts that way, though at the ſame time it is founded on no leſs than 'the evidence of a demonſtration. Nay, we may yet carry it farther, and diſcover in 'the ſmalleſt particle of this little world, a new inexhauſted fund of matter, capable of 'being ſpun out into another univerſe.

'I have dwelt the longer on this ſubject, becauſe I think it may ſhew us the proper 'limits, as well as the defectiveneſs of our imagination; how it is confined to a very 'ſmall quantity of ſpace, and immediately ſtopt in its operations, when it endeavours to 'take in any thing that is very great, or very little. Let a man try to conceive the dif-'ferent bulk of an animal, which is twenty, from another which is a hundred times leſs 'than a mite, or to compare in his thoughts, a length of a thouſand diameters of the 'earth, with that of a million, and he will quickly find that he has no different meaſures 'in his mind, adjuſted to ſuch extraordinary degrees of grandeur or minuteneſs. The 'underſtanding, indeed, opens an infinite ſpace on every ſide of us; but the imagination, 'after a few faint efforts, is immediately at a ſtand, and finds herſelf ſwallowed up in the 'immenſity of the void that ſurrounds it: our reaſon can purſue a particle of matter 'through an infinite variety of diviſions; but the fancy ſoon loſes ſight of it, and feels in 'itſelf a kind of chaſm, that wants to be filled with matter of more ſenſible bulk. We 'can neither widen, nor contract the faculty to the dimenſions of either extreme. The 'object is too big for our capacity, when we would comprehend the circumference of a 'world; and dwindles into nothing, when we endeavour after the idea of an atom.'

'Spectator, No. 420.'

'which I pronounce to be animalcules will be ftill obferved to 'move. The contrary of this, however, I have demonftrated to 'many eminent men, and I will be bold to fay, that thofe gentle-'men who hold this language, have not attained to a degree of 'proficiency to obferve fuch objects truly. For my own part, I 'will not fcruple to affert, that I can clearly place before my eye 'the fmalleft fpecies of thofe animalcules concerning which I now 'write, and can as plainly fee them endued with life, as with the 'naked eye we behold fmall flies, or gnats fporting in the open 'air, though thefe animalcules are more than a million of degrees 'lefs than a large grain of fand. For I not only behold their 'motions in all directions, but I alfo fee them turn about, remain 'ftill, and fometimes expire; and the larger kinds of them I as 'plainly perceive running along, as we do mice with the naked 'eye. Nay, I fee fome of them open their mouths, and move the 'organs or parts within them; and I have difcovered hairs at the 'mouths of fome of thefe fpecies, though they were fome thou-'fand degrees lefs than a grain of fand.

'But fince it is pronounced to be incredible, that within the 'fpace occupied by a grain of fand fo many animalcules can be 'contained, and that it is impoffible for me to calculate truly fuch 'numbers, I have thought on the following method of computa-'tion, to place this matter in a clearer light. I lay it down as a 'pofition or truth, that with the microfcope I can fee the fpace 'occupied by a grain of fand* magnified to the fize reprefented 'by the circle ABGC. Next, I fuppofe that I obferve within 'this fpace an animalcule fwimming or running along, and ap-'pearing of the fize reprefented at D. Taking the meafure of 'this by my eye, I conceive the axis or thicknefs of the animal-'cule thus pictured at D, to be the twelfth part of the axis of the

* 'A grain of fand the Author in another place defcribes to be of that fort called 'fcowering fand, or glafs-grinders fand.

'grain of ſand repreſented by ABGC; therefore, by the com-
'mon rules of arithmetic, the ſolid contents of a ſphere or globe 'whoſe circumference is deſcribed by the circle ABGC, will be '1728 times larger than a ſphere of the ſize of D. Next, I ob-'ſerve another kind of animalcule, which, meaſuring by my eye 'through a good microſcope, I judge the axis or thickneſs of it 'to be one fifth, but ſuppoſe it only a fourth part of the ſize of 'the firſt animalcule D, ſuch as is repreſented by the circle E, 'and then, by the ſame rule, the ſize of D muſt be 64 times larger 'than that of E; and if this laſt number be multiplied by the for-'mer, (1728) we ſhall find that 110,592 animalcules of the ſize of 'E, (ſuppoſing their bodies to be of a ſpherical figure), will be 'required to make up the ſize of the ſphere ABGC. Laſtly, I 'perceive a third kind of animalcule, the ſize of which appears 'to be only a tenth part of the animalcule at E, ſuch as the point 'at F denotes; and that conſequently one thouſand of theſe will 'be no more than equal to the ſize of that at E. And, if this 'number be again multiplied by the former, it will be plain to 'demonſtration that more than an hundred millions of animal-'cules can be contained within the compaſs of a grain of ſand*.'

This paſſage reſpects the ſize of animalcules, which the Author repreſents by compariſon with the known ſize of a grain of

* 'The ſolid contents of ſpheres being in the ſame proportion as the cubes of their 'axes, the mathematical demonſtration of the Author's poſition is ſet down by him 'thus:—

12	4	10	1728
12	4	10	64
144	16	100	6912
12	4	10	10368
1728	64	1000	110,592
			1000
			110,592,000

ſand; other minute objects which he frequently deſcribes, are, the veſſels in the bodies of inſects, the threads of Spiders, the filaments or threads of wool, the fibres compoſing the fleſh of animals and the like. All theſe he conſiders as of a cylindrical form, that is to ſay, if hollow, like a round pipe, and, if ſolid, like a round ſtick, wire, or rope, and he conveys to his readers an idea of their minuteneſs, by comparing them with the known ſize of a ſingle hair. The method uſed by him in aſcertaining this proportion he deſcribes as follows:

'In examining the inteſtines of flies and other inſects by the mi-'croſcope, I have diſcovered veſſels conveying the blood and 'juices, the ſmalleſt ramifications or branches whereof appeared 'to me more than two hundred thouſand times leſs than an hair 'of my beard. And I will here explain how I compute this pro-'portion, which to many may appear wonderful.

'I have a plate of copper, with many lines engraven on it, and 'divided into a number of ſmall equal parts. I then carefully ob-'ſerve how many of theſe parts one hair taken from my beard, 'and ſeen through the microſcope, appears to cover. Suppoſing 'that the diameter of this hair, when magnified, appears equal 'to fifty of thoſe parts, then with the point of a needle I 'trace on the copper a line of the ſame ſize by the naked eye 'as is equal to one of thoſe ſmall veins or veſſels in a fly, ſeen 'through the microſcope; and I find that nine of thoſe ſmall lines 'ſo traced with a needle, when placed cloſe together, are a fiftieth 'part of the diameter of the hair. If then 450 diameters of thoſe 'ſmall veins which I moſt plainly ſee in a fly are no more than 'equal to the diameter of one hair taken from my beard, it fol-'lows,* by the rules of arithmetic, that one of ſuch hairs is more

* 'Mr. Leeuwenhoek here conſiders the hair to be round, as well as the ſmall veſſels 'he alludes to, and ſuppoſing each of theſe to be cut through or acroſs the middle, the

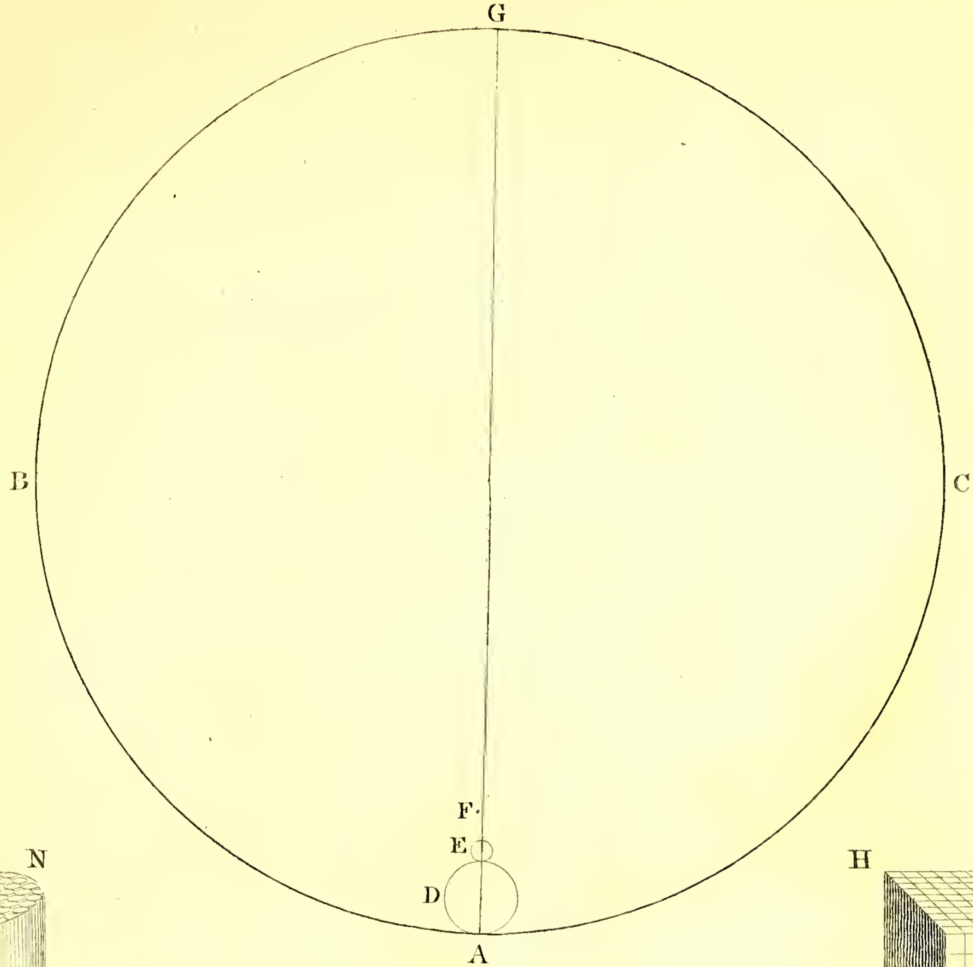
' than 200,000 times larger than thofe very fmall blood veffels in
' a fly.'

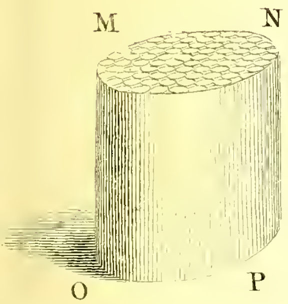
The author fometimes computes the fize of fmall objects by aliquot or equal parts of an inch, and, for the more readily placing thefe before the reader's view, the tranflator has fubjoined a fcale of inches divided into feveral different numbers of equal parts, and in each of thefe divifions is marked the proportionate fize of the fame number of parts in a fquare inch.

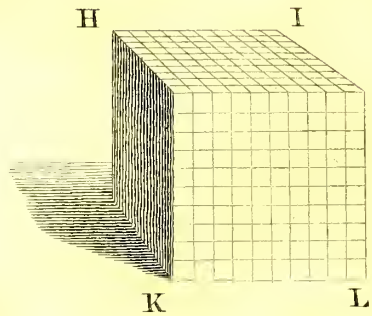
Further, at H I K L, is given a reprefentation of a cube, and at M N O P, a drawing of a cylinder, in order to convey an idea of thofe figures to fuch readers as have not been much converfant in the doctrine of folids. The number of parts or circles contained in the cylinder, will not be found to anfwer fo exactly to the arithmetical computation as thofe in the cube, and this is occafioned by the interftices or fpaces between the circles in the cylinder, which only touch each other in a point.

' fection would exhibit a circle. Now the areas of circles being in proportion to the
' fquares of their diameters, the Author's propofition is mathematically demonftrated
' thus:

$$\begin{array}{r} 450 \\ 450 \\ \hline 22500 \\ 1800 \\ \hline 202,500 \\ \hline \end{array}$$

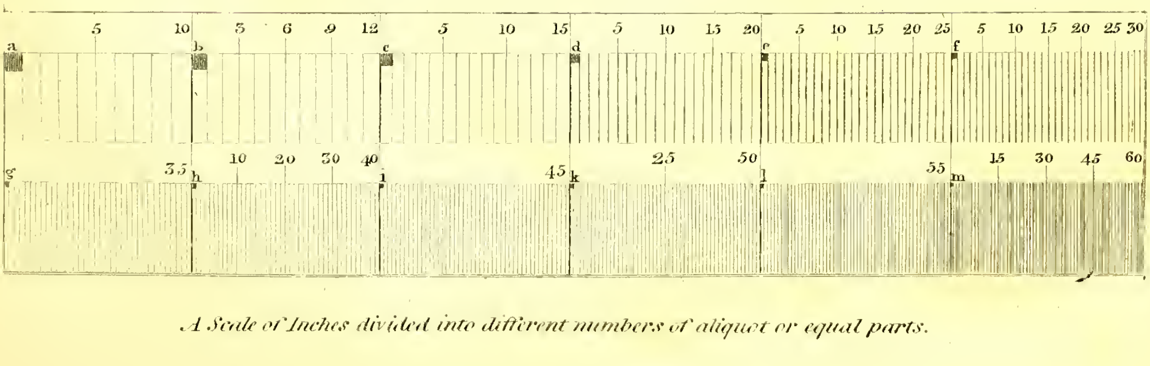






The Aliquot parts of a Square Inch are marked at the letters a.b.c.d.&c.

a *denotes the*	100th p.t	g	1225
b	144	h	1600
c	225	i	2025
d	400	k	2500
e	625	l	3025
f	900	m	3600



A Scale of Inches divided into different numbers of aliquot or equal parts.

Of the OAK.

The Nature of it's Production; the different Degrees of Goodness in Oak Timber; and the Causes of that Difference. The Author's Opinion as to the proper Season for felling Timber.

IN order to form a true judgment of the nature of this Tree, and the better to comprehend the following descriptions of the * vessels which compose the same, let us first attend to Plate I. *fig.* 1 †, B C D, and imagine it to represent the surface of an Oak when cut transversely or across the middle, on which surface eighteen circles appear; which circles are the clear and undoubted marks of eighteen years growth, the tree being increased every year by the addition of one circle, (and in the latter of those years the circles are the largest, though not all of equal magnitude, but in proportion to the fertility of each year.) The small portion of this wood, described in the next figure is marked in the sixteenth circle by the letter E. Farther, supposing the tree to be sawn across, as above-mentioned, and afterwards planed or polished, we shall observe throughout the surface, streaks or creases, reaching from the centre A, to the circum-

* By the word vessels, are to be understood, throughout this Work, small tubes, or pipes, running in different directions, in the subjects treated of.

† This figure, which in the original, is only so many circles, the Translator has caused to be engraved from a piece of Oak of the size here described; at F is represented a knot which was in the tree.

ference B, and thefe are veffels conveying the nutritive juices of the plant outwards towards the bark, as in the next figure will be more fully explained.

Fig. 2, A B C D, reprefents a fmall piece of Oak, drawn as nearly as could be done, according to its appearance feen through a microfcope, prepared by me for that purpofe, and which piece of wood appears to the naked eye of the fize reprefented at *fig.* 2, X.

The dark fhades at FF, FF, indicate the part where, towards Autumn, the vegetation and increafe for that year ceafe, and about this time, and in this part, the wood becomes exceeding hard, being compofed of fuch fmall veffels, that it is difficult, and at laft impoffible, to diftinguifh them, for which reafon they affume the appearance of dark ftreaks or fhades. Between the letters F F, F F, is contained that fpace, or thicknefs, which the tree acquires through its circumference, in the fpace of one year.

This fpecies of timber tree, has five different kinds of veffels, three rifing perpendicularly, and two extending, or fpreading horizontally.

E E E, reprefent the firft fort of thefe perpendicular veffels, which are very large, and are produced in the fpring, with the firft rife of the fap. The infides of thefe veffels are full of a kind of veficles, or little bladders, compofed of very thin membranes, or fkins, and thefe are to be feen in *fig.* 3, where at the letters L K I M, is reprefented a fection of one of thefe large veffels, divided longitudinally, and feen through the microfcope.

The fecond fort of thefe perpendicular veffels is much fmaller, and is alfo compofed of exceeding fine membranes, intermixed with a kind of fpots, which by the microfcope, appeared to my eye like globules, or little balls, as reprefented in *fig.* 4, O N, which exhibits one of thefe fecond fized veffels, divided longitudinally.

The third kind of thefe perpendicular veffels is exceeding fmall, but in great numbers: likewife compofed of exceffively minute membranes, and theſe are alſo repreſented when cut longitudinally, or lengthways, at *fig*. 4. P Q.

All theſe perpendicular veſſels, which are found in ſo ſmall a piece of wood as that before repreſented, and which in ſize, is about the ninetieth part of a ſquare inch, do amount in number, in my opinion, to twenty thouſand; ſo that an Oak tree of four feet in circumference* contains, according to my computation, more than three thouſand two hundred millions of theſe perpendicular veſſels, and in a tree of no more than one foot in circumference, will be found two hundred millions of ſuch veſſels.

Theſe perpendicular veſſels do, for the moſt part, infuſe, or inſtil their juices into other veſſels, which are almoſt innumerable, lying in an horizontal poſition in the tree, and by the means of which it's bulk or thickneſs is daily increaſed: theſe veſſels are of two ſorts.

Fig. 2, G G G, repreſents one ſort of theſe horizontal veſſels, which originally, or at the firſt formation of the plant, are derived from the marrow, or pith, in the centre of it; but afterwards, in great numbers, take their origin from the perpendicular veſſels. Theſe veſſels appeared to my eye like dark ſtreaks; but in order to examine them more clearly, I cut a piece of the wood lengthwiſe, ſo that they were cut exactly acroſs, and then each of them appeared to be formed of five, ſix, or even ſeven veſſels joined one on another, as they are repreſented in *fig*. 4, intermixed among the perpendicular veſſels.

The other ſort of horizontal veſſels, lying in great numbers or cluſters, cloſely joined to each other, though not evenly diffuſed throughout the wood, when examined in their horizontal poſition, appear as in *fig*. 2, A B, or C D, (but when cut tranſverſely, they are repreſented as ſeen by the naked eye, in *fig*. 5, R S,) and where they are repreſented magnified and ſeen longitu-

* The circumference of a circle being about three times it's diameter, a tree of four feet in circumference, will be ſixteen inches in diameter, and one of a foot in circumference, four inches diameter, the ſize repreſented in *fig*. 1.

dinally in *fig.* 2, I have in many places drawn crofs lines, to reprefent what I conceive to be minute valves, and though I could not fee them fo diftinctly, as here they are drawn, yet I cannot doubt of their exiftence, having frequently feen thefe valves in other woods, and particularly, very diftinctly in the Elm; befides, it feems evident to me, that without fuch valves the tree could not be increafed in its bulk, on account of the great force required to feparate and loofen the bark from the tree, in the time of fpring, and alfo for the violent burfting open of the bark, to allow for the growth and increafe of the wood: and if there were not fuch valves, the juices, which, by the action of the fun are drawn outwards, would, at fun fet, when that motion of the juices ceafes, be drawn back again, and their exertions to diftend the bark become fruitlefs. A portion of thefe veffels is reprefented in *fig.* 4, T V, which figure is drawn from a microfcope of greater magnifying power than that from which the perpendicular veffels are drawn, in order that thefe horizontal ones may be more clearly feen: and in this fmall piece of wood, and in this little fpace, which is no more than the feven hundredth part of a fquare inch, are more than two thoufand veffels.

It is well known that there is a great difference in Oak Timber, namely, whether it grew in mountainous fituations, or low lands, and whether in warmer or colder climates, and laftly, whether it was of quicker, or flower growth. As to the fpecimen of Oak which has been juft defcribed, it was taken from a tree of the beft quality, very compact and clofe grained, and which had been very flourifhing in its growth.

Oak timber of this fuperior quality we muft not expect to find in the Northern or cold countries, but in the warmer ones. The very beft timber that we have here, in Holland, is brought down the Rhine from the places of its growth, which are nearly in the fame parallel of Northern latitude with ourfelves. The Oak which we have from Riga, Koningfberg, and Dantzick, is very periſhable, and of a ſpongy nature, becauſe it grows in a colder climate, and increaſes in it's bulk much more ſlowly than that before-mentioned; but yet this wood, though ſo periſhable, is deemed the beſt for making beer-barrels, becauſe it does not impart any ill taſte to the beer, the reaſon of which I take to be, that in cold climates the Oak does not acquire ſo much acrid ſalt as it does in warmer ones; but I do believe, that if the better ſpecies of Oak, after being cleft into ſtaves, were to be ſoaked in water for a certain time, this acrid ſalt would be extracted from it, and that the caſks made of it would be greatly ſuperior to thoſe made of Riga Timber.

The Oak, as has been before obſerved, in the beginning of its growth every ſpring, produces very large veſſels, but the reſt of the year much ſmaller ones; conſequently, when the tree ſo flouriſhes as to acquire an increaſe in it's ſemi-diameter, or on one ſide of it's outward ſurface, of one half, one third, or a quarter of an inch, there will be in this ſpace only one ſeries, or row of ſuch large veſſels; but on the contrary, where the increaſe is ſlow, then, within the ſame ſpace of one half, one third, or a quarter of an inch, there will be formed from twenty to ten, or eleven ſuch rows of large veſſels. This great number of large veſſels in ſo ſmall a ſpace, not only renders the wood very porous and brittle, but alſo very periſhable, eſpecially if it is uſed in works expoſed to much moiſture, and where there is no free current of air: and hence it is, that ſhips built of French or Engliſh Oak, are much more durable than thoſe built of timber growing in the more Northern and cold countries.

In order, more clearly, to explain the nature of the beſt Oak timber, let us revert to *fig.* 2, repreſenting a portion of a tree which, in one year, had acquired in thickneſs almoſt a ſixth part of an inch in it's ſemi-diameter, or one third of an inch in the whole, and in this ſpace, one row or circle, and no more, of the very large veſſels, before deſcribed, had been formed. Then, to difcern the difference between this timber and that brought from Riga and Koningfberg, let us attend to *fig.* 6, A B C D E F, wherein is exhibited a fmall piece of fuch timber cut tranfverfely, and drawn from the microfcope.

The piece of wood which, in this figure, is reprefented by A B C, or D E F, contains about the fifteenth part of an inch in length*, and this length, or rather this thicknefs, the tree had acquired in two years growth, fo that A B denotes the thicknefs produced in the tree in one year, and is about the thirtieth part of an inch in length; B C or E D, indicate the increafe of the following year; A B C and F E D reprefent the larger horizontal veffels, which in *fig.* 2, are explained by A B or C D; and the dark lines H H H H, indicate the fmaller horizontal ones, which in *fig.* 2, are defcribed by G G G: all the round cavities, of which there are three different fizes reprefented in this figure, and which are found within the compafs of the thirtieth part of an inch; in length, are the three different forts of perpendicular veffels before defcribed. Hence we fee that in a tree, which is augmented in fize, in it's femi-diameter, one inch, or in the whole diameter two inches and no more, in the growth of thirty years, there will be formed thirty rows, or feries of large veffels: from whence it follows, that the greateft part of Oak Timber, of fuch flow growth, muft be very foft and perifhable: and if on the other hand we confider, that Oaks growing in a warmer climate may, in one year, increafe in fize, in their femi-diameter half an inch, or an inch in their whole diameter, we may eafily perceive how large a portion of wood will be formed in them, having only one row of the large veffels in it, and how firm, folid, and durable fuch wood muft be.

Let a tree of flourifhing growth be increafed in magnitude, in the fpace of a year, one fourth part of an inch, in fuch a fpace

* This fize is reprefented in *fig.* 6. at X.

will be produced one circle of the large veſſels; another tree growing in a colder climate ſhall require eight or ten years growth to increaſe in the ſame degree: in this laſt tree, within the fourth of an inch ſpace will be formed eight or ten circles of large veſſels, the neceſſary concluſion is, that Oak Timber growing in cold climates muſt be ſoft and periſhable, and it muſt be acknowledged that Oak timber growing in this country of Holland, is ſuperior in quality to that produced in more Northern latitudes: again, that the Oak Timber of Brabant and Flanders, is ſuperior to ours, and laſtly, that the French and Engliſh Oaks are the moſt excellent of all.

One thing muſt however be conſidered, which is, that the very largeſt Oaks are not always ſo valuable as trees of a more moderate ſize, that is to ſay, if they were of good growth, and are free from decay; for though large trees, in the firſt thirty, forty, or fifty years may grow very faſt, and produce excellent timber, yet when they come to the age of an hundred, or an hundred and twenty years, the circles of wood added every year, become very narrow, and the thickneſs increaſes ſlowly, ſo that the large veſſels in the wood approach near together, and conſequently the exterior or outward parts of ſuch large timber become very ſoft, in compariſon with the inner part of it.

It is the general opinion in this Country that timber is much more ſolid or durable when felled in winter than in ſummer. But I think that if we examine this opinion, we ſhall find it to be erroneous.

It is true, that if timber be felled in the ſummer time, the bark can much more eaſily be ſeparated from it than in the winter; for the wood newly formed each year always adheres to the bark, and the bark is every year propelled or driven outwards from the laſt year's wood, and as the tubes or veſſels of which ſuch newly formed wood is compoſed, are during the time of their growth not ſolid, but of a very ſoft texture, this is the reaſon why the bark can be ſo eaſily ſtripped off in the ſummer time. But that any part of the tree, except that of the new growth, ſhould be more ſolid in winter than in ſummer, ſeems to be altogether impoſſible ; for it is plain to demonſtration that all trees are compoſed of multitudes of ſmall tubes or veſsels, which are formed every year by the tree's growth, and that when once formed they preſerve their ſhape and ſize, without any alteration, although the tree be above an hundred years old. Theſe tubes, which in all ſeaſons are filled with juices, are neither leſs in winter nor larger in ſummer, for the juice which circulates through them is at all times the ſame. But if it were poſſible that the ſubſtance of trees in winter could be more cloſe or compact, and in ſummer more ſpongy or diſtended, it would follow that the hard and dead bark ſurrounding the tree would in winter be ſeparated from the wood, and in ſummer more ſplit open than it is found to be ; but ſince we do not obſerve this to happen in either inſtance, it muſt be the better opinion that timber felled in ſummer is equally good with that cut down in winter ; and if any one will take the trouble to examine thoſe ſmall chinks or fiſſures which are produced in the bark during the tree's growth in ſummer, he will find that trees are not increaſed in their ſize or ſubſtance in an haſty manner, but by very ſlow degrees.

OF THE FIR.

The different Degrees of Goodneſs in Fir Timber, how diſcoverable; the minute Veſſels which enter into the Compoſition of this Tree deſcribed at large.

IN treating of the Oak I have conſidered, that the ſpecies of it growing in warm climates, is ſuperior to that which is produced in cold countries. But we muſt not imagine this to be the caſe with all Woods; on the contrary the Fir Timber growing in cold countries is ſuperior to that produced in warm ones, where it's growth is rapid. For the perpendicular veſſels of which the Fir is compoſed are comparatively ſmall, and though we may ſee here and there in this wood a large perpendicular veſſel, that is no great exception to the general nature of it.

In the Fir, at the beginning of its growth every year, the perpendicular veſſels, (which are all of the ſame kind), are formed twice as large as thoſe towards the end of the ſeaſon, when the growth ceaſes, and theſe latter formed veſſels are, in reſpect of their component woody parts, very compact and cloſe, having very ſmall cavities, and conſequently producing durable timber; and the leſs this tree grows every year, the greater number of theſe compact veſsels enter into its compoſition. Hence we may gather, that if, upon examining Fir Timber at the ends, when it has been cut or ſawn acroſs, we obſerve the circles denoting each years growth to approach very near together, we may eaſily conclude that ſuch timber is firm and durable, eſpecially if we perceive great part of theſe circles to be moiſtened or tinged with a reſinous or gummy ſubſtance, named Turpentine.

The production or growth of the Fir is ſhewn in Plate I. *fig.* 7. which repreſents a ſmall piece of this wood, as ſeen by the microſcope, when cut tranſverſely, in order to ſhew the difference between the perpendicular veſsels formed in the Spring, and thoſe produced in Autumn, when the growth ceaſes.

The natural ſize of the ſpace contained between A B C, or E F G, is about the fifteenth part of an inch in length; A B F G, denote that portion of the wood formed towards the latter end of the year, and the line of ſeparation appearing at B F, is the place where the increaſe for that year ceaſed. B C E F indicate a part of the ſame wood, produced in the beginning of the following year.

D D, and G G, are the horizontal veſsels, which in this wood are placed very cloſe to each other, ſo that when cut tranſverſely it is difficult to diſtinguiſh them.

In this figure, we ſee the difference between the veſsels formed at the beginning and at the end of each year's growth. And if the wood here repreſented, within the ſpace A B C (which is the fifteenth part of an inch) required two years to enlarge the ſemidiameter of the tree to that thickneſs, it follows, that in this ſpace there will be two rows or circles of the compact veſsels pictured, between A B. Moreover, the piece of wood which is here deſcribed was from a tree of quick growth, and timber of ſlower growth not only would produce fewer of the large veſsels, but alſo thoſe veſsels firſt formed in the ſpring would be ſmaller in proportion, eſpecially if growing in a colder country, and in a good ſoil. In a word, the nearer the circles before mentioned approach together, the ſlower was the growth, and this ſpecies of Fir is the moſt durable.

In reflecting upon the nature of the tubes or veſsels of which wood conſiſts, I conſidered with myſelf, whether each of theſe tubes was not formed of two diſtinct kinds of exceſſively ſmall veſſels or coats, one ſort extending lengthways, and the other ſort encompaſſing each tube in a circular direction, as I had obſerved the quills * of feathers to be formed, in order to give to each tube a degree of ſtrength and firmneſs.

To inveſtigate this, I examined ſeveral kinds of wood, and particularly the Fir, and at length I obſerved in ſplitting the larger tubes or veſsels of the wood, that ſome of them were indented or jagged in the ſplitting, and I alſo imagined that I ſaw the tube to conſiſt of ſmaller veſsels in a ſtrait perpendicular direction which were not diffuſed all over the membrane or coat, but only placed on each ſide of it, whence I gathered that though the minute veſsels, ſome of which I conceived to extend longitudinally, and others to encompaſs each tube of the wood, cannot always by reaſon of their exceeding ſmallneſs be diſcovered, yet that the tubes are in reality formed like the quills of birds in order to give them the greater ſtrength.

In further proſecuting this inquiry, I procured a piece of the pitch Pine or Fir newly felled, and which had been of very quick growth; and having placed a ſmall part of it before the microſcope, I directed the Engraver to copy the figure of it as exactly as poſſible.

Fig. 8. A B C D E F G, repreſents this ſmall piece of wood, which I ſplit longitudinally as thin as poſſible. It's extreme thinneſs brought clearly into view a great number of globules contained in the veſsels of this wood, and which afford a moſt pleaſing ſpectacle, not only on account of their exact globular figure, but alſo becauſe in each of the globules is a lucid or bright ſpot.

This ſmall piece of wood I found particularly eligible for my

* The Author's examination of this ſubject will appear in the courſe of the work.

obfervations, partly becaufe it is very rare to find a piece fplit out fo long, and fo thin with the perpendicular vefsels fo clearly difcernible in it without obftruction to the fight from the horizontal ones, and partly becaufe I have feldom found fo many of the globules in fo fmall a fpace. Thefe globules in my opinion are the fubftance we call Turpentine, and from which, by burning the wood, Pitch and Tar are procured.*

Between D E and F, are to be feen the tubes of the wood when divided, which plainly appear to be fplit, not exactly ftrait in length, but in a manner indented or jagged and broken fideways.

I alfo put into the Engraver's hands two feparate microfcopes that he might make diftinct drawings of thefe tubes of the wood, and from one of thefe was taken *fig.* 9, M N, where two of fuch tubes are reprefented when fplit lengthways; but the Engraver faid, that he could not poffibly draw all the jagged parts which he faw. And we both of us perceived in the broken membrane or coat of the tube, many exceffively minute veffels, which by reafon of their fmallnefs he was unable to exprefs in the drawing. *Fig.* 10, O P, reprefents a fingle tube of the wood, in which, as plainly as could be done, is reprefented the broken parts of the membrane of which the tube is chiefly compofed.

Since then we find by thefe obfervations, that the very fine membranes of which thefe woody tubes confift, is not always fplit lengthways, but often in an indented or jagged form, me may eafily conceive that the tubes of wood, however minute they be, are partly formed fimilar to the quills of feathers.

The fiffure or fplitting of the particle of wood, reprefented in

* It is well known, that Turpentine is procured from the Fir, by making a wound or incifion in the Tree, from whence the Turpentine flows in great abundance. This, upon being diftilled produces the fpirit of Turpentine, and what remains at the bottom of the ftill, is the fubftance called Rofin.—Pitch and Tar are obtained by burning large quantities of the billets of Fir, either in the open air, covered with fods to prevent evaporation as was the ancient practice, or in ovens conftructed for that purpofe, as is the modern method.

fig. 8, was in ſuch a direction that, as I may ſay, it paſsed or took its direction through the centre of the tree, by which means the horizontal veſsels, as well as the perpendicular ones, were divided longitudinally, and therefore are both exhibited in the ſame figure.

Between K I and H G, the horizontal tubes or veſsels are repreſented when divided longitudinally. Theſe veſsels are found in great abundance in this wood, and in ſome places ſix, ſeven, or even twelve of them ſhall be found cloſe together, and it is very rare to ſee ſo large a ſpace of the perpendicular veſsels without horizontal ones, as is between G and F in this figure, though the real ſize of that ſpace is not more than the thickneſs of a large grain of ſand.

I have often reflected on the nature of theſe horizontal veſsels, that is, how they are formed, and how ſupplied with nutritive juices, for through them a new coat of bark is every year produced round the tree. At firſt, they undoubtedly have their riſe from the marrow or pith in the center, but afterwards, they muſt neceſsarily proceed from the aſcending veſsels. In this enquiry I could not fully ſatisfy myſelf, except that I obſerved the appearance of certain ſmall dots or points in many parts of the perpendicular veſſels, which at length I diſcovered to be no other than ſmall round apertures. Theſe are repreſented in *fig*. 8, between B C, and G H, and as I did not ſee them in any other places than where I had divided the horizontal from the aſcending veſſels, I concluded that at theſe ſmall apertures the horizontal veſſels are united to the perpendicular ones. And I began to conſider whether the aſcending tubes were not air veſſels, as well as inſtrumental in conveying the nutritive juices.

I then ſat about a more accurate examination of this wood, by cutting off thin ſlices with the ſharpeſt edged tools I could procure, and placed them before the microſcope, and hereupon I diſcovered a much larger number of aſcending veſſels than I had before obſerved, which laſt diſcovered veſſels were exceeding ſmall in compariſon of the former; ſo ſmall, indeed that if a large grain of ſand were divided into ten millions of parts, theſe veſſels would ſtill be impervious to them. Hereupon I concluded that all the perpendicular veſſels which I had before diſcovered in this wood, and through which I had ſuppoſed the juices for the nouriſhment of the tree, and its fruit, were conveyed, were really only air veſſels; for thoſe which I now name air veſſels are ſurrounded with three or four of the very ſmall veſſels before mentioned. And I am clearly of opinion, that theſe minute veſſels do conſtitute and form thoſe others which I name air veſsels, and connect them one with another; and that theſe ſmaller veſsels convey all the nutritive ſubſtance for the ſupport of the tree, its leaves and fruit, and that therefore they may properly be named arterial veſsels.

The wood which in *fig.* 8, is repreſented, ſplit longitudinally, I now cut or divided tranſverſely, to ſhew the nature of theſe veſsels when inſpected into or looked down upon, if I may ſo expreſs myſelf; and at *fig.* 11, U V W Y Z, a portion of it is repreſented as ſeen by the microſcope, the natural ſize of which was no more than could be covered by a middling ſized grain of ſand; and in this figure, between the veſsels compoſing the wood, or the air veſsels before mentioned, are ſeen the very minute veſsels which I call the arteries of the wood cut tranſverſely; but as they are ſo very minute, I cauſed four of the air veſsels to be drawn ſeparate as viewed by a ſtill deeper magnifier, that theſe laſt might be the better diſtinguiſhed, and theſe are ſhewn at *fig.* 12, as they lie between the air veſsels.

The dark ſtreaks which are repreſented in *fig.* 11. at W Y Z, are a ſmall part of the horizontal veſsels divided longitudinally, and which veſsels are repreſented in *fig*, 8, between G H, and I K.

To this deſcription I muſt add a little piece of the ſame wood which I cut longitudinally, but in a different manner from that defcribed in *fig.* 8; for as in that figure the wood is reprefented when fo fplit that the air vefsels, and thofe fmaller ones which I call arteries, and alfo the horizontal tubes of the wood, are all divided longitudinally, here on the contrary the perpendicular vefsels are fplit or divided longitudinally, but the horizontal ones are cut obliquely.

Fig. 13, L M N O, reprefents fuch a particle of the wood in which the horizontal vefsels may be feen placed fo clofe to each other as to be only feparated by one or other of the air vefsels. Thefe horizontal vefsels lying fo clofely and regularly befide each other it is no wonder that this kind of wood is of all, the moft eafily fplit, and ftraight in the fplitting.

I have caufed a feparate drawing to be made of thefe horizontal tubes or vefsels in their pofitions adjoining to each other, in order the better to diftinguifh how they lie among the perpendicular ones.

Fig. 14. P Q, reprefents thefe horizontal tubes or vefsels, many of which are feen in *fig.* 13. Thefe vefsels in fome places lie twice as clofe together as they do in others; and upon examining them with the greateft accuracy I was able, I muft fay that I faw two kinds of thefe horizontal vefsels or tubes of the wood, one fort of which was fo much fmaller than the other as almoft to efcape the fight.

For the more fully elucidating this fubject, and for the information of any who may have the curiofity to repeat my obfervations, I have in *fig.* 15, given a drawing of the manner in which I cut or fplit the wood. In this figure ABCDF, reprefents the fourth part of a round piece of the tree or a branch of it, of which B denotes the center of the tree or branch; at G is fhewn how the particle of wood, reprefented in *fig.* 8, was fplit off; at C, how the particle reprefented in figures 11 and 12, was cut off, and at E, how the particle reprefented in *fig*, 13, was fplit off.

I have ſometimes (as I before hinted) ſeen ſome of the perpendicular or aſcending veſsels in the fir, much larger in diameter than others; but theſe are ſo few, that it is very rare to obſerve them.

In *fig*. 8, between B and C, are to be ſeen the minute round apertures in thoſe parts of the aſcending tubes or air veſsels, where the horizontal ones are ſeen, which apertures I conceive are deſtined to tranſmit air or the juices of the tree, from the aſcending to the horizontal veſsels.

Theſe diſcoveries of mine, reſpecting the ſmallneſs or thinneſs of the veſsels or tubes, compoſing the ſubſtance of trees, may not eaſily be credited by many, as not comprehending how, by reaſon of their exceeding ſmallneſs, any juice or liquor can poſſibly paſs through them, and, what is more difficult to conceive, how through ſuch veſsels aſcending perpendicularly, any nutritive ſubſtance can be derived from the root of the tree to the extremities of the upper branches.

But as, on the one hand, it is out of the reach of our finite capacities to comprehend the extent of the Univerſe ;* ſo on the other we are equally unable to conceive the minuteneſs of the veſsels and component parts of which not only animals, but alſo vegetables are formed, and much leſs, how the parts of matter are united together, or how one part grows out of, or is added to, another.

* This ſentiment is more fully expreſſed and largely dilated on, in the Spectator, No. 420, and many of the reaſonings in that Paper ſeem to have been taken from the diſcoveries then newly made by our Author and his cotemporaries.

Of the WEEVIL or CORN-BEETLE.

Wherein the common Opinion that this Inſect is bred in Corn ſpontaneouſly, is ſhewn to be erroneous; the true nature of its Generation explained; with the Means to preſerve Corn from its Infection.

I have heard it ſtrongly argued, that the Weevil or Corn-Beetle, (which is a very noxious inſect, well known to corn-dealers and bakers in this country,) is produced by what is called equivocal or ſpontaneous generation, that is to ſay, from inanimate ſubſtances without any parent. The principal reaſons alledged in ſupport of this opinion are, that we often find this inſect in a new granary, where never wheat was kept before, and therefore it is deemed a neceſſary concluſion, that ſuch Weevils are not propagated by the ordinary courſe of generation. Again it is ſaid, that we may open many grains of wheat, which are ſound and uninjured, ſo that no mark of a perforation or hole, ſhall be diſcernible on the outſide, yet within theſe grains ſhall be found perfectly formed and living Weevils.

The anſwer which I have given to theſe arguments has been, that theſe little animals may, by ourſelves, be removed from one granary to another without our knowledge: for ſuppoſing the perſon employed to remove corn, to have come out of a granary, or barn, infeſted with Weevils, he may eaſily carry ſome grains of corn containing them, or ſome of the inſects themſelves, ſticking about his clothes, or in his ſhoes, and thus remove them into a granary where none had ever been. Beſides, the ſhip, waggon, or cart, employed to carry corn, may be infected with

Weevils, by having carried grain in which they abound, and thus from a few of thefe infects, multitudes may be produced by the ordinary courfe of generation.

But in order fully to inveftigate the truth of this, I defired the perfons who had argued this matter with me, to bring me the firft Weevils they themfelves fhould find, (it being then the winter feafon); and on the 13th of March, I received fome grains of wheat, (many of which had the infides eaten away) mixed with Weevils.

I took three glaffes, in each of which I put fix, eight, or nine Weevils, and eight, ten, or twelve grains of wheat, which wheat I was the more affured could not be infected, becaufe it had been kept for feveral months, clofely covered up, in my ftudy. In a fourth glafs I put fome Weevils without any wheat, but this laft mode of experiment I afterwards rejected, obferving that in the fpace of twelve days they all died. As to the other three glaffes, the weather being cold, and, obferving the animals, for the moft part, to lie motionlefs, I put them into a leather cafe, which I always carried about me. And I had no doubt, but I fhould clearly prove to all, that the Weevil proceeds from a maggot, for which reafon I frequently examined thefe objects by the microfcope.

I, at firft, entertained an opinion, that the Weevil, like the Silk-Worm's moth, and many other infects, did not, while in that fhape, take any food: but herein I found myfelf miftaken, and obferved that the Weevil not only feeds upon wheat, but that it can excavate or fcoop out the whole contents of every grain, and creep about in the infide, being provided with a beak, or trunk of a great length, in proportion to the fize of it's body, at the extremity of which are certain exceedingly fmall organs, or inftruments like teeth, and with thefe it can bore or pierce through the outward hufk or fhell of the wheat, and thus open to itfelf a paffage to devour the contents.

At a fortnight's end, namely, on the 27th of March, I obferved fome of thefe Weevils coupled together, and from this time I frequently infpected them, but faw no appearance of any living creature being produced from them until the 10th of June, when I obferved lying among the Weevils and the wheat, two fhort and thick little maggots; one of them about the fize of a large grain of fand; and the other about one fourth part larger: feeing this, I opened one of the glaffes in which I had enclofed fix Weevils, and examined the different grains of wheat that had been put in with them, and found two of them to be entirely hollow and empty; from another of the grains, which by the external appearance was the leaft eaten or confumed, but had many fmall perforations or little holes not difcernible by the naked eye, I drew out a perfectly formed Weevil, which was of a yellow colour: whereas thofe which were at firft brought to me, and had been fhut up in the glafs for three months, were of a deep red, almoft approaching to black.

In another grain of the wheat I found a Weevil, of a very pale or white colour, with it's claws, horns, and beak, or trunk, lying clofe to it's body, in exact order, as we fee the wings and legs of a Silk-Worm's chryfalis or aurelia, when it is almoft arrived at the ftate of a flying infect, only with this difference, that the unformed Weevil is not inclofed in a fhell or cafe, like the aurelia of a filk worm.

In other grains of the wheat I found maggots of different fizes, and from one grain I took out a perfectly formed Weevil, whofe white colour was changing to a red, and which was continually in motion.

Examining the other glaffes, I found fome of the grains of wheat perforated with little holes, and others half eaten. Some of the Weevils which had been fhut up in thefe glaffes I opened, and in one of the females, I found five white eggs, which I conceived to be of their full fize: in others I obferved eggs, ſome of which were arrived to maturity, and others gradually leſs and leſs.

Hence I concluded, that whereas the Silk-Worm's moth, living only a few days, in that time lays a multitude of eggs and then dies: on the contrary, the Weevil, which every day produces but few eggs, is a long-lived animal, and by this means may be as prolifick as Silk-Worms or other inſects: for the Weevils which I am now treating of were all alive the preceding ſummer.

As to the two maggots which I at firſt found in the glaſs among the wheat, I had no doubt that they had fallen out of the grains wherein they had been firſt depoſited, by reaſon that thoſe grains had been rather too much eaten away before the eggs were laid in them, and the holes which had been made in them rather too large; and, as all creatures, however minute, are endowed with moſt admirable faculties and powers to anſwer the ends of their creation, I think it very probable that the large trunk or beak with which this inſect is provided, (furniſhed with teeth or pincers, which open and ſhut in exact correſpondence with each other,) is given to it of ſuch a length that it may be enabled to bore a ſmall deep hole in every grain of wheat, and therein depoſit an egg, otherwiſe the maggots breeding from theſe eggs would never grow to maturity: for if a Weevil were to lay it's egg on the outſide of a grain, and a maggot ſhould be hatched from it, ſuch a maggot could not poſſibly pierce the huſk of the wheat. Again, were a Weevil to lay more than one egg in one grain, and all theſe eggs produced maggots, they would hinder each other's growth, for want of having ſufficient nouriſhment, inaſmuch as one grain is not more than ſufficient to nouriſh one maggot, and ſo to produce one Weevil.

I obſerved in opening one grain in which a ſmall hole had been made, and out of which I took one ſingle egg, that round about that part where the egg was placed, the mealy ſubſtance of the wheat had been looſened or reduced to powder, from whence I concluded that the parent Weevil, before it laid the egg, had by means of it's trunk, feparated the particles of meal in that part, both to make a foft place for the egg to lie in; and alfo, that when the minute maggot fhould creep out, it might find this foft and loofened meal prepared for it's firft feeding on.

Some of thefe maggots I placed in glaffes by themfelves, and obferved them gradually to affume the form of Weevils, the beak, horns, and claws, appearing by degrees, and the colour alfo changing from a white to a yellow, and then to the red colour of the Weevil.

As I had obferved, that none of thefe infects which were kept in glaffes together with grains of wheat, ever depofited their eggs on the glafs, I put three females into a glafs by themfelves, and in the fpace of twenty-four hours they laid four eggs. One of which eggs drawn from the microfcope, is reprefented in Plate II. *fig.* 1: ABC. In the fpace of feven days thefe eggs produced the kind of maggots before mentioned, which, when firft hatched, were not larger than a grain of fand, and one of thefe as lying on its back, and drawn from the microfcope is reprefented at *fig.* 2. wherein D E F, is the head and F G D the body. This maggot was in continual motion, but when a little at reft, it contracted its body together, and in this pofition the limner drew its figure, and when it attained to its full fize, the fhape remained the fame until the time approached for its being changed into a Weevil. Another maggot which I had fixed or faftened by its hind part before the microfcope, I caufed to be drawn when it extended its body, and this is fhewn at *fig.* 3. H I K.

Thefe maggots have very little ftrength to move from place to place, fo that it feems defigned by nature, that they fhould be fed no where but in grains of corn: for if a Weevil were to depofit it's egg in any place, except in the infide of a grain, it would, in my opinion, be impoffible for the maggot thence produced to procure any nourifhment and become a perfect Weevil.

Thefe things confidered, we may be fully fatisfied refpecting the reafon, why in corn, which is frequently moved and fhifted, the Weevil can increafe but little: for fuppofing one of thefe infects to have pierced and prepared two or three grains ready to depofit it's eggs, and foon afterwards the corn is moved or fpread about, the animal, when it is ready to lay an egg, finding no grain prepared to receive it, muft leave fuch egg on the outfide of the corn, where the young maggot, when hatched, will be in the fame fituation as feed fown in barren land; and confequently muft perifh.. But if fuch corn is undifturbed, the Weevil may multiply, in a great degree, by depofiting it's eggs in the grains fitly prepared for them, and which may be confidered as fo many nefts for the reception of the young. Again, the long life of this infect caufes it to multiply exceedingly, for the Weevils which I received in the month of March, (the youngeft of which was undoubtedly a year old,) were alive and vigorous in June following, and who can tell how long the natural life of this infect may be?

For the information of thofe who never faw a Weevil, one of thefe infects is reprefented of it's natural fize at *fig.* 4, X, and underneath it, I have given a drawing of it's beak or trunk, as feen by the microfcope, to fhew by what organs or inftruments this creature is enabled to pierce the corn, partly to feed on the contents, and partly to depofit it's eggs in the fmall holes it makes therein; for, as other animals are taught by nature to prepare their nefts for the reception and fupport of their young, fo it is the peculiar inftinct of the Weevil to aim at depofiting it's eggs in no other place than where the little animals produced from thofe eggs fhall be able to find fubfiftence, and this is in the grains of corn.

At M N O P is reprefented the probofcis, trunk, or beak of the Weevil, which naturally is not fo ftraight as here pictured, but appears bent downwards when feen fideways, as marked at M Q O; but had the figure been drawn in that view, the opening at the extremity with it's pincers or teeth would not have been vifible, as it is now to be feen at O: within this mouth or orifice are two ftings or piercers which are continually in motion and one of which is feen in the figure, but I never obferved the animal to protrude or thruft thofe ftings or piercers farther than the extremity of the pincers at O; fo that I imagine the only ufe of thefe organs is to break or divide the hufks of the wheat and the meal within it; and, having frequently contemplated this animal, while feeding, I obferved it, after having thruft its trunk into a grain of wheat, to ftick fo clofely to it, that, though toffed about, it would not let go its hold.

S T, are the two horns; L M R, is part of the head; and at M are reprefented* a collection of globules, which through the microfcope exibit the fame appearance as if by the naked eye we were to fee a parcel of very minute black coral beads placed in exact order clofe together; and this I concluded to be one of the eyes.

I am not very fond of drawing the whole bodies of fmall animals from the microfcope, becaufe I confider that to be of little utility, and this is the reafon why I have only given a figure of part of this infect when magnified.

I truft that thefe experiments and obfervations will prove that Weevils cannot be produced, otherwife than by propagation, that is to fay, by copulating and laying eggs, from which eggs maggots proceed; and finally thofe maggots are changed into Weevils. But whether the vulgar will be hereby convinced of the error of their opinion in this refpect, I much doubt, being continually peftered with their objections to what I have advanced. It is,

* To thofe who have not been much converfant in thefe objects, it may feem ftrange that a collection of globules or little balls fhould conftitute but one eye; but fuch readers will be pleafed to underftand, that in moft infects, each eye is formed of a great number of fmaller optical organs, or eyes, and this fubject will be found amply difcuffed in the courfe of this work.

however, with me, a moſt certain truth, that what I have demonſtrated reſpecting the Weevil, namely, that it cannot be produced otherwiſe than by generation, does alſo hold good with regard to all creatures endued with life and motion. And although this is a very minute animal, yet it's ſpecies muſt have been continued in the way I have laid down, from it's firſt being formed at the creation: and were it otherwiſe, namely, that from inanimate matter, ſuch as ſtones, wood, earth, plants, or ſeeds, this or any other animal ſhould be produced, that would be a departure from the general courſe of nature; and ſuch formation or new creation, muſt be continually derived from the ſupreme Almighty Creator.

Probably what I here advance may appear ſtrange to ſome, and they may perhaps wiſh me to enquire into the propagation of other minute animals; but for the preſent I leave the proſecution of theſe matters to thoſe who may chuſe to beſtow as much labour thereon as I have done in this examination of the Weevil, aſſuring them that my obſervations are the reſult of more than four months application to the ſubject.

Of the Maggot or Caterpillar infesting Corn in Granaries; the Nature of its Generation explained, and the means to prevent its Increase pointed out.

HAVING, as I hope, by my Obſervations on the Weevil, convinced mankind, that it is propagated in the ordinary way of generation, I have ſince employed myſelf in the examination of that Inſect or maggot which our Bakers and Corn-dealers name "*de Wolf*."*

This creature is a very ſmall white maggot, provided with two red pincers, or organs like teeth, placed in the fore part of its head, by which it not only feeds on, and conſumes wheat, and other grain, but alſo can perforate or gnaw holes in wood. The common opinion is, that it is produced from corruption, or elſe from what ſome call a blight. But, in order to refute this vulgar error, I procured, from a Merchant, a box of wheat, in which this inſect abounded, that I might diſcover to all, the real manner of its propagation.

Upon inſpecting this wheat, I found, that one ſingle maggot had ſtuck or faſtened together from five, to ſix, ſeven, or even eight, grains of wheat, in one of which itſelf was concealed, and that moſt of the other grains were hollowed or ſcooped out in the middle; and it ſeems to me that this maggot is much more per-

* That is, in Engliſh, "the Wolf." This Inſect is not much known in England among the country people, for the Tranſlator having procured from an Importer of Corn, a ſample of Pruſſian wheat infected with it, and ſhewn it to ſeveral farmers, the appearance ſeemed new to them, nor could they aſſign to the animal any name in Engliſh. But to the Dutch, who have always been great importers and exporters of corn, it ſeems to have been familiar, and the Author's remarks on this ſubject may be well worthy the attention of our Engliſh merchants.

nicious than the Weevil, becaufe it fcatters a great quantity of its excrements in the fhape of white round balls, which are very large in proportion to the fize of its body.

Moreover, this maggot has in the anterior, or fore part of its head, an organ, or inftrument, through which it continually fpins an exceeding fine thread, which thread it fixes to every fubftance it approaches. By this means its body is always fupported fo that it cannot fall, and in a clean glafs it can move from place to place, being fufpended by this thread, and by this thread alfo it connects or binds the grains of wheat together.

Some of this wheat I put into a glafs tube, about the fize of a finger, and a foot in length, clofing each end with a good ftopper, and the reft of the wheat I kept in a wooden box. But, towards the end of the fummer, I obferved feveral of the maggots forfaking the wheat, and faftening themfelves to the glafs, and others of them I faw creeping about among my papers, and I found the box, in which I had put them, perforated in two places, through which many of them had efcaped. I alfo faw the ftopper to the glafs tube gnawed into, as deep as the thicknefs of a finger, and upon taking it out, I found that eight or ten of the maggots had crept into it; upon which I placed them again in the glafs tube, with the grains of wheat, and ftopping the orifices with a cork, I covered the cork on the outfide with fealing-wax, to prevent the maggots again efcaping, but at the fame time I contrived a fmall aperture that they might not be deprived of air. Plate II. *fig*, 5. A B C D reprefents the glafs tube, of which A D, and B C are the two extremities, each clofed with a ftopper covered with fealing-wax; E G and F H are two fmall glafs tubes, paffed through the ftoppers, to fupply the maggots with frefh air, but thofe apertures were fo fmall as not to permit their efcape.

About the fame time that I was employed in thefe obfervations, I vifited a granary infefted with this infect, and faw the maggots, in great numbers, creeping up the walls, from whence I concluded, that in like manner as the maggots in the glaſs tube quitted the wheat, and lodged themſelves in the ſtoppers, ſo in the granary they concealed themſelves in the linings and beams, until their transformation into flying inſects ſhould be compleated. And I was confirmed in this opinion by obſerving the granary to have been ſo perforated, or eaten into by theſe maggots, that not a finger's breadth was left untouched by them.

I alſo obſerved that great part of the ſtopper which was within the glaſs tube, was gnawed or reduced to powder, and many chinks or crannies formed in it, and though the maggots endeavoured to conceal themſelves within the ſtopper, yet three of them remained in the glaſs, in which they lay quiet the whole winter, and they were ſo little covered with their web or thread, that, with the microſcope, I could diſcover them move their heads.

On the 29th of the April following, I ſaw them begin to aſſume a reddiſh colour, and to be ſomewhat contracted in length; the next day the redneſs increaſed, and they ſeemed to me to be turned into aurelias.

At the ſame time, upon examining the wheat, which was kept in the box, and had been full of the maggots, I found that they had all eſcaped through the holes perforated by them in the box.

On the 23d of May, the aurelias before-mentioned, had become of a red colour, and the next day I ſaw a flying inſect, which is called a Moth, fluttering about the glaſs tube. This had proceeded from one of the aurelias, which had been the chief ſubject of my obſervations, and I ſaw lying near it, a pellicle, or little ſkin, which had been the caſe or ſheath in its aurelia ſtate.

Two days before I diſcovered this moth, I had obſerved ſeveral of the ſame winged inſects flying about my ſtudy, two of which I killed, and upon examining them by the microſcope, I found them to be formed in the ſame manner with this in the glaſs, ſo that I was convinced they had proceeded from ſome of the maggots which had eſcaped out of the box. And on the 25th of

May I ſaw two more moths come out of the ſtopper to the tube, leaving their ſhells or caſes hanging to it.

As many perſons are unacquainted with the figure of theſe moths, I have cauſed a drawing to be made of them, which is to be ſeen at *fig.* 6, A A; and alſo a drawing of the covering, ſhell or caſe which encloſes them while in their aurelia ſtate, *fig.* 7. P Q. Theſe figures were drawn of the natural ſize, and if I had not had ocular proof of it, I could not have believed it poſſible for the moths to come out of ſo ſmall a caſe or covering as is here pictured.*

On the ſame 25th of May, I went to the granary, where, the preceding autumn I had ſeen the maggots before-mentioned creeping up the walls, and there I ſaw a number of moths, ſome clinging to the wall, and others flying about. I had brought with me ſix glaſs tubes, and, as it was eaſy to diſtinguiſh the males from the females, the former being ſmaller than the latter, I put in each of theſe glaſſes ſome of both ſexes.

At my return home, I diſſected three of theſe females, and, by the moſt accurate reckoning I could make, I found in each of their bodies upwards of fifty eggs. At another time, I judged that I took out of another female moth, above ſeventy eggs. Theſe eggs were exactly the ſhape of hens eggs, but no larger than ſmall grains of ſand. The reſt of the moths which I had brought from this granary, and kept alive, laid many eggs, and one of them produced to the number of ſeventy.

I next conſidered, whether the moths, which thus propagate the pernicious inſect I am treating of, might not, by ſome means,

* This obſervation of the Author is corroborated, and, at the ſame time, the appearance can be accounted for by a circumſtance which was ſome years ago communicated to the tranſlator by a curious obſerver of the change of aurelias into butterflies and moths, namely, that immediately after their emerging from the ſhell, or covering, which incloſes them, they increaſe in ſize ſo rapidly, particularly in the wings, that their growth may be diſcerned by the eye.

be deſtroyed in the granaries, ſo as to prevent their propagation.

For this purpoſe I took a round glaſs veſſel, large enough, as I ſuppoſed, to hold ſix pints of water, and in it I put eight living moths newly taken. In the orifice of this veſſel I ſet fire to the fourth part of a grain of ſulphur, and as ſoon as the moths began to feel the vapour or ſmoke of the ſulphur, they fluttered about the glaſs with great violence, though but for a ſhort time, for they all fell to the bottom, and after a little motion in their their feet, they died. Four hours afterwards, I took them out of the glaſs, and put into it ſome freſh ones alive, in order to repeat the experiment, but while I was preparing to burn the ſulphur, I ſaw them all lie dead, they having been killed with the bare odour of the ſulphur which had been left in the glaſs.

From the ſize of this glaſs, I computed what quantity of ſulphur would be requiſite to fumigate a granary twenty-four feet long, ſixteen broad, and eight feet high, and I reckoned that half a pound would be ſufficient for the purpoſe.

After this I fumigated a granary, in which were eight loads of wheat, and a great number of moths flying about. For this purpoſe I took two pieces of ſulphur, containing about a quarter of a pound, prepared in the ſame manner as is done by wine-merchants or coopers, to fumigate their wine caſks. Theſe pieces of ſulphur I ſuſpended by a braſs wire, in a tall earthen veſſel, with a narrow top, and placed the veſſel in an earthen diſh, to prevent any danger of fire. This apparatus I ſet in the middle of the wheat, and as ſoon as the ſulphur began to burn, I retired out of the granary and ſhut the door. In a large granary two or three of theſe veſſels might be uſed.

Two days afterwards, I viſited the granary, and then I ſaw ſeveral moths ſtill clinging to the wall and beams, but before the fumigation, I believe there were ten times as many. And I accounted for theſe moths being found alive, by reaſon that many of the panes of glaſs in the windows were broken, through which much of the ſmoke of the ſulphur had eſcaped, or elſe, that the moths which I now ſaw, had come out of their aurelia ſtate after the fumigation was over, for I am well aſſured, that ſo long as the moths are incloſed in their aurelia caſe, or covering, the ſmoke of ſulphur cannot do them any injury. Therefore it will be neceſſary for thoſe who may chuſe to fumigate their granaries in the manner I have recommended, to begin the operation as ſoon as ever the moths appear, that they may be prevented laying their eggs, and alſo to continue the uſe of it ſome days, indeed as long as any moths are to be ſeen, becauſe theſe creatures do not all come out of their aurelia ſtate at the ſame time. The expence of fumigating is no object, for a pound of ſulphur may be bought for a trifle, and it is in no ſort injurious to the wheat, nor is it prejudicial to the health of any perſon, but rather ſalubrious*.

Towards the end of ſummer, when the maggots quit the wheat, and creep up the walls, they may eaſily be ſwept down and deſtroyed, for this inſect is a very tender animal, and ſoon killed. And theſe precautions being obſerved, very few moths will be ſeen the following year.

Some of the eggs laid by theſe moths I put in glaſſes by themſelves, which I carried about in my pocket, others of them I placed in my ſtudy, and I obſerved that thoſe which I carried about me were, by the heat of my body, much ſooner hatched than thoſe which were in my ſtudy, for theſe latter were ſixteen days before the maggots crept out of them; but at ſeven days end thoſe in the former made their appearance.

One of theſe maggots, when newly hatched, I put into a glaſs tube, the inſide of which was about the fifth part of an inch wide, and having placed this before the microſcope, I gave it to the limner to make a drawing of, but as it was impoſſible for him to

* This opinion is confirmed by Dr. Hodges, and Dr. Mead, in their Treatiſes on the Plague.

draw all the minute parts of it, he drew it without the feet, as is ſhewn in *fig.* 8, K L.* The fore part of this maggot is provided with ſix feet, which ſometimes could be diſcerned when the animal lay flat on its belly, and theſe, with part of the body are ſhewn at *fig.* 9, M N. In the hind part are various organs aſſiſting in it's motion. This maggot, although, when newly hatched it appeared no longer to the naked eye than is deſcribed in the center of the circle at *fig.* 10, was yet twice the length of the egg from which it was produced.

As I obſerved ſome of theſe young maggots to be dying, I put ſome grains of wheat into the glaſs, and ſoon afterwards the living ones diſappeared, whence I concluded that they had found their way into the wheat, and in three or four days time I ſaw their excrements ſcattered about the glaſs.

I have often contemplated the ſhells of the eggs from whence theſe maggots proceeded, and obſerved veſſels in them in the nature of net-work, which I could not diſtinguiſh while the eggs were full. A drawing of one of theſe is given at *fig.* 11, R S T V, but as the eggs are exceedingly minute, this drawing was made from a microſcope of greater magnifying power than that from which the former figures are drawn. S T V is the broken ſhell of the egg in the part where the young maggot crept out.

The moths I have been deſcribing are very pretty objects to behold, the wings, which are four in number, being white, ſprinkled all over with black ſpots; and on examining them by the microſcope I found that this whiteneſs proceeded from the white feathers on the wings, and that the black ſpots were cauſed by other feathers which were black at the edges. Some thouſands of theſe feathers I ſaw ſticking to the glaſſes in which I kept the

* This figure does not ſeem taken with ſo much exactneſs as is generally found in thoſe given by Mr. Leeuwenhoek, therefore the Tranſlator has cauſed a drawing from one of the maggots when full grown, to be made of the ſame ſize it appears to the naked eye, and this is to be ſeen at fig. 12.

moths, which in their fluttering againſt the glaſs or one another, had been rubbed off their wings and other parts of their bodies; and to the naked eye, exhibited the appearance of a vapour or ſmoke on the glaſs.

Though I examined ſome thouſands of theſe feathers, they were all ſo differently formed, that I cannot ſay I ſaw two exactly alike. *Fig.* 13, A B, C D, E F, repreſents three of the largeſt of them, when ſeen through the microſcope. At their broad ends, they are tinged with black, and when ſeveral of them lie cloſe together, they exhibit a black ſpot. Others of theſe feathers, as *fig.* 14, G H, I K, L M, are tranſparent, but when lying one on another they produce the whiteneſs I have mentioned. All of them, although ſo very minute, have quills like the feathers of birds, by which they are fixed or rooted in the membrane that forms the wing, and ſo completely cover it that it cannot be ſeen.

The feathers, which cover the edges of the wings, are much longer than the others, and of different ſhapes; five of them are repreſented at *fig.* 15. RS, T V W, and at *fig.* 16, N O P Q, are ſhewn a number of the ſmall feathers of different ſhapes.

This maggot, which among us is called the wolf, is not only miſchievous, by devouring corn, but it is of that ſpecies which is found in houſes, and gnaws holes in wood, alſo in boxes and books, and likewiſe hides itſelf in woollen garments, eating holes in them, and at length becomes a flying inſect, named, as before mentioned, a moth.

This moth, of itſelf, is very innocent, for while in that ſtate, it does not, as I could diſcover, take any food, but, if not deſtroyed in time, one female may produce ſeventy maggots, for out of upwards of ſeventy eggs, laid by one moth, I only ſaw one barren; and in three others of the eggs, I could diſcern the maggots lying dead, by reaſon, as I ſuppoſe, that they could not break the ſhells.

I heard it affirmed, by a corn-dealer, in ſupport of his opinion, that thefe maggots are produced in wheat fpontaneoufly, that they are more rarely found in old wheat than in new; to which I gave for anfwer, that when firft hatched, they are very fmall and tender, fo that it is difficult for them to pierce the hufk of old wheat, the fame being very dry and hard, and confequently many of them die for want of nourifhment. This I fully proved by experiment, for I had three glaffes ftanding in my ftudy, in one of which there were more than fixty maggots newly hatched. In this glafs I put fome grains of wheat, one of which was broken, or fplit down the middle, and this alone was eaten into, the others remaining uninjured, and all the maggots, except one or two, died; all which, I had no doubt, proceeded from this, that thefe grains of wheat were remarkably dry and hard, having been kept for two or three years in a box in my ftudy: and in another of the glaffes, wherein I obferved the maggots creeping about on the furface of the wheat, without being able to penetrate it, I cut feveral of the grains in pieces, and by this means many of the maggots were kept alive.

Towards the end of the month of September, I received from a baker a handful of very excellent rye, with many of thefe maggots in it, all which I put into a large glafs veffel, and I obferved the maggots quit the rye and creep up the fides of the veffel. I then burnt a fmall quantity of fulphur in it, and in a fhort time they were all killed.

It may not here be unworthy of notice, that, in the glafs tube before defcribed, and in which I imagined I had put nothing but wheat, and the caterpillar or maggot, of which I have been treating, I found a Weevil make its appearance; this creature I kept in the glafs to fee if any more would appear, and I obferved, that in the winter or in cold weather it lay motionlefs as dead, but upon applying fome warmth, it would revive. At length, after keeping it upwards of eighteen months, in which time, I did not obſerve any more of the ſpecies, it died.

Moreover, while I was examining the granary before-mentioned, I ſaw many very minute animalcules*, no bigger than grains of ſand, creeping up the walls. Some of theſe I brought home with me in glaſſes, and I obſerved them to couple together, and to lay exceſſively minute eggs, which eggs, after ſome time, produced animalcules formed like the parents. So that it appears theſe little creatures propagate their like without undergoing any ſuch change, as is obſerved in fleas, moths, flies, and many other inſects. I think, however, it is fully proved, that no living creature is produced from corruption or putrefaction.

Indeed, can any man in his ſober ſenſes imagine, that the moth, of which I have given the deſcription, which is fitly provided by nature with the means to propagate its ſpecies, furniſhed with eyes exquiſitely formed, with horns, with tufts of feathers on its head, with wings covered with ſuch multitudes of feathers, all of different ſhapes, and theſe exactly covering the wings in every part; can this moth, I ſay, adorned with ſo many beauties, be produced from corruption? For, in a word, in this little creature, contemptible as it ſeems to us, there ſhines forth ſo much perfection and ſkill in the formation, as to exceed what we obſerve in larger animals.

* Mr. Leeuwenhoek has not given any figure of theſe animalcules, but they ſeem to be a ſpecies of mite, the tranſlator having obſerved ſome of the like kind in bran.

Of the SPIDER.

THE following obſervations were made on thoſe kinds of Spiders which are found in gardens, where they fix their webs to vines, herbs, and ſhrubs.

I have often ſeen theſe Spiders, when dropping, or falling, as it ſeemed, from a tree, ſtop or ſupport themſelves in the mid-way, by means of their thread, and I found that this was done by the help of one of their hind feet, which they continually apply to the thread as they ſpin it. Theſe feet are each of them furniſhed with three nails, or claws, ſtanding ſeparate, or apart from each other. Two of theſe claws are at the extremity of the foot. and each of them is formed with teeth, or notches, like the cuts in a ſaw, growing narrower towards the bottom; and with theſe they are enabled to hold faſt the thread, in like manner as the pully or wheel, uſed by clock-makers, in their thirty-hour clocks, is contrived to lay hold of the clock-line, by means of the groove being alſo narrow at bottom. For the more perfectly underſtanding this formation, I cauſed the following figure to he drawn.

Fig. 17, A B C D E F, repreſents a ſmall part of the Spider's hind foot, magnified, and at B C D, are ſhewn the two claws, or nails, with the notches or teeth in them, as before deſcribed: at letter E, is ſeen the third claw, which is deſtitute of teeth or notches, but, as I conceive, ſerves for various uſes to the animal, and this is always to be noted, that when the Spider does not want to aſcend to an height, but only to lay hold of the web it has ſpun, it always uſes this claw for that purpoſe.

The kind of Spider I am now defcribing, has the hind part of its body much larger than is feen in other Spiders ; it is provided with eight longer and two fhorter legs, which fhorter ones are placed in the fore part of its body on each fide of the head, and all furnifhed with an indented or notched claw as before defcribed. Some will have it, that Spiders have no more than eight legs, but this appears to be a miftaken opinion.

In thefe Spiders I plainly perceived eight eyes, two of which are placed near to each other at the top of the head, and, in my judgment, defigned to fee thofe objects which are above the animal. Two others of them are fituated a little lower down, in order to difcover all objects in front; and on each fide of the head are a pair of eyes clofe to each other, and of thefe, the two which ftand forward, are to take in the view of all objects lying obliquely, or not ftraight in front ; and the two which ftand backward, are undoubtedly defigned to behold all objects behind the animal. And if we confider that the pupils of thefe eyes are immoveable in the head, we may eafily conclude, that this number is neceffary, for enabling the Spider to behold all circumjacent objects, and to go in fearch of its food.

That the form of thefe eight eyes, and their fituation, may be more eafily conceived, I have caufed a drawing to be made of them at *fig*. 18, G H I K L M N O, which reprefents a part of the Spider's head ; P Q, are the two eyes which look upwards, K and L, the two defigned to view objects in front, I and M, thofe which take in objects obliquely in front, and H and N, thofe which look obliquely backwards.

I have often heard it faid, that the Spider has a fting, with which, it is alfo reported, it can kill the toad ; but no one could tell me in what part of the body this fting was placed, therefore, I concluded that if there was one, it muft be in the pofterior or hind part as in other animals and infects ; but on examination, I found this opinion to be groundlefs. The Spider is, however, provided with two organs or weapons anſwering every purpoſe of a ſting, which are placed in front of its head juſt below the eyes, and when not in uſe, they lie between the two ſhorter feet.

Theſe weapons or inſtruments of offence, which are bent in the nature of claws, are very ſimilar to the ſting of the Scorpion and the fangs of the * Millepeda of India, and in each of theſe fangs (for ſo I will call them) is a ſmall aperture, through which, in all probability, a liquid poiſon is emitted by the Spider at the time it inflicts the wound.

At *fig.* 19, A B C D E F G H I K L M, are repreſented both theſe fangs as ſeen through the microſcope: B C, is one of them when lying ſtill, H I K ſhews the other, raiſed to ſtrike. At C and I, is to be ſeen the ſmall aperture † I have mentioned, which aperture appears the ſame on both ſides of each fang, and through this we may reaſonably conclude that the Spider ejects its venom. At the letters E F G, is a double row of teeth, between which each fang is placed when at reſt, and the uſe of theſe teeth ſeems to me to be for the firmer graſping the prey, that when bitten it may not eſcape. All the other parts of theſe weapons or organs which are repreſented in *fig.* 19, were thick ſet with hairs, but which it was not thought neceſſary to exhibit in the drawing.

I at ſeveral times incloſed two or three large Spiders in the ſame glaſs, and always found that when they approached each other,

* That is in Engliſh, thouſand legs, the name vulgarly given to this animal; the Dutch call it Duyſent-been, a word of the ſame import.

† Dr. Mead, in his celebrated Eſſay on Poiſons, when treating of the Spider, expreſſed his doubt of this fact, by reaſon that he could not himſelf diſcover the aperture, and Mr. Henry Baker, in his Treatiſe on the Microſcope, concurred in opinion with the Doctor, that Mr. Leeuwenhoek muſt have been miſtaken in this particular. But in another Treatiſe *, afterwards publiſhed by Mr. Baker, he informs his readers, that he had at length plainly perceived the aperture, and had ſhewn the ſame to Dr. Mead, who was much pleaſed with the diſcovery. A teſtimony this, greatly to the honour of our Author.

* Employment for the Microscope.

they would fight to that degree, as to be covered with the effufion of blood from their bodies*, which was foon followed by the death of the wounded Spider. I alfo obferved, that the fmaller Spiders always avoided the larger, but when two of nearly equal fize approached each other, neither would give way, but both of them grappled together furioufly with their fangs, till one of them lay dead upon the fpot, its body being as wet with the blood flowing from the wounds received, as if water had been poured upon it.

I at one time had a Spider which was wounded by the bite of another in the thickeft part of its leg, and from the wound there iffued fome blood, in quantity, about the fize of a large grain of fand; this wounded leg, the Spider held up, as unable to ufe it, and foon afterwards the whole leg dropped from its body: whenever the breaft or fore part of the Spider was wounded, I always obferved the wound to be mortal.

I had imagined, that when a Spider applied its thread either to fome foreign fubftance or to another thread, that the thread newly fpun muft be covered with fome vifcous or glutinous matter by which it became faftened, in like manner as we obferve in Silk-worms threads. But I now found that the Spider cannot fix its thread to any thing, without imprinting the hind part of its body on the place, by which preffure, it emits an incredible number of exceffively fmall threads, diverging in every direction, from whence we may conclude, that as foon as the threads are expofed to the air, they lofe their vifcofity or glewy quality.

When I at firft began the diffection of the Spider, and endeavoured to difcover the vifcous or gummy fubftance from whence thefe threads proceed, and could not fatisfy myfelf in that particular, I was aftonifhed, not being able to conceive how, from

* If any reader fhould be difpofed to try this experiment, he muft not expect to fee a red liquor iffue from the wounded Spider. For the circulating fluid in many infects is clear or colourlefs, though as fitly to be denominated blood, as that which flows in the veins of animals.

ſo moiſt a body as this creature's, there could in ſo ſhort a time, be produced threads ſtrong enough to bear the weight, not only of one, but of ſix Spiders at a time, And upon endeavouring to diſcover the texture of theſe threads, I could at that time perceive no more, than that the ſame thread appeared in ſome places to be one and entire, and in others, to be compoſed of three, four, or more threads; and though I often endeavoured to obſerve thoſe threads immediately as they iſſued from the Spider's body, I could not obtain a perfect view of them, notwithſtanding which, I did not doubt, that what is commonly ſuppoſed to be one thread, is, in fact, compoſed of many.

I determined therefore, ſo to fix a Spider on its back, that it could not move the hind part of its body; and this being done, I contrived with a ſmall pair of pincers to draw out from the body, that ſmall part of the thread which projected from the organ or inſtrument from which the threads proceed, and then I perceived a great number of exceeding ſmall threads iſſue forth, which, when at about one or two hairs breadth diſtance from the Spider's body, united in one or two threads, and that in this manner the larger threads were compoſed.

Not content with theſe obſervations, I ſat about deviſing means of keeping the threads ſeparate, as they iſſue from the Spider's body, ſo that I might be able to give ſome repreſentation of their inconceivable fineneſs, and at three ſeveral times I ſucceeded herein to my wiſh. But yet, this fineneſs cannot by any efforts of the pen or pencil, be adequately deſcribed. For upon applying the utmoſt magnifying powers of the microſcope, threads are diſcovered ſo exquiſitely ſlender, as almoſt entirely to eſcape the ſight. I have ſometimes endeavoured to count theſe threads as they iſſued forth, but always without ſucceſs.

The Limner, to whom I exhibited this object by the microſcope, declared, that it was not in his power to give a true drawing of it with the pencil, but that by an engraving, it might in fome meafure be reprefented· This is done in *fig.* 20, MNOPQ, being a portion of thefe threads, as magnified by the microfcope, and pictured feparate and diftinct from each other, as they iffued from the body of the animal. Thefe feemed to me to iffue from two of the organs, which I fhall prefently defcribe.

If we duly confider that the threads of Spiders, which to the naked eye feem to be fingle, are compofed of many fmaller ones, and that they thence acquire the ftrength we obferve them to have, we fhall more than ever be affured, that no flexible bodies (except thofe made of metal, the component particles of which are, by the force of fire, moft clofely compacted or knit together), can have any great ftrength or toughnefs, unlefs they are compofed of oblong parts laid fide by fide, and that their ftrength or toughnefs will be greater where thefe oblong component parts are twifted together, or made to cohere by fome glutinous matter, as are fpun filk, linen garments, ropes and the like. And this is the reafon why all the fingle threads of flax are very tough in proportion to their fize, for each of them is compofed of ftill fmaller particles or fibres, which are not only joined together by a certain vifcous or gummy matter, but are alfo furrounded with a coat or bark, as it may be called, whereby their inward component fibres are rendered ftill ftronger.

Again, if we advert to the great number of exceffively flender threads, proceeding, all at the fame time from the body of the Spider, we muft acknowledge that this kind of formation is neceffary, for were it a fingle thread which is fpun by this creature with fuch celerity, the liquid matter of which it is formed, could not on its expofure to the air, become a folid fubftance fo quickly as thefe leffer threads, an hundred or more of which, taken together, do not in my opinion equal the hundredth part of one of thofe hairs I can take from the back of my hand.

In a word, the infcrutable power and wifdom of the Almighty Creator, are manifeftly difplayed in the formation of fuch a thread as the Spider's, the wonderful make of which is feldom obferved, becaufe, the finenefs and delicacy of its texture are not difcernible by the naked eye.

Upon beholding the exquifite flendernefs, and alfo the multitude of thefe threads, I was ftruck with aftonifhment, upon confidering how wonderful muft be the organs in a Spider's body to produce fo many, and at the fame time all diftinct from each other. And although I never expected that I fhould be able to dive into this fecret of nature, yet, upon diffecting the hind part of one of the largeft Spiders I could procure, and attentively examining it, I at length, with the greateft admiration, perceived a great number of exceffively fmall organs, from each of which, one exquifitely fine thread proceeded, and thefe were fo many, that I thought their number muft at leaft exceed four hundred. They were not all placed clofe together, but in eight diftinct fpots or compartments, fo that if the Spider ufes all thefe organs at the fame time, eight feveral threads may be formed, each of which will confift of a great number of fmaller ones. Again, thefe fmaller threads differ in fize, for one of the organs will be feen to fpin a thread twice as large as the next adjoining to it.

If any perfon examines by the microfcope that part towards the extremity of the Spider's body, from whence its thread proceeds, he will obferve the fpot to be, as it were, furrounded by five feveral protuberances or rifings, each ending in a point, and altogether forming a kind of enclofure ; but from the anterior or forwardeft of thefe five protuberances no threads proceed. The other four, on their outer fides are thick fet with hairs, fo that all the fmaller organs deftined to fpin the threads, are fituated towards the infide, the reafon of which, I take to be, that they may be preferved uninjured, when the Spider is creeping into holes, where it does not want to ſpin its web, or while running along the ground, or after its prey. When theſe laſt mentioned four protuberances are put aſide from each other, there will be ſeen in the middle or ſpace between them four ſmaller ones, each furniſhed with the like organs for ſpinning threads, but leſſer in ſize and fewer in number.

Theſe organs for ſpinning, being by this means all expoſed to view, exhibit the appearance, as it were, of a field, thick ſet with an incredible number of pointed parts, each producing one thread; but theſe pointed parts are not made gradually tapering from the baſe to the point, they are formed, as if one were to imagine a ſmall reed ſomewhat tapering, having a ſtill ſmaller one joined to its taper end*, and this latter terminating in a point, which point, in theſe organs I am now deſcribing, is as fine as imagination can conceive.

Now if we lay it down as a fact, that a young Spider which is ſeveral hundred times ſmaller than a full grown one, is furniſhed with the ſame organs as the larger, and that as the Spider, ſo the organs do by degrees grow proportionably larger, the neceſſary concluſion is, that the threads ſpun by a young Spider, are many hundred times finer than thoſe ſpun by one full grown, which exquiſite ſlenderneſs, it ſeems beyond the power of the human mind to form a true idea of.

I have given a repreſentation of ſome of the organs, by which theſe incredibly ſmall and numerous threads are ſpun, as nearly as the Limner was able to draw them, when ſeen by the microſcope. And at *fig.* 21, R S T V, exhibits one of the four external parts or protuberances I have been deſcribing; this part, including all which with it is repreſented in the figure, was not in its natural ſize ſo large as a common grain of ſand, from whence ſome judgment may be formed how minute muſt be theſe organs, and how exquiſitely fine the threads which iſſue from them.

* See *fig.* 22.

In this figure, that part which is marked with the letter W, was covered with as many organs, and thofe placed as clofe together, as are reprefented between the letters R and S, but as thefe latter ftanding directly in front, could not by any means be diftinctly fhewn in the drawing, I ordered that fpace to be left vacant: the part which is out of fight, was not covered with thefe organs but with hairs.

While I held this object up to the Limner's view, I turned round the different parts of it, that he might declare how many of the organs for fpinning the threads, in his judgment, it contained, upon the view of which, he was confident that there were above one hundred.

I have before mentioned, that fome of thefe organs appeared to me to be larger than others, and that I fuppofed their ufe was for fpinning the larger threads. One of thefe, as it ftood between two fmaller ones, I placed in view of the Limner, directing him to make a drawing of it. This is feen at *fig.* 22, C F, and in the fame figure, at the letters A B and D E, are reprefented the two leffer organs, from one of which, a thread is feen to iffue.

After this, I took a fmall Frog, whofe body was about an inch and an half in length, which I put into a glafs tube together with a large Spider, in order to fee the actions of thefe two animals when brought together; and I obferved the Spider pafs over the Frog without hurting it, though with its fangs difplayed as if to attack the Frog. Upon this, I caufed the Frog to fall againft the Spider, who, thereupon, ftruck his fangs into the Frog's back, making two wounds, one of which, exhibited a red mark, and the other a purple fpot. I then brought the Frog to the Spider a fecond time, who, thereupon, ftruck his fangs into one of the Frog's fore feet, whereby fome few of the blood veffels were wounded. And having provoked the Spider a third time, he ftruck both fangs into the Frog's nofe, prefently after which, I took the Spider out of the glafs. The Frog, thus wounded, fat without motion, and in about the fpace of half an hour, it ftretched out its hind legs and expired,

The next day I brought another Frog, about the fame fize as the former, to the fame Spider, but though it was twice wounded, I did not perceive it to be injured thereby, perhaps becaufe the Spider's bite may not be fo venomous in our climate as in warmer regions, or elfe, that the poifon of this Spider might have been exhaufted by former attacks; the Frog I threw back into the water whence I had taken it.

Towards the end of October, I took feveral of the largeft Spiders that could be got, and placed them in glaffes apart by themfelves, in order to wait for their laying eggs, which I purpofed to open, and examine the contents. Two of thefe Spiders, after being confined ten or twelve days, I found had laid their eggs, and enveloped them in fo thick a web, that I was aftonifhed to behold it, confidering that it had been fpun in a few hours fpace.

Some of thefe eggs I opened, and found the infide to be of a yellowifh colour; the form of each egg was almoft round, and nearly the thirtieth part of an inch in diameter, and the whole collection of eggs laid by one Spider compofed a rounding figure, almoft fpherical, nearly half an inch in diameter, from whence may be computed how great a number of eggs the fpider lays. And one would almoft think it impoffible for fo many to be contained within this creature's body; fince upon viewing them with the naked eye, as they lie together in regular order, they occupy a larger fpace than the fize of the animal itfelf. But it muft be confidered, and it is what I have often experienced in opening Spiders, that the eggs while within their bodies are not of a globular figure, but being very foft they lie compreffed together, and therefore are of divers fhapes, but as foon as emitted from the Spider they affume a fpherical form, by reafon of the equal preſſure of the atmoſphere on every part of them; and when of this round figure, being placed in exact order, ſide by ſide, and only touching each other in a point, they muſt neceſſarily, to our view, occupy more ſpace than they did while in the animal's body.

I at firſt was not able to conceive by what means the Spider could place its eggs ſo exactly in the centre of the web, but now I was ſatisfied in that particular, for while I was obſerving a third Spider which was fixing a web to the glaſs in order to lay her eggs in it, I ſaw that firſt ſhe made a kind of thick layer of threads, and faſtened them to the glaſs before ſhe began to lay one egg; and it was moſt worthy of remark that this layer or ſtratum was not flat. but curiouſly made with a roundiſh cavity. In about three quarters of an hour's ſpace, upon again obſerving the Spider, I ſaw that this cavity was not only filled with eggs, but that eggs were piled up above the edges of it to the ſame heighth as the hollow of the cavity below, and the Spider was then buſied in ſpinning a web to encloſe the eggs on every ſide. For this purpoſe ſhe employed not only the hind part of her body from whence the threads were ſpun, but her two hinder feet, with which ſhe placed the threads in due order. And now all the organs uſed in producing the threads appeared in view, each of them in the act of emitting its particular thread. I alſo obſerved the Spider elevate the hind part of its body about the breadth of a ſtraw, and then fix the thread which by the elevation had been drawn out to that length, to the web which was already ſpun about the eggs.

I was very deſirous to ſee a Spider in the act of laying its eggs, which at length I obtained a ſight of, and obſerved that they were not emitted from the ſame part as is uſual in all other minute animals; but from the fore part of its belly, not far from the hind legs, and near the place, I obſerved a kind of little hooked organ, handſomely ſhaped, which I had often before ſeen in this animal, and could not imagine for what purpoſe it was deſigned; but now I perceived, that it extended over that part whence the eggs iſſued, and I therefore conjectured that its ufe was to depofit them in regular order within the web prepared to receive them. To give fome reprefentation of thefe parts, I caufed a drawing to be made of a middling fized Spider, lying flat on its back, with the legs contracted, as if it were dead. This is fhewn in *fig*. 23, A B C, and near to letter D is the hook juft mentioned.

This hook I then feparated from the Spider's body, and placing it before the microfcope I delivered it to the limner, that he might make a drawing of it as it appeared to him. This drawing is given at *fig*. 24, G H I K, and therein between the letters I and K, certain folds or wrinkles appear, this organ being fo formed as to have a greater extent of motion and action than ufual. The letters E F denote that part which was joined to the Spider's body.

On the firft of January, I put fome Spider's eggs into a glafs tube which I conftantly carried about me, in order to difcover whether by the warmth I imparted to them, they would be hatched fooner than the ufual time, which is in the fpring; and on the 17th of January I faw above twenty five young fpiders compleatly hatched, and as many more half way out of the eggs; and in the evening of the fame day I counted above an hundred and fifty young ones. The next day, the number was not increafed, for the remainder of the eggs, to the number of fifty, or thereabouts, were either barren, or the young fpiders were dead within them.

Upon expofing the glafs tube at this cold feafon, to the air for about a quarter of an hour, the young Spiders lay without motion, but upon applying fome warmth to it, they began to move, and the greater number of them crowded themfelves together in an heap, after the manner of bees, within the web where the eggs had been. On the 21ft of January I could difcern eight eyes in each of them, which till then had not been vifible, and on the 25th of January they began to fpin webs in the fame manner as full grown fpiders.

I had hitherto been at a loſs to conceive how this great number of young Spiders could be ſupplied with nouriſhment, conſidering that the natural food of this creature is the ſubſtance of other inſects; but I now perceived that they had fed on the barren eggs which had been left in the glaſs, and they afterwards devoured one another till they were reduced to a very few in number.

I have often compared the ſize of the thread ſpun by full grown Spiders with a hair of my beard. For this purpoſe I placed the thickeſt part of the hair before the microſcope, and from the moſt accurate judgment I could form, more than an hundred of ſuch threads placed ſide by ſide could not equal the diameter of one ſuch hair. If then we ſuppoſe ſuch an hair to be of a round form, it follows that ten thouſand of the threads ſpun by the full grown Spiders when taken together, will not be equal in ſubſtance to the ſize of a ſingle hair.*

To this if we add that four † hundred young Spiders at the time when they begin to ſpin their webs, are not larger than a full

* This is found by multiplying the number of Spider's threads, conſtituting the diameter of the hair (which the Author computes to be one hundred) into itſelf, the contents of cylinders (which round threads may be called), being in the ſame proportion as the ſquares of their diameters—

therefore	100	diameters of the thread
multiplied by the ſame number	100	
the ſquare will be	10,000	the proportionate ſize of the hair,
and this being multiplied by	400	the ſuppoſed bulk of a young Spider com-
	4,000,000	

pared with an old one, gives four millions, the proportion aſſigned by the Author to the young Spiders threads.

The Author's manner of computing theſe very minute dimenſions, is fully explained in the Introduction.

† The difference in the ſize of garden Spiders in Spring and Autumn, muſt have been noticed by almoſt every one, and the Author in his computation, conſiders them as ſpherical or round bodies, which according to the rules of arithmetic, are in the ſame proportion to each other as the cubes of their reſpective diameters. Thus, if a young

grown one, and that each of thefe minute Spiders poffeffes the fame organs as the larger ones, it follows, that the exceeding fmall threads fpun by thefe little creatures, muft be ftill four hundred times flenderer, and confequently that four millions of thefe minute Spiders threads cannot equal in fubftance the fize of a fingle hair. And if we farther confider of how many filaments or parts each of thefe threads confifts, to compofe the fize we have been computing, we are compelled to cry out, O what incredible minutenefs is here! and how little do we know of the works of nature!

I never could procure a fight of thefe animals when coupling together, either in the gardens or fields, nor when inclofed in glaffes, for I always perceived the female to run away at the approach of the male, and having at one time inclofed three male Spiders with a female in one glafs, the female flew at the males with fo much fury, and wounded them to fuch a degree, that blood iffued from their legs and feet. Hereupon I killed the female, and the next day I faw two of the males lie dead, and the furvivor employed in devouring the dead female.

Thefe are the chief of my obfervations on the Spider, an animal held in fuch deteftation by many, that they dread even the fight or approach of it, but in which we find as much perfection and beauty as in any other animal.

Spider's body is a feventh part the diameter of a full grown one, the latter will be 343 times the bulk of the former, if an eighth part, 512 times. The proportion here affigned by the author, is nearly the medium between thefe two.

Of the SILK WORM.

THE Royal Society having recommended to my examination, the fruitful and barren eggs of the Silk-worm, I procured a number of thofe eggs, which had been lately laid by the Moth or Butterfly, produced from that infect; this was about the beginning of the month of September. Thefe eggs, when firft laid, were of a yellowifh colour, which in about two days time affumed a reddifh caft, and at fix days end they appeared to the naked eye of a liver colour. Several of thefe eggs I opened, by taking off the upper part of the fhell with as light a touch as poffible, and in every one of them I obferved an exceeding fmall and delicate membrane, which to the naked eye appeared blackifh, but on examining it by the microfcope, I found the real colour to be violet, but where the violet particles compofing it lay clofe together, they affumed a blackifh appearance. This membrane lay next to the fhell of the egg, and I imagined, that within it the future Silk-worm would be formed; and in the part where this membrane was joined to the fhell, I faw a minute fpeck or fpot, which I concluded to be the vital principle, and the rather, as this fpeck was wanting in thofe eggs which I found to be afterwards barren; and it is further to be noted, that in the barren eggs no fuch membrane as I have mentioned was formed, nor did they change their original yellow colour. This membrane in a fhort time extended over the whole infide of the egg, and being feen through the fhell, which is tranfparent, caufed it to appear of a bluifh colour.

Some of thefe eggs, which were fix weeks old, I put into a flat fcrewed box, which in the day time I carried in my pocket, and at night placed befide me in bed, that they might continually be kept warm; and in another box of the fame kind, I put fome more eggs, three weeks old, and thefe my wife (who was always very warmly clad) conftantly carried in her bofom. This we did, to try the experiment, whether it were poffible to promote the growth of the Silk-worms in the autumn.

In the month of October I opened fome of the eggs which I had thus kept by me for about a month, and in one of them, I obferved a minute Silk-worm, about the thicknefs of an hair, and proportionable in length, but I was not able to diftinguifh any particular parts in its body. In the fpace of ten days more, I found larger worms in the eggs, whereupon, I opened fome of thofe which my wife had carried about her, and in thofe, I faw Silk-worms, which by the microfcope, appeared as large as one's finger, and thefe I propofed to have given drawings of, but the animals foon drying, and all the moifture in the eggs evaporating, they entirely loft their figure, fo that neither the head nor tail, nor any other parts of their bodies could be diftinguifhed, although I had very plainly feen them when the eggs were firft opened.

After this, I from time to time opened others of thefe eggs, but I could not perceive any farther growth in the animals, and at length all the moifture in the eggs fo dried away, that they loft their fhape and became flattened.

In the beginning of May, in the following year, I opened feveral of the eggs which had remained all the winter in my ftudy, and then I obferved minute Silk-worms within them, and a kind of globular particles lying clofe to them, which I judged would afterwards be formed into the limbs of the animals.

Towards the end of this month, the Silk-worms increafed in growth very rapidly, fo that on the 20th of May, upon opening feveral of the eggs, I could perceive, not only feveral parts of each animal's head, but alſo a great number of ſmall veſſels in it which branched out into others extending all over the body, particularly to thoſe parts where I could perceive the claws begin to appear, and which, therefore I concluded, were nouriſhed by thoſe veſſels. In ſhort, I ſaw ſuch multitudes of veſſels, with their branches, all of a blackiſh colour, as is not to be conceived, for when theſe branches became beyond meaſure ſlender, they loſt their dark tinge, and at length became inviſible. And I can ſafely ſay, that I do not think I have ſeen ſo many arteries pictured in the drawing of an human body, as appeared in theſe objects, which I ſhould have given a drawing of, but the moiſture in theſe minute veſſels dried ſo quickly, that they loſt their figure, and could no longer be diſtinguiſhed.

On the 21ſt of May, I opened ſeveral more eggs, and ſaw that many of the Silk-worms in the ſpace of the laſt twenty-four hours were ſo much grown, that they appeared compleatly formed, for I could not only ſee the head perfectly formed with all its parts, but alſo all the claws and limbs, and the body every where covered with hairs: upon opening theſe Silk-worms, I ſaw the inteſtines, and now the membrane, which hitherto had incloſed the animal, was diſappeared, the ſubſtance thereof by this time having paſſed into its body, which had aſſumed a blackiſh colour, but the head was particularly black, and I perceived ſome motion in the animal when taken out of the egg.

The next morning, upon opening more eggs, each Silk-worm which had lain in a round poſture within, immediately extended itſelf and crept about, and I found that all the moiſture which I had hitherto obſerved in the eggs was gone, it having paſſed into the body of the worm, which was perfectly dry. In the afternoon of the ſame day, I obſerved that ſeveral worms had crept out of the eggs placed in my cloſet, whereupon I ſat about examining the remainder of thoſe eggs, chuſing ſuch of them, wherein the formation of the animal appeared to be leaſt advanced, whereas before this I had opened the moſt perfect ones: and theſe I found in the ſame forwardneſs of growth as the eggs I had opened on the 20th of May, and by this time all the dark coloured bodies of the animals, eſpecially the head, might plainly be diſcerned through the tranſparent ſhell.

This rapid formation of the Silk-worm, and its motion within the egg, excited in me the greateſt admiration, and if I had not proſecuted the obſervations I have been relating, I ſhould have thought it abſolutely impoſſible: for in the preceding autumn I had placed theſe eggs in a much greater degree of heat than they were now expoſed to, and yet I could not at that time promote the perfect formation of the animals within them. And, from my preſent obſervations, I was led to conclude that it has been an eſſential property of this creature, implanted in its ſpecies at the firſt creation, that the vital principle muſt lie ſhut up in the egg for more than the ſpace of ſix months, without any augmentation of its ſubſtance, except in the formation of that part which is to ſerve firſt for the defence and preſervation, and afterwards for the nouriſhment and increaſe of the animal, and this is the membrane or ſkin I have before deſcribed; and that were it not for this proviſion made by nature, the whole ſpecies of the Silk-worm would be liable to periſh in one year: for if a warm ſeaſon in autumn ſhould cauſe the worms to be excluded from the eggs, the ſucceeding cold and rains muſt prove their deſtruction.

I obſerved, that the Silk-worms always came forth from their eggs in the morning, and not in the afternoon. To aſcertain this, on the laſt day of May, in the evening, I counted the eggs I had then left, which I found to be about two hundred. The next day, namely, on the firſt of June, at ſix in the morning, ninety-ſeven Silk-worms had come out of their eggs, and the ſame day at dinner-time, or about one o'clock, thirty-two more. In all the afternoon, although the atmoſphere was warm, only one made its appearance; but the next day, at feven in the morning, forty more were excluded from their eggs.

I always found that the openings in the fhells, through which the worms crept forth, was blackifh about the edges, and, as I could not conceive this blacknefs to be caufed, merely by the touch of their bodies as they crept through the opening, I carefully obferved the animals at the time they were employed in biting or gnawing open the egg, and I always perceived, that in doing this, they frequently emitted a blackifh watery humour or liquid from their mouths, with which they moiftened the fhell in that part where they were biting it, and this not merely on the infide, for when they had made the aperture large enough for them to emit this liquor on the outfide, they then moiftened the fhell both within and without. I alfo obferved, that when the worm was about moiftening the fhell, it ceafed biting or gnawing for a fhort time, until (as I fuppofe) it had brought into its mouth a portion of the liquid for that purpofe, in like manner as oxen, while chewing the cud, defift at intervals for a fhort fpace, until they have produced a frefh portion of their food from their ftomachs.

From hence I concluded that without this kind of liquid, it would be impoffible for the young Silk-worm to open to itfelf a paffage through the fhell of the egg. And I faw that the animal was very fparing in the confumption of this liquid; for in that part where it had moiftened the fhell, it continued to bite or gnaw (without moving to a frefh place), until (as it appeared to me) it had eaten or taken into its mouth the liquid, and the bitten or fcraped-off part of the fhell. At which inconceivable perfection in this little creature, I was ftruck with aftonifhment, and I drew from it this conclufion in my mind, that not only the Silk-worm, but other creeping infects, when come to maturity in their eggs, do emit fome liquid matter from their bodies, in order to foften the fhell in that part where they are endeavouring to break forth, and poffibly this liquor may have in it fome acute or corrofive falt, fitted for foftening the fhell of the egg.

I cannot quit this part of the fubject, without exhibiting the formation of the Silk-worm's egg, becaufe the feveral particles of which it confifts, are fo firmly and clofely united together, that they preferve the liquid fubftance within the egg many months without the leaft evaporation.

Plate II. *fig.* 25, FGH, is the fhell of the Silk-worm's egg, opened by the animal, as it appeared to the limner through the microfcope; GH, is part of the aperture which the worm, by biting or gnawing, opened for itfelf, and through which it crept out of the fhell.

Some years after the preceding obfervations, I further profecuted my enquiries by obferving the Silk-worms as they advanced in growth, which I could eafily do, having two mulberry trees in my garden, which fupplied me with food for the worms, of which I had three or four hundred young ones.

I have often by the microfcope examined the cuticle or thin fkin which is fhed by thefe infects the * laft time before they are full grown, and particularly the more folid part of it which covers the head; and with great wonder, I beheld in it all the organs or members with which the head is furnifhed, and particularly I faw a number of eyes difpofed on each fide of the head, in fit order to enable the animal to fee every object around it: further to examine which, I have feveral times cut off the heads of full grown Silk-worms, for otherwife they were in fuch continual motion, that I could not clearly diftinguifh thefe eyes. When the Silk-worms were changed into aurelias, I faw the fkins of their heads and the reft of their bodies, which they had put off on the change, and upon examining thefe by the microfcope, I always found the horny coats of the eyes in their caft-off fkins. Several

* The Silk-worms fhed their fkins four feveral times, before they begin to fpin their cone or covering.

parts or pieces of the head with the eyes in them, I placed before the microfcope, and delivered them to the limner, that he might make adrawing of one of them.

Fig. 26, Q R S T V W, reprefents one fide of the Silk-worm's head, with fix eyes placed therein; on view of which, it plainly appears that the eye marked with the letter Q, is defigned to view objects directly in front; that marked R, to look a little obliquely forwards, and at the fame time upwards; the eye marked S, to look on one fide, and at the fame time a little upwards; that marked T, to look rather backwards, and alfo obliquely upwards; the eye marked V, to look entirely backwards; and that marked W, downwards. And, confidering that the eyes of thefe creatures are immoveable, the number and pofition of them as before defcribed (fix on each fide), are the beft calculated for enabling the animal to fee all circumjacent objects.

At the fame time, I obferved the teeth or pincers with which the head is provided, and with which this animal bites or chews the leaves it feeds on; a row or fet of thefe teeth is placed on each fide of the head, and they moft exactly fit into or correfpond with each other. *Fig.* 27, A B C D E, reprefents thofe teeth which were placed on the right fide of the head, and here may plainly be feen how each tooth has a thicknefs or rifing about the middle of it, in order to give it ftrength, whereas the parts of theteeth between D and E, are exceedingly fharp and fine, in order more effectually to cut or chew the leaves: and each of thefe teeth has the fame thicknefs or rifing, both on the infide and outfide. The part reprefented at A B C D, appears very thick in proportion to its fize, but upon more narrowly examining it, I found that this thicknefs did not confift of a folid bone, but was hollow within, which cavity probably had been filled by fome kind of mufcle. At A and B, appear two round boney parts, which in my opinion fit into hollow fockets in the head, fo as to give the teeth free and fufficient motion.

When I firft examined the Silk-worm's thread by the microfcope, it feemed to me not to be of a round form but flat, for the fame thread appeared in fome places four times thicker or broader than in others, I alfo thought, that each of the threads was double, or compofed of two others, forafmuch as the middle of the thread always feemed darker than the reft, and the whole appeared, as if one were to fuppofe, two tranfparent threads lying clofe and parallel to each other, and glued or faftened together, and each of thefe two threads not to be fo pellucid at the fides as in the middle.

I next confidered with myfelf, whether thefe fingle threads might not be compofed of many fmaller ones, and having at length found means to break or feparate them into very fmall fragments, I plainly perceived each of them to be compofed of a number of exceffively minute filaments.

Farther, I placed a Silk-worm which was beginning to fpin its ball or covering, in a glafs tube, large enough to give the animal liberty to move and turn itfelf about, and I obferved it to fix the thread in various places, fometimes to the glafs and afterwards to the threads already fpun, by means of a certain glutinous or gummy matter, with which the threads are fmeared when they firft iffue from the animal's body. In the progrefs of its fpinning or forming its ball or cone, the Silk-worm frequently changed its pofition, and carried the thread by various turnings and windings in every direction, it being implanted in this creature by nature, always to form its cone or web of an equal fubftance and ftrength in every part next its body.

Upon examining this cone or ball of filk by the microfcope, I perceived in hundreds of places, that the threads of which it was compofed, were not fingle but double threads, and this was more particularly diftinguifhable in thofe places where they were bent in a very fhort elbow or turning in their fixure, either to the glafs or to one another. This is explained at *fig*. 28, A B C D, which repreſents a very ſmall particle of the Silk-worm's thread, and this is here ſeen to be formed of two others, which, for the greateſt part, are joined together as at letter A, but where there is a ſhort turning or winding they are ſeparated, and appear in two parts. This double thread remains united, by means of the viſcous or gummy matter before mentioned, until, by being immerged in water, the gum is diſſolved.

Now, if we conſider that the Silk-worm's threads are not round but flat, we ſhall preſently diſcover the reaſon why no ſubſtance, whether of wool or hemp, how fine ſoever it may be, can be formed into cloths or ſtuffs, that will compare with ſilken garments in the gloſſineſs of their appearance. For, the flat ſurfaces of the ſilken threads, reflect the light more copiouſly and ſtrongly, producing their glittering or gloſſy appearance, whereas the light which ſhines on ſmall round bodies is very little reflected from them.

In order to exhibit the flatneſs of theſe double threads more plainly to the limner, I twiſted ſome of them a little, and then placing them before the microſcope, I cauſed him to make a drawing thereof. One of theſe threads is ſhewn at *fig.* 29, E F G H I, and between the letters F G and H I, it is pictured as ſeen obliquely, proving that the threads as ſpun by the worm are not round but flat; they are likewiſe ſo tranſparent, that one thread can eaſily be ſeen through another which is placed upon or over it.

Let us but attentively conſider the make and compoſition of ſuch a thread as the Silk-worm's, bearing in mind alſo, how wonderful muſt be the ſtructure of the creature's body from which theſe double threads are produced, each of which again conſiſts of a great number of oblong particles or ſmaller filaments; and when we further reflect that from ſo moiſt and watery a body as is the Silk-worm's, ſuch ſtrong and tough threads are produced, capable of being applied to the many purpoſes we continually experience, who, upon feeing all this, can refrain from exclaiming with me "How infcrutable and incomprehenfible are the hidden works of "Nature!"

The filken cafe or web of which I am now treating, and which the induftry and ingenuity of mankind has converted to fo many ufeful purpofes, is conftructed by the animal for no other end than that, when its change into a chryfalis or aurelia approaches, and it cannot then be concealed under the leaves of the trees, nor can during the time of its change adhere to any thing, nor even change its place, and during all that time lies as it were motionlefs, it may be preferved from becoming a prey to birds; and this I am well convinced is the cafe with all infects of the caterpillar kind, which, when they are full grown, and their change approaches, wrap themfelves in fome kind of web or covering.

But my chief object, in all thefe my obfervations, was, to difcover as much as poffible the nature of that organ from which thefe two threads proceed, and by what contrivance they are joined fo clofely together: the common opinion refpecting which threads is, that they iffue from the animal's mouth. For this purpofe I found it neceffary to fix a Silk-worm on its back, and then the organ, which is placed below the mouth, appeared in fight. *Fig.* 30, ABC, exhibits this organ. The parts marked DE and FG are placed below the mouth, and the organ from which the threads iffue is fituated ftill lower. While the limner was making this drawing, fome part of the teeth appeared in his view, which he alfo included in the figure, at the letters HIK, and this was done, more clearly to prove, that the threads do not proceed out of the Silk-worm's mouth, as is the vulgar opinion.

After I had difcovered the particulars above enumerated, I endeavoured to inveftigate the matter or fubftance from which the threads are formed in the body of this infect. For this purpofe I cut off the heads of feveral Silk-worms which had begun to fpin their web or cone, and then I faw, befides the other internal parts, two oblong and round bodies four times folded or doubled together, which I took out of the animal's body. Thefe parts were almoft twice the length of the Silk-worm, and at one end, the fituation of which I conceived was in the head, they terminated in a point, and fometimes I faw iffue from this pointed end, an exceffively flender thread, four times the length of the Silk-worm.

Thefe organs, or rather veffels, in the thickeft parts of them, were of a red colour, yet when examined by the microfcope they feemed yellow; but when I feparated the inner from the external part of them, the exterior part feen by the naked eye appeared of a perfect yellow.

Fig. 31, L M N, fhews one of thefe bodies or parts which I have been juft defcribing, and of the fame fize it appeared to the naked eye when dry and contracted. The letters M and N denote how far the red colour extended; from L to M was of a perfect yellow, and here I judged that the thread when produced from the interior part of the animal's body was kept ready for ufe. At N is the fmall end, the fituation of which was near the head, and indeed within the head itfelf. Between L and O, in my judgment, is the way or paffage through which is conveyed the matter or fubftance of which the threads are compofed. This part was of a yellow colour, and is longer than here pictured, being broken off at O. Another part or organ of the fame make and fhape, was alfo contained in the Silk-worm's body, and from thefe two parts the fubftance is fupplied for producing the two diftinct threads I have been defcribing.

Sometimes when this part or organ was broken off at N, I perceived in it a kind of cavity, but extremely minute.

I oftentimes took hold of the end of the thread which the Silk-worm was preparing to fpin, and drew it out from the body with fo much rapidity, as by twenty-five times to exceed the fwifteft motion of the worm in its own fpinning; and I found that when the thread was drawn forth to the length of about fifteen or fixteen inches, it broke off, either near the organ from whence the threads proceed, (marked in *fig.* 30, with the letter C) or elſe within the body of the Silk-worm itſelf. And on theſe occaſions I alſo obſerved that the threads were covered with much more of the viſcous or gummy ſubſtance than uſually adheres to them when ſpun by the worm, which ſubſtance alſo appeared of a yellow colour.

Further, I took a Silk-worm which had ſpun more of its ball or cone than any I had before examined, and on opening it, I perceived that the part which in *fig.* 30, had appeared of a red colour was now quite yellow; and when I opened another Silk-worm which had, as it were, conſumed or exhauſted all its ſilk in ſpinning the web, the ſame parts appeared quite of a pale colour.

When I examined by the microſcope that part which is repreſented in *fig.* 31, at L M N, I diſcovered in it a great number of blood veſſels, moſtly compoſed of annular parts or rings. A ſmall portion of one of theſe veſsels in a place where it divides into two branches, is repreſented at *fig.* 32, F G H I K. This was not one of the largeſt veſsels I ſaw, for near to it was one four times the ſize.

I have at ſeveral times when the Silk-worms had, as I ſuppoſed, nearly finiſhed their web or covering, cut it open, in order to obſerve the change they underwent, and at that time I remarked, that when the ſkin about the head became looſened, the worm was then changed into a chryſalis or aurelia, and nothing wanting to compleat that change, but the putting off its ſkin of a worm. But when I myſelf endeavoured to ſtrip off this ſkin, I found the under one ſo ſoft and tender, that I could not avoid injuring it.

Moreover, I have examined by the microſcope the Silk-worm, when it firſt iſſued from the egg, to diſcover, if poſſible, whether the exceeding ſlender thread ſpun by ſo minute a creature was a double thread, and in more than one inſtance, I found this to be the caſe. Theſe threads I judged to be above a thouſand times ſlenderer than thoſe ſpun by full grown Silk-worms, and they were all covered with a proportionable quantity of the glutinous or gummy matter before-mentioned. In ſhort, there is no doubt that the ſame perfections exiſt in a newly-hatched Silk-worm, as can be diſcovered in one full grown.

I have frequently examined the flying inſect, moth or butterfly produced from the aurelia or chryſalis of the Silk-worm; and, having before particularly deſcribed the eyes of this creature while a worm, I now employed myſelf to diſcover the nature of its eyes, when changed into a moth; and for this purpoſe I placed before the microſcope one of thoſe organs of ſight, which in this animal is commonly deemed one eye. This is protuberant or riſing above the head, rather more than an hemiſphere, and is compoſed of a number of ſmaller optical organs: Theſe I counted with the greateſt exactneſs I was able, beginning at the bottom of the hemiſphere, and proceeding to the ſummit or uppermoſt part of it, which diſtance made the fourth part of a ſphere; and in this ſpace I counted thirty-ſix optical organs or eyes. But, not ſatisfied with my own computation, I delivered the microſcope to the limner, deſiring him to count them, and in the ſame ſpace he reckoned thirty five. This latter number I will ſuppoſe to be right, and from it I proceed to compute as follows:—If the fourth part of the circumference or great circle ſurrounding a ſphere contains thirty-five, the entire circumference will contain 140. Now Metius informs us, that, having the length of the great circle in a ſphere, the calculation of the whole ſuperficies of ſuch ſphere is beſt and eaſieſt computed, thus: As 22 is to 7, ſo is the quadrature of the great circle to the ſuperficies of the ſphere, therefore in the preſent caſe the computation is as follows:—

As 22———7———19600	140 the circumference or length of the great circle.
7	140
22)137,200(6236	5600
8	140
	19600 the quadrature of the great circle.

From hence it follows, that each of the fmall parts or organs of fight of this infect, which is vulgarly deemed but one fingle eye, is compofed of more than three thoufand optical organs or eyes, but if both parts together con itute a fphere, they then contain 6236 optical organs or eyes.

I have caufed this part or eye of the infect to be drawn of the fame fize as it appeared to the naked eye of the limner, to give the better idea of the wonders which are concealed in fo fmall an animal. This is fhewn at *fig.* 33, between the letters L and M. Each of the optical organs contained in this eye is feparated from the reft by a line or divifion of fix fides, or of an hexagonal figure, and all thefe hexagonal organs or eyes are placed in the moft exact order that can poffibly be conceived. A few of them, as feen by the microfcope, are feen at *fig.* 33, *a, b, c, d.*

When this little part, cleared from the optic nerves within it, was placed before the microfcope, all the furrounding objects were clearly to be feen through each of the fmall optical organs I have been defcribing, though wonderfully diminutive; for the great tower or fteeple of our new church in Delft, which is three hundred feet high, and about feven hundred and fifty feet diftant from my houfe, when viewed through any one of thefe optical organs, appeared no larger than the point of a fmall needle feen by the naked eye: and from hence may eafily be collected how minute the optic nerves muft appear to me.

Now, if we confider that a Silk-worm, within the fpace of eight or nine days, fhall not only have fpun its web, cone, or ball, but alfo fhall be changed into an aurelia or chryfalis, and that in the fame fpace of time, not only its eyes but all the members pertaining to it as a flying infect fhall be formed, who can avoid being ftruck with amazement at all thefe wonders in one Silk-worm? And yet, how little do we difcover in comparifon of thofe things which now are and for ever will be hidden from our fight? the whole of which I am fully perſuaded no one will ever be able to dive into, and to explain their cauſes and effects.

If we examine the wings of this creature by the microſcope, we ſhall find them covered with an incredible number of feathers, of ſuch various forms, that if an hundred or more of them were to be ſeen lying together, each would appear of a different ſhape. To ſhew more clearly this wonderful object, I cauſed eight different feathers to be delineated, for I do not remember that I ever ſaw them of ſo curious a make in any other flying inſect. Theſe feathers are ſhewn at *fig.* 34, A B C D E F G H I K L M N O, and the letters A C E G I L N, denote their quills which were fixed in the membrane or ſkin of the wing.

Although the microſcope by which theſe feathers were drawn, repreſented objects very diſtinctly, the limner could not, through it, ſee the ſtreaks or ribs in each feather, until I pointed them out to him. Therefore I put into his hands a microſcope which magnified objects almoſt as much as that by which the Silk-worm's thread was drawn, deſiring him to give the figure of that feather which through it he could ſee the moſt diſtinctly. This is done at *fig.* 35, P Q R, in which plainly appear a great number of ſtreaks or parts like ribs, which give ſtrength to the feather, and in ſome of theſe feathers, where they ſpread very wide, as at the part marked R, I have counted as many as thirty of theſe ſtreaks, and if we conſider that every feather is nouriſhed through the quill which is pictured at P, how many and how various muſt be the veſſels in this quill?

After this, I wiped off the feathers from a part of one of the wings, that I might diſcover how cloſe they were placed together, and I found that they were about an hair's breadth aſunder. And if, as a certain writer aſſerts, 640 hairs breadths are equal to one inch, we may demonſtratively conclude, that the four wings of this inſect are covered with more than four hundred thouſand feathers, for the ſurface of all the wings when laid ſide by ſide takes up almoſt three quarters of a ſquare inch; and, as each wing is covered on both ſides with feathers, this makes the ſpace of an inch and an half ſquare. To which if we add, that the body and legs of this butterfly are covered with as many feathers as are on the wings, the number of feathers above enumerated will be doubled.

I then examined the boney parts which give ſtrength and ſtiffneſs to theſe wings, and I ſaw more plainly than in other flying inſects the crooked or twiſted veins within them. A very ſmall portion of one of theſe boney parts is ſhewn at *fig.* 36, A B C D E F, within which is ſeen that twiſted-vein, and where the bone is divided into two parts, the vein is the ſame. In the ſame figure, at A B H, is repreſented a ſmall part of the membrane or ſkin of the wing ſtripped of its feathers. The dots in it indicate the cavities wherein the quills of the feathers had been fixed.

It is alſo a pleaſant object to behold the curiouſly formed claws in each of the ſhort feet of the Silk-worm, and which are ſhed or put off with the ſkin at the animal's change into an aurelia, one of theſe is ſhewn at *fig.* 37, I K L, and when changed into a flying inſect or butterfly each foot is furniſhed with two nails or claws, with which it very ſtrongly clings to every thing it touches. Theſe nails or claws are ſhewn at *fig.* 38, M N O.

To cloſe this ſubject; ſeeing that the Silk-worm, in its change, only puts off the ſkins of its feet, and that, in the ſame places where, while a worm, it had very ſhort feet; it is, when a butterfly, furniſhed with legs, covered with numbers of feathers, and armed with nails or claws as before deſcribed, the metamorphoſis or change of this creature muſt ſeem almoſt incredible, and cannot but excite in us the greateſt admiration.

On the nature of the ſcales of Fiſhes, and how the age of thoſe Animals may be determined by obſervation of the ſcales; The Author's reaſonings and opinion reſpecting the Longevity of this part of the Animal Creation.

IT is the opinion of the Jews that they are forbidden by their law to uſe the Eel as food, becauſe that Fiſh is ſaid to be without ſcales; and in the book of *Deuteronomy*, Chap. xiv. *v.* 10. it is written, "whatſoever hath not fins and ſcales, ye may "not eat, it is unclean unto you;" and in *Leviticus*, xi. *v.* 12, are theſe words, (which they apply to the ſame ſpecies of Fiſh,) "what-"ſoever hath no fins nor ſcales in the waters, that ſhall be an "abomination unto you.

But when I examined this kind of Fiſh, by the microſcope, after I had cleared away that viſcous or ſlimy matter which adheres to them, I found their ſkins to be as completely covered with ſcales as thoſe of any other river Fiſh, which ſcales (though very ſmall and thin) lie as cloſe together and are placed one on another in as regular order as can be obſerved in any other Fiſh whatever, whether of freſh or ſalt water. Moreover, this ſpecies of Fiſh is provided with fins equally as others, namely, one at the head; and one above, and another below, the tail; and, becauſe I apprehend that this diſcovery of mine is new, at leaſt to perſons of the Jewiſh nation, (for to this day they deem this delicate Fiſh to be unclean,

clean, and hold it as an abomination to them,) I determined to give a figure of one of thefe fcales, (taken from the belly of the Fifh, where they are the fmalleft,) as it appeared through the microfcope.

Plate III. *fig.* 1, A B C D, exhibits this fcale ; it was taken from the belly of a large Eel, which, next the head was of the thicknefs of feven fingers or thereabouts : on the back and fides of this Fifh the fcales are larger. The greateft part of this fcale, A D C was covered by two others. The part B, was placed towards the tail, and in this pofition were all the fcales ; they were all principally compofed of a kind of globules or little balls, which globules in many places exhibited an appearance, as if they were covered with a cobweb, which by reafon of its exceffive finenefs, could not be expreffed in the drawing.* In thefe fcales the globules compofing them were very tranfparent, though fome more than others ; again, fome had in them a dark fpot. Thefe opaque globules lying in rows contiguous to each other, produced the appearance of divers circles or rings on the face of the fcale. And although I did not obferve thefe fcales to be exactly alike, yet the circles or rings feemed to me to be of the fame number in all of them, whence I was led to conclude, that the fcale had been every year augmented by the addition of one circle, and confequently, that, as there were feven circles in this fcale, this Eel was probably feven years old. Thefe circles are marked in *fig.* 1, by the letters E F G H I K L, and at X the fcale is reprefented of the fame fize as it appeared to the naked eye.

Having examined the fcales on the body of a very large Eel, I perceived that thofe on the back and belly of the Fifh were placed in regular and even courfes behind each other, but that thofe between the back and the belly were many of them laid obliquely, fome

* This appearance feems to have been afterwards more fully inveftigated by the Author, and explained by a drawing, as will appear in the following pages.

towards the belly and others towards the back, but all ſo diſpoſed as to cover the ſkin exactly in every part.

*After this, I examined the matter or ſubſtance with which theſe ſcales are covered, which, as well as the ſcales, has been generally deemed nothing more than ſlime, and is by moſt perſons thought to be an excrementitious matter, adhering to this ſpecies of Fiſh; but I am now convinced by experience, and the cleareſt ocular demonſtration, that this ſuppoſed ſlime does not collect on the animal's body from without, but is really part of the body itſelf; forasmuch as this ſubſtance, although it appears to the naked eye, and very often through the microſcope no otherwiſe than like a cryſtalline or pellucid humour or ſubſtance, yet in fact it is no other than a congeries or collection of veins or veſſels, which in their exquiſite fineneſs or ſlenderneſs do almoſt exceed belief, ſpreading themſelves one among another in ſuch an incomprehenſible and immenſe number of branches, that I could not contemplate them without the greateſt admiration. Indeed, many were ſo thin and ſlender, that I could not diſcover them without the moſt careful attention, and I thought it probable that there might be others ſtill more minute, ſo as entirely to eſcape the ſight. Such of theſe veſſels as I could diſtinctly perceive, I judged to be ſo ſmall (meaſuring them by my eye) that if one of the globules† of blood from whence its redneſs proceeds, were to be divided into a thouſand parts, not one of thoſe parts could paſs through theſe wonderfully thin and ſlender veſſels.

From theſe obſervations I concluded, that this ſubſtance only

* Theſe obſervations of the Author on the Eel appear to have been written poſterior to the time when he publiſhed the preceding ones, and it ſhould ſeem, that what he before deſcribes to be an appearance like a cobweb adhering to the ſcales, is the effect of the veſſels here deſcribed.

† The Author's computation of the ſize of a globule of blood, will be found in another place, where he treats of that ſubject.

anſwers the purpoſe of a membrane or ſkin lying next to the ſcales, and that, when an Eel is creeping through a narrow paſſage or hole, a part of this membrane or cuticle, which we call ſlime, is rubbed off in the paſſage; and that when Eels are kept in any kind of veſſel without water, and in their motion wear off this cuticle, they cannot long ſurvive; and upon my talking over this ſubject with a Fiſh-monger, who was a very intelligent man in his buſineſs, he confirmed all that I have here mentioned.

Further, I imagined that this cuticle or ſkin ſo covering the ſcales of Eels, and in ſome ſort proceeding from the ſcales themſelves, and the veſſels which in a great meaſure compoſe that ſkin which we imagine to be ſlime, extend ſo far and wide, that the veſſels proceeding from one ſcale ſpread over more than twenty-five others, and that this is the reaſon why this ſlimy matter covering the ſcales is ſo thick and tough.

But, not yet ſatisfied with theſe obſervations, I endeavoured to find out the veſſels in the ſcales from whence theſe ſlimy excrementitious veſſels were formed, and in order to exhibit more plainly the rough or wrinkled make of the ſcales, I have cauſed an exceeding ſmall particle of one to be delineated, the appearance of which, by the microſcope, was that of a lucid or bright cryſtal, both within and without. This is ſhewn in *fig.* 2, I K L M, wherein the ſide I M, repreſents that part which was fixed or rooted in the Fiſh, being about the length of two common grains of ſand. I have ſometimes divided the ſcales of this Fiſh into ſmall parts, and I always found that though the wrinkles in them appeared very pellucid, they were compoſed of nothing but thoſe inconceivably ſlender ſtreaks, or rather veſſels, mixed and twiſted one within another, as is in ſome ſort repreſented in this figure by the letters K L N.

Some years after the preceding obſervations were publiſhed, I received from a perſon of ſome note in this city, a parcel of ſcales taken from a very large Carp which had been kept in his Fiſh-pond, and was ſo tame that it would take food out of a perſon's hand.

But in the time of a fevere froft, the gardener being employed in breaking the ice with an hatchet, to give frefh air to the Fifh in the pond, this Carp came to the hole, and unfortunately received a wound from the hatchet; which occafioned its death. This Fifh was in length $42\frac{1}{4}$ inches, and in circumference at the thickeft part of its body $33\frac{1}{4}$ inches.

In order more eafily to cut one of thefe fcales in pieces, I fteeped it in warm water, and then I cut off a flice from it, paffing through that part where the firft formation of the fcale appeared, which original fcale was very minute, and I then obferved forty rows of fcales lying one on another, or in other words, this fingle fcale was a clufter of forty other fcales lying on one another. For every year a new fcale fomewhat larger than that immediately preceding it, is added tot he number, and is as it were glued to the former ones, therefore as many of thefe fcales as are found thus joined together, fo many are the years of the Fifh's age. This affertion of mine is however violently contradicted, becaufe many people think that I cannot by any means prove what I affirm.

I determined therefore, to cut off a flice from this fcale very obliquely, whereby the rows of the component fcales might be more clearly difcerned, and I caufed a drawing of this to be made from the microfcope, which is fhewn at *fig.* 3, A B C D; the part reaching from A to B, or from D to C denotes the difference in fize by which each newly-formed fcale exceeds that of the preceding year, the whole thicknefs of the fcale as it appeared through the microfcope, is the fpace between B and C, but in fact, the real thicknefs, as feen by the naked eye, is no more than that of an hog's briftle.

Another piece of the fame fcale, cut ftill more obliquely, I placed before another microfcope, a drawing of which is given at *fig.* 4, E F G H. The fpace between E and F is the thicknefs of the fcale, and as many divifions or rows as are there pictured, fo many of the fmall component fcales lie heaped one on another, (at leaft as far as the limner was able to obferve them,) and fo many years had elapſed between the formation of the firſt ſcale, and all the others which were added to it.

This cutting or ſlicing off pieces from the ſcales, does not ſucceed equally well in all, for ſometimes their thinneſs cauſes it to fail, but if the extremity of each ſcale can but be perceived, the age of the Fiſh may be gathered from it with little danger of miſtake. In order to ſhew this irregular kind of ſection, I cauſed a ſmall piece of that deſcription to be drawn from the microſcope, and this is ſhewn in *fig.* 5, I K L M; here the additional ſcales produced every year, ſometimes appear of a darker ſhade than they are in reality, and therefore the yearly increaſe in ſize ſeems repreſented at I O and M O, but the addition of three years growth appears at I O K. At *fig.* 6, between P and Q, is ſhewn the natural ſize of the ſlice or piece of ſcale repreſented when magnified, at *fig.* 4.

Since we now find, that the ſcales of Fiſhes are every year augmented in the way I have been deſcribing, we may form a pretty good judgment as to the time when this augmentation is made, by analogy to what we obſerve in the other productions of nature, and thence we ſhall conclude that the additional ſcales are compleated at that ſeaſon, when the further growth ceaſes. For this is evident in trees, at leaſt ſuch as grow in theſe regions. The like alſo is the caſe in regard to cows, for between certain ſpaces of time, when their growth is intermitted or ceaſes and when it again returns, it is ſhewn in the horns, whence we gather that as many knots or rings as are found on the cow's horn, ſo many years of age is the animal. And, though this may not appear exactly in the ſame manner in all creatures, yet we muſt allow, that ſuch a diſtinguiſhing circumſtance exiſts, and this is proved in the falling off of the hair from animals, and the ſhedding of feathers by birds, at certain regular periods.

I have often conſidered with myſelf, reſpecting the longevity of Fiſhes, and I am perſuaded that in deep and extenſive waters, and in running ſtreams, where the water does not corrupt or putrefy, they are not liable to any difeafes, nor ever die of old age. Such wounds as a Fifh may receive, either by fwallowing the hook baited to catch it, and which, being broken off and remaining in the ftomach, may caufe an exulceration; or by devouring fome fubftance which it cannot digeft, are not to be deemed difeafes, but accidents. Now, terreftrial animals, through great fatigue, heat, cold, hunger or thirft, may eafily fall into diftempers and die, but to thofe accidents Fifhes are feldom or never fubject.

Firft, as to fatigue, this in Fifhes cannot be great, becaufe their chief exercife confiftsin the larger purfuing the fmaller, in queft of them for food; or in the flight of the fmaller ones from the larger; and in thefe exertions the fine juices of their blood can in no degree, or at leaft but very little, be exhaufted; becaufe in fuch kind of purfuit or flight, no evaporation can be produced from their bodies through heat or drynefs; befides, they never want for drink, by which means their blood, and the other juices of their bodies are kept continually diluted, fo that the circulation is conftantly preferved.

No one can pretend to fay that a Fifh is ever killed by heat, for many kinds of fifh, in the middle of fummer, and in the burning heat of the fun, do either play, as it were, on the furface of the water; or hide themfelves under the leaves, weeds, or other fubftances at the bottom.

As to cold, we do not know that Fifh in deep waters ever perifh with cold; but we know by experience, that at fuch feafons they feek the bottom of the water.

As to food, they are not eafily killed by hunger; many Fifhes live for five or fix months fpace without any other fupport than what they receive from the water, or rather from the fmall particles in it, which are by us commonly confidered as part of the water only; in fuch a fituation indeed, they increafe little or nothing in fize, but rather if they were before fat and plump, they will fall away.

I am alſo perſuaded, that all Fiſhes which have a conſtant ſupply of food, do daily increaſe in ſize, and this without ever ceaſing to grow, ſo that any real definite ſize cannot be aſſigned to them, as it can to terreſtrial animals, ſome of which arrive ſooner, and others later, to their full and perfect ſtature, which they never afterwards exceed, although they continue to live many years. The reaſon of which, I am convinced is this, that terreſtrial animals continue growing as long as their nutritive juices have force ſufficient to protrude or thruſt themſelves through the cavities of the bones, and ſo to increaſe the ſize of them, as well in length as in thickneſs. But when the bones of theſe animals, by being expoſed to the air, are become ſo rigid and hard, that they cannot be any more diſtended, their farther growth muſt neceſſarily ceaſe, and any freſh ſupplies of nutritive juices can only tend to increaſe the animal's fatneſs. But the bones of Fiſhes are for the moſt part deſtitute of marrow, and they cannot be rendered rigid by expoſure to the air, conſequently the very ſmall tubuli or pipes of which they are compoſed, are exceedingly ſoft in compariſon with thoſe of other animals. All which conſidered, there ſeems no reaſon to exiſt, why the bones of Fiſhes ſhould not continue always growing, ſo long as the animals do not want for food.

In the lakes with us, where are many Fiſheries, Pike have been caught of the length of 56 inches, and 36 or 38 pounds weight. Pearch alſo 28 inches long; and who can tell to what ſize theſe Fiſhes might have arrived, if they could have longer eſcaped the nets?

The Author's refutation of the doctrine of equivocal or ſpontaneous generation in the inſtance of the Sea-Muſcle, with a particular deſcription of that ſpecies of Fiſh.

I HAVE been informed, that a book is publiſhed at Rome, by a learned Jeſuit, named Philippo Bonanni, wherein he maintains, that animalcules, or ſmall living creatures, can be produced out of inanimate ſubſtances, ſuch as mud or ſand, by ſpontaneous generation, according to the doctrine of Ariſtotle; and it ſeems that this learned gentleman is himſelf very deſirous to ſee my obſervations on the ſubject. I ſhall therefore proceed to conſider Signor Bonanni's poſitions, and I doubt not, that upon inveſtigation, they will be found of no weight or ſubſtance, but will vaniſh like ſmoke or vapour.

We will admit, that out of the mud or ſand which is found on the ſea-ſhore, or the beds of our rivers, at low water, ſhell-fiſh or teſtaceous animals come forth; but it does not from thence by any means follow, that they are produced without any regular courſe of generation.

Among the mud, in the creeks or ſhallows of our ſea-coaſts, are taken great quantities of that ſhell-fiſh, called Muſcles, which are uſed by us as an article of food; and, as I had in the autumn been employing myſelf in obſervations upon this ſpecies of fiſh, I applied to a fiſherman who made it his buſineſs to catch Muſcles, and queſtioned him as to what his opinion was, with regard to the propagation of that fiſh.

This fiſherman, who was a very intelligent man, and of good eſtimation in his profeſſion, and had been brought up to it from his youth, informed me, that he had often experienced, that in the ſame tract of coaſt where he had found for ſeveral years ſucceſſively very good Muſcles, and in great abundance, yet afterwards in or about the ſame place, very few or none were to be got; for which he aſſigned theſe reaſons:

"At the time of the Muſcles laying their eggs or ſpawn, which laſts but for a ſhort ſeaſon, this ſpawn, by ſtrong tides and heavy gales of wind, will be carried from the places where it is depoſited, and when the water becomes ſtill and calm, it will ſink to the bottom, or adhere to the weeds growing there; and then in the ſpace of two or three years, a good and plenteous Muſcle-bank will be formed in the place; adding, that by this means Muſcles are taken where none were ever found before, and Muſcle-banks formed of very great extent, the ſpawn laid by the Muſcles being in ſuch abundance, as to make the ſea-water appear of a white colour."

If then, at the ſeaſon when the Muſcles depoſit their eggs or ſpawn, we take up a quantity of the mud or ſandy matter from the ſhore, and keep it covered with water, we need not wonder if we find Muſcles or other ſhell-fiſh produced from thence; but if we imagine that this comes to paſs by any other means than the ordinary courſe of generation, we ſhall therein deceive ourſelves. And for my part, I hold it equally impoſſible for a ſmall ſhell-fiſh to be produced without generation, as for a whale to have its origin from the mud.

The eggs or ſpawn of Muſcles, and other ſhell-fiſh, being carried along with the ſea-water to the ſides of ſhips lying in harbours, will adhere to them, and become ſhell-fiſh, by which means thoſe ſhips in their voyages to other countries, will introduce ſuch kinds of ſhell-fiſh as were before unknown in thoſe parts.

But how can it be conceived that living creatures can proceed from ſand, or obtain any nouriſhment from thence? for there is no other difference between the grains of ſand, and the beach-ſtones on the ſea-ſhore, than that the one are larger than the others; and, as incapable as glaſs is of affording ſupport to any living creature, ſo is it impoſſible for any nouriſhment to be found in ſand.

If it were poſſible for the mere ſand on the ſhore to produce ſhell-fiſh, how much would our coaſts abound with them, and not with them only, but alſo with all other ſorts of fiſh; for the flat-fiſh feed on theſe ſmall ſhell-fiſh, and thereby become very fat and good; and ſo does alſo the whiting.

The chief reaſon, in my opinion, why we do not find ſhell-fiſh in equal plenty, at all times, is, that the ſtrong north-weſt winds blowing directly on our coaſt, do ſo ſtir up the ſand and muddy bottom on the ſhore, that the ſhell-fiſh are thereby overwhelmed and buried, and ſo periſh.

During the laſt five or ſix years, we have not had any great ſtorms from that quarter, and we have for theſe laſt three or four years ſucceſſively, had ſuch excellent flat-fiſh, eſpecially flounders, that no one remembers to have ſeen the like; the reaſon for which I have already aſſigned, namely, that the ſhell-fiſh during that ſpace of time, multiplied exceedingly, affording plenty of food for fattening the flat-fiſhes. And this is alſo proved by experience; for whenever flounders are in perfection, their ſtomachs and bowels are found to be full of fragments of ſmall ſhells. And, upon reflecting with myſelf as to the cauſe of theſe ſmall ſhells being ſo broken into fragments, I could not aſſign any other reaſon than the following:

The flounder, ſole, turbot, and other flat-fiſh, are formed by nature with their mouths diſtorted and in a different poſition from that of moſt other fiſhes; and this formation ſeems to be, for enabling them to pick up their food from the bottom of the ſea, and not to go in chafe of other fifh ; and I conceive that thefe flat-fifh, when picking up the fmall fhell-fifh, do break their fhells to pieces in their mouths (which feem to me to be formed principally for that purpofe) and then fwallow them, rejecting thofe fhells which are too hard for them to break, for which reafon we never find any very hard or large pieces of fhells in their ftomachs ; and it is not in the power of the flat-fifh to feparate thefe fmaller ones from their fhells, becaufe they are all, as far as I have ever obferved, clofely united to them by ligaments or tendons, and always keep their fhells clofely fhut.

I have enquired of thofe Fifhermen, whom I thought men of reflection, what could be the reafon why fome years ago our flounders were very indifferent, and for thefe laft three or four years fo exceeding good ; for which they could not affign to me any reafon ; but when I laid before them my fentiments refpecting thefe fifh being fattened by feeding on the fmall fhell-fifh, they were furprifed thereat, and added, that this might very probably be the cafe. But upon converfing with two principal merchants who fend out fifhing-veffels, they not only agreed with me in my opinion, as before related, but alfo in the following, namely, that not only the flat-fifh feed fo much on the fmall fhell-fifh, but the whiting is fo abundantly nourifhed by them, that in the fummer-time its flefh becomes hard and tough ; for this reafon, at the time when the fhell-fifh abound on our fhores, the whiting reforts thither in queft of them, and this latter is followed by the cod-fifh, which preys on the whiting. In fhort, I conclude that the plenty of fifh found on our coaft, proceeds from this caufe only, the great quantities of fhell-fifh which every year breed there.

Towards the end of the month of February, being the firft time in the fpring that Mufcles were brought to our city for fale, I caufed fome of them to be bought, in order to make my obfervations thereon : I found thefe to be very lean, and for a long time my fearch after their fpawn was fruitlefs, though I could not think that the time was paft for their depofiting it.

Upon examining that part of the Mufcle which is called the beard, I not only found it of a wonderful make, but the motion I faw in the fmall component parts of it was fo incredibly great, that I could not be fatisfied with the fpectacle ; and it is not in the mind of man to conceive all the motions which I beheld within the compafs of a grain of fand.

When I obferved the large and ftrong tendons or finews in the Mufcle, which are fixed to the fhell, and thofe which lie in the fame order and pofition as the ribs in a terreftial animal, I thought that we cannot fufficiently admire the wonderful make of this fifh ; and that if we could obtain an infight into all thofe parts which we fee in one of them, and could we affign their feveral ufes, and give them names, and alfo make drawings of them, I doubt not that we fhould admire fo elaborate and curious a work, beyond many others of nature's productions ; and that thofe perfons who now affert that fhell-fifhes (among which the Mufcle is in leaft eftimation) are produced fpontaneoufly, or of themfelves, would renounce their opinions, and embrace the truth, namely, that fo perfect a creature cannot be produced from corruption, congealed water, or mud, but can only be generated by parents of its own fpecies.

I obferved that every Mufcle was provided with a kind of ftring or ligament, which, at a little diftance from the fifh, was divided into 8, 10, 12, 15, and even 20 other ligaments of different lengths ; and with thefe ligaments, I obferved, that the Mufcles faftened themfelves to other Mufcles, and alfo to pieces of fhells, and to fhell-fifh of other fpecies.

I was defirous to know how this faftening was effected, and which I immediately difcovered ; for I faw, to my great furprife, that the extremity of every ligament was provided with a thin flat membrane or ſkin, of a roundiſh ſhape, which was as firmly fixed to the ſhell on which it was placed (the ligament being in the middle of it,) as if it were glued to the ſhell; and when I endeavoured to pull off the ligament, I found, by ſeveral trials, that (though it was very ſtrong and tough, in proportion to its ſize) it would break before the flat thin membrane could be looſened.

Hereupon I recollected, that when a boy, I had often amuſed myſelf with a play-thing which we called * "een Treck-leertje." This is a ſmall round piece of leather, about two inches in diameter, having a ſmall hole in the middle, through which was drawn a packthread, with a knot at the end. This leather being firſt ſoaked in water, was placed flat on a ſtone, and with this we could not only lift up the ſtone, but carry it to ſome diſtance.

Now, upon the ſame principle as the ſtone adheres to the leather, partly by the preſſure of the atmoſphere, and partly becauſe no air or water can gain admittance between the ſtone and the leather, the like effect is produced in the coheſion or ſticking of the membrane I have been deſcribing.

I have thought it proper to give a drawing of the ligament before-mentioned, and its ſeveral branches; and in Plate III. *fig*. 8, is ſhewn a part of it, which is cut off at A in the part which comes out of the ſhell; this in *fig*. 7, is ſhewn at B E of its natural ſize. In *fig*. 8, F G H I K are ſeen the ramifications or branches, or rather a ſmall part of them; and at L M is ſhewn one of the ſhort ligaments, with its membrane N O P, the ligament here appears on the upper ſide of the membrane, in like manner as if the latter was fixed to ſome other ſhell; and here are to be ſeen the many parts whereby the ligament is joined to the membrane, which latter alſo appears ſomewhat elevated at the place of joining.

* That is, in Engliſh, a pulling, or drawing-leather; it is a common play-thing among boys in England, and is called by them a ſucker.

At Q R is reprefented another ligament, and at S T V its membrane, with the concave part of it, appearing open, being in a contrary pofition to the former reprefentation. I have often feen this cavity reach into the ligament as far as M or R, but otherwife it is quite clofe and compact.

Each of thefe ligaments confifts of a great number of exceffively fmall particles, which cannot be contemplated without the greateft admiration, efpecially when we recollect the power which the Mufcle has of moving each of thefe ligaments, and alfo that the membrane muft be placed quite fmooth and flat upon the fhell, to which it is fixed, in order to caufe it firmly to adhere thereto.

Now, if we farther confider that Mufcles, while in the fea, always lie with that fhell upwards which they open occafionally, and that their fhells (which are very thin) and their bodies together are but little heavier than the water wherein they live, and alfo that many of them at low ebb-tides are left deftitute of water, at which times, in my opinion, much air muft infinuate itfelf between their fhells, by which means they become lighter than the water; they would then be liable either with the ebb to be carried out into the deep, or by the flood to be thrown upon the land, and fo would perifh. But provident Nature has taken care to preferve them in this refpect, by furnifhing them with a ligament, fpreading into various branches, and at the end of each branch an organ, which I have named a membrane, by the help of which the Mufcles can fix themfelves either to empty fhells, or other fubftances, or to one another, by which means they are preferved.

But as my principal defign was to difcover, as far as poffible, the generation, or procreation, of thefe fifh, I come now to that part of the fubject.

I obferved, that thefe Mufcles, fome in a greater, and others in a lefs degree, had the outfides of their fhells covered with a kind of fubftance, thinly fpread upon the fhell, and firmly adhering to it, or rather to the membrane which covered it. Obferving this by the microfcope, I faw that the particles of which it confifted, were all of a fimilar form, and alfo placed fide by fide, in regular order, and the membranes or fkins of thefe particles, as it were, united, or clofely joined together. I feparated a part of this fubftance from the fhell, and placing it before the microfcope, I found that all the regularly difpofed particles were much longer than they were broad, alfo that one of their edges was roundifh and thick, the other terminating in a point or edge, and moreover that in many of them one fide was rifing, and the other flat; in a word, many of thefe particles, in fhape, were very like a Mufcle; and I not only thought that they were the eggs or fpawn of the Mufcle, but I alfo obferved, that when I broke the ftrong membranes inclofing them, feveral of the eggs, which were in fhape like a Mufcle, appeared lying fingly and feparately on the outfide of that membrane; and when I feparated thefe unformed Mufcles fingly, one from another, I imagined that I could fee the membranes or tendons of which they were compofed.

I alfo faw the fhells, membranes, or coverings of feveral eggs which were empty, and which I faw, or more properly fpeaking, imagined to be barren eggs. In other parts of this fubftance I faw eggs wherein I concluded that there were unformed Mufcles, which conclufion I gathered from the multitude of veffels which I faw, which veffels conftituted the fhape or figure of a Mufcle.

Thefe eggs were not larger than a grain of common fcoweringfand.

Moreover, I obferved, that the fmall or taper ends of the fhells were feldom or never covered with the fpawn or eggs, the reafon of which I took to be, that at the time the Mufcles emit their fpawn, they lie with the flat and broad part, as fhewn at *fig.* 7, A B C D, uppermoft, and that part marked with the letter A, next the ground, or bottom; for I have often obferved, that when Mufcles have been cleaned and put into a veſſel of water, and an handful of ſalt thrown upon them, many will be ſoon found placed in the poſition I have mentioned; and while they lie in this poſition, and the eggs are put forth from the part marked C D, there muſt neceſſarily be more eggs lodged near that ſpot, than towards the farther end of the ſhell.

Several of theſe Muſcles I placed in my ſtudy, in two glaſſes of water, with ſome ſalt ſprinkled on them, in order to examine them daily, and ſee the progreſs of growth in the young ones; and upon this occaſion, I could not ſufficiently admire the exact and regular order in which the eggs were in many places diſpoſed, juſt as if they had been ſo placed by men's hands; and from hence I was convinced that Muſcles do not, like many other fiſhes, lay their eggs promiſcuouſly, but that they muſt be furniſhed with ſome kind of organ, which they can project beyond the ſhell, and with it diſpoſe them ſo regularly.

I have before ſaid, that I thought I ſaw a kind of ſinews or tendons in the eggs; and upon further examination, I perceived ſixteen of theſe tendons, like ſtreaks, in the unformed Muſcle, and among them I ſaw ſome ſtill ſmaller ſtreaks, from whence I concluded, that they were in fact, veſſels to form the ſubſtance of the future ſhell, for they lay all in one direction, that is, from the ſmall end, ſpreading or diverging round about; and they were thickeſt at that part, and thinneſt at the extremities, ſpreading wider towards the broad and thin end of the ſhell: I cauſed a drawing to be made of a few of the eggs, in the order they lay on the parent ſhell, and as they appeared through the microſcope; this is ſhewn at *fig.* 9, A B C D E, repreſenting eight of them, in ſome of which it may be ſeen that one ſide is more curved than the other, and in which eggs may alſo be ſeen the ſinews, veſſels, or ſtreaks I have mentioned.

Upon conſidering that the lobſter and the ſhrimp carry their eggs about them until the young are perfectly formed, it ſeems probable to me, that this is alfo the cafe with the Mufcle, for otherwife, how could this fpecies of fifh be propagated? efpecially if we confider that they lay their eggs in the middle of winter, and are generally in fhallow waters, where the fhore is muddy; and if the eggs were not depofited on the fhells, they would be buried in the mud, with the common flux and reflux of the tide; not to mention that in ftormy weather they would be carried out to fea; but while they are fixed to the fhells of the parent, and thefe laft adhering to folid fubftances on the fhore, the eggs are, by this means, in great numbers, preferved; and thefe young Mufcles, when come to fuch maturity as to be feparated from the fhells, may, in windy weather, ftrong tides or currents, be eafily carried to other muddy fhores on the coaft, in places where for many years before no Mufcles were to be found.

I have made a rough calculation of the numbers of thefe eggs, and I compute that there are frequently more than two thoufand fixed to the fhell of one Mufcle; in fact, I have feen Mufcles, each of which I judged had more than three thoufand on it.

I have before faid, that the eggs of Mufcles are the fize of common fcowering-fand, but as this is not of the fame fize in all countries, I compute that, to the beft of my judgment, feven of thefe eggs, in breadth, are equal to the fifteenth part of an inch, confequently the breadth of 105 eggs, is equal to one inch; and I alfo compute, that fixty eggs, in length, make an inch; therefore a fquare inch will contain 6300; and as each egg is no thicker than broad, 105 of them muft lie one on another to make the thicknefs of an inch; the fum total then of the eggs which will be contained within the fpace of a cubic inch, is 661,500; and hundreds of fuch eggs may lie under fhells, fand, or mud, without being perceived, and yet Mufcles be produced from them.

Having taken fome of the unformed Mufcles out of the eggs, I caufed a drawing to be made of their figure, as near as the Engraver was able to imitate it; this is fhewn at *fig.* 10, F G, which repreſents ſuch an unformed Muſcle, incloſed in its membrane, or covering, in which the ſtreaks before-mentioned, did not appear, until the greateſt part of the moiſture thereof, was evaporated. *Fig.* 11, H I K, ſhews another of them, the ſtreaks, or veſſels in which, between I and K, appear ſeparated, or ſundered from each other; and this was done in the taking it out of the egg, being in that operation deprived of the ſurrounding membrane, or ſkin.

At the latter end of April, when I had finiſhed the preceding obſervations, I received a large jar full of Muſcles out of Zealand; upon examination of which, I was much ſurpriſed to ſee that moſt of the ſhells were quite ſmooth and poliſhed, being not only deſtitute of eggs, but for the moſt part, bare of the membrane, which gives them a blackiſh colour, ſo that they now appeared of a lively blue; however, I found four or five with perfect eggs on them, and in them were young Muſcles; ſome of theſe I took out of the eggs, and now plainly ſaw, that what I had at firſt taken for the unformed Muſcle, was, in fact, only the ligament, or ſtring, whereby the young Muſcle was nouriſhed. A drawing of the real ſhape, as it now appeared to me, is given at *fig.* 12, where G H I repreſents the ligaments of the unformed young Muſcle, and I K the Muſcle itſelf; another of them is repreſented at *fig.* 13, where L M ſhews the ſtrings or ligaments, and M N the Muſcle; and this laſt figure, I think, exhibits the true form of the young Muſcle, as it lies in the egg; and, from theſe laſt obſervations it appears, that the parts repreſented in *fig.* 10, at G, and in *fig.* 11, at H, were only the ſubſtance, or matter, from whence the Muſcle would be formed, and which, at the time when that drawing was made, had not come to ſufficient perfection to render the parts diſtinguiſhable.

Now, ſince we ſee, that the eggs of Muſcles adhere ſo long to the ſhells of the parent, before they are perfectly formed, and alſo conſider that during all that time they muſt be ſupplied with nouriſhment, we ſhall not wonder that the parent Muſcles, during that time, do become lean, efpecially in the month of April, for then the young are moft in need of fuftenance.

We may alfo here obferve, that in our enquiries after any truth, and more efpecially in regard to the generation of fmall living creatures, which cannot be examined by the naked eye, we ought not to rely on any tales that are told on thefe fubjects, but on our own experience, and even that not lightly, but by long and unwearied trials and experiments, whereby to come at the truth.

In the courfe of the laft obfervations, I examined that hard and variegated, or marbly-coloured part, lying in the middle of the Mufcle, which fome call the heart, and others take to be the tongue of this fifh; and when, upon opening the Mufcle, I cut out this part, and placed it before the microfcope, I obferved fo tremulous or quivering a motion in the furface, as if millions of little living creatures were running about upon it; befides another motion, which the part had to and fro. This part, the Mufcle can extend fo far, that I think it will almoft reach all over the fhell, which made me think that, perhaps, by this organ, the eggs are placed on the fhell in the regular order I have before defcribed.

Of the Muſcle which is found in freſh water; a particular deſcription of its internal formation, and of the manner in which its young are produced.

I HAVE obſerved, that when our navigable canals here in Holland, or our ditches are cleaned, a kind of large fiſh are taken from the bottom, named by us, "*Veen Moſſelen," or Peat Muſcles. Of theſe I procured ſome, which were about three or four inches long, with very thin ſhells.

A countryman, whom I ſaw collecting theſe ſhell-fiſh, told me they were to be found under the banks, and in the ſhallow parts of the ditches, or canals, among the leaves and twigs, or other litter; and, indeed, I have ſeen them taken in thoſe places; but as I was certain that theſe ſhallow places were frozen to the bottom in the winter, which the ſhell-fiſh could not ſurvive, I was told that they had a power of moving from place to place.

To ſatisfy myſelf, in this reſpect, I made two experiments on theſe Muſcles, of which I put ſix or eight into an earthen veſſel, with a flat bottom, and poured on them ſome of the ſame water in which they were taken; this veſſel I placed in my ſtudy, and I found that in a few hours time, they had all changed their poſitions, and had approached nearer together, than they were when firſt placed in the veſſel:

* This word, "Veen," means the Turf or Peat, which is dug up in great quantities in Holland, and is their principal article of fuel. Our author has a very ingenious diſſertation on the origin of this ſubſtance, a tranſlation of which will be found in its place.— Theſe freſh water Muſcles are found in the rivers in England.

And I obferved, that thefe Mufcles, about the middle of their fhells, thruft out, through the opening, a flefhy fubftance, or organ, about two-third parts the length of the fhell; this part was about half an inch broad, and fharp at the end; and in order to move themfelves from place to place, they thruft this organ under their fhell, and applying it with a quick motion to the bottom of the place where they lay, could by this means not only change their pofture, but turn themfelves upfide down.

At the end of the month of Auguft, upon opening fix of thefe Mufcles, I found many eggs within them, which were fo perfect, that I could diftinguifh the newly formed fhells, fo that they were not fo properly to be named eggs as unborn Peat-Mufcles. Two of the parent Mufcles were fo fmall, that I judged they were not above a year old, whereas the others were, in my opinion, fix, eight, or nine years old; but the young Mufcles were of the fame fize in all of them.

In the beginning of September, I procured about fifty more of thefe Mufcles, and upon opening twelve of them, I found two, wherein the young ones feemed to be fo perfect, that they would probably foon be excluded from the parent. I always found that the eggs were firft formed in the flefhy part of the Mufcle, but as they advanced in growth, they were moved to that part which, in oyfters, is called the beard, and which, by the great number of the young Mufcles contained therein, then fwells in bulk.

As there are many perfons who are unacquainted with this fpecies of Mufcle, and others who may wifh to inveftigate the particulars of my obfervations, I have caufed the following drawings to be made:

Fig. 14. G H I K L, fhews one of thefe frefh-water, or, as I call them, Peat-Mufcles, of the ordinary fize, which is opened fo as to leave the whole of the fifh lying in one of the fhells; at H I K, is reprefented the empty fhell, and at M M, the two tendons, or finews, by the help of which the fifh fhuts and opens the fhell; and here it is to be noted, that thefe fifhes, by reafon of the length of their fhells, are each provided with two of thofe tendons, or finews, whereas oyfters and falt-water Mufcles have only one. N O P is a thin membrane, or fkin, lying folded up, with which the whole infide of the empty fhell had been covered, or lined

Q R S is one of the two receptacles wherein the eggs, as they advance to maturity, are lodged, and which parts do then become fwollen thereby, but at other times they are very thin; thefe parts, in oyfters, are called the beard; T V is the other of thefe receptacles, which, in oyfters, is alfo called the beard; and in thefe receptacles, I did not obferve any thing particularly remarkable, except their wonderful make.

W X Y is a folid flefhy part, wrinkled on the outer edge, and in refpect of the other parts of the fifh, very ftrong; this part, as I have already mentioned, the Mufcle protrudes, or thrufts out of its fhell, to a confiderable length, when it prepares to change its place; and when at reft, it generally has a fmall portion projecting out of the fhell; but if it be touched, though very lightly, it immediately withdraws it. The fpot marked with the letter Y, is the place where the eggs lie before they are depofited in what we call the beard; and if an incifion be made in this part, the eggs, with a watery liquor, iffue forth.

Some of thefe Mufcles I opened in the prefence of the Engraver, in order, that as foon as I had taken fome of the young ones out of their receptacle, he might make a drawing of them, for, were they fuffered to ftand but a few hours, their true figure would be loft. The unborn Mufcles being put into a glafs tube, and placed before the microfcope, I faw with aftonifhment a moft pleafing fpectacle, for every one of them, each in its particular membrane or covering had a flow circumvolution, and that not for a fhort fpace of time, but fuch turning round or rotatory motion was obfervable for three hours afterwards, and it was the more curious, becaufe the young Mufcles, during the whole of their motion, conftantly kept in the centre of their membranes, juſt as if one were to ſee a ſphere or globe revolving upon its axis. This uncommonly pleaſing ſpectacle was enjoyed by myſelf, my daughter, and the Engraver for three whole hours, and we thought it one of the moſt delightful that could be exhibited.

Fig. 15. A B C D E exhibits ſix of theſe unborn Muſcles incloſed in their reſpective membranes; they were drawn by the Engraver in the moſt accurate manner he could, while they were in motion. Of theſe, I computed that each parent Muſcle contained ſome thouſands.

I had at the ſame time ſome unborn Oyſters before a microſcope which I had taken out of the parent Oyſter five weeks before, and as they ſtill appeared perfect in ſhape, I cauſed a drawing to be made of them alſo, and this is ſhewn at *fig.* 16, F G H I. In ſome of theſe the openings of their ſhells were plainly to be diſcerned.

Theſe young Oyſters bore the moſt exact reſemblance to full grown ones, though they were ſo minute that one hundred of them laid together would not equal an inch in length, and I have computed that each parent Oyſter contained three or four thouſand of them.

On the Circulation of the Blood; that it is not difcoverable by the fight, in an human body, nor in the bodies of terreftrial animals: the fame completely feen in fifhes, and the nature of it particularly defcribed.

THE Blood is compofed of exceeding fmall particles, named, globules,* which, in moft animals, are of a red † colour, fwimming in a liquor, called, by phyficians, the ferum; and by means of thefe globules the motion of the Blood becomes vifible, which otherwife would not be difcoverable by the fight. Thefe particles, or globules, are fo minute, that one hundred of them, placed fide by fide, would not equal the diameter of a common grain of fand; confequently, a grain of fand is above a million times the fize of one fuch globule.

I have often endeavoured to view the circulation of the blood in terreftrial animals, but without fuccefs, by reafon that no parts of their bodies were fufficiently tranfparent. Among others, I tried the experiment with a young Cock; which I wrapped in a cloth, in order to keep him quiet, leaving out only his head; and infpected his comb, but could not therein perceive the motion of the Blood:

* Later writers contend, that the particles of Blood are not fpherical, as this word imports, but plane, or of a flat fhape; and this Mr. Leeuwenhoek admits to be true with regard to fifhes. However, the word globules is always ufed to denote the component particles of the circulating fluid.

† In fome fifhes the Blood is not of a red colour, and alfo in many infects, which have been therefore improperly denominated exfangues, or bloodlefs.

I afterwards examined his gills, or thofe parts hanging under the throat, and there I faw it running in an inconceivable number of veffels; many of which were fo minute, that numbers of them taken together would not equal the fize of a fingle hair: but it was impoffible for me to trace the circulation in them, by reafon of their immenfe number, croffing each other in all directions: for the rednefs which we obferve in a cock's comb and gills, proceeds entirely from the great number of blood-veffels on their furface, where they are only covered with a thin tranfparent fkin.

After this, I made my obfervations on white Rabbits, by placing their ears before the microfcope; but, with all my pains, I could not do more than fee the Blood running with great fwiftnefs through the arteries and veins. When I plucked off the fhort hairs from the extremities of the ears, becaufe they obftructed my fight, I obferved, that the pulling off each hair had broken or injured feveral of the veffels, and caufed an effufion of blood. From hence I gathered the reafon, why I had perceived that the pulling out any hairs from the back of my hand produced a rednefs in the part; and I now concluded, that we cannot pull out a fingle hair from any part of our bodies, while fuch hair is growing, without injuring fome veffels, fo as to caufe the Blood to ftart.

But my greateft expectation of fuccefs, was placed on a Bat, becaufe I conceived that the membrane, or fkin, which ferves this animal for wings, muft be fo thin and tranfparent, as to afford a view of the veffels. And, having procured one of thefe creatures, I put it into a glafs and examined it by the microfcope. Here I faw the motion of the Blood, both in the arteries and viens, moft diftinctly, and fully to my fatisfaction, though by no means fo clearly as is to be feen in fifhes; firft, becaufe the membrane compofing the bat's wing, is not fo tranfparent; fecondly, becaufe there is more of the watery part (or ferum, as it is called) in the Blood of fifhes than in terreftrial animals; and thirdly, becaufe the particles of blood from which its rednefs proceeds, appear much larger in fifhes, they being of a flat and oval fhape; whereas, on the contrary, as far as I could judge from my eye, they, in this animal were fpherical. I ufed every means I could devife to fee the compleat circulation of the blood, namely, that one of the fmalleft of thofe veffels which we call veins, arofe from another which is called an artery, and afterwards conveyed its contents into a larger vein; but this I found to be impoffible, for when I followed the courfe of the artery, until it became fo fmall as only to admit one or two globules to pafs through it at a time, I then loft fight of it. If this artery, throughout its circuit, had not been fmaller than the twenty-fifth part of an hair, I do not doubt that I could have feen the whole circulation; but as thefe veffels were at their extremities diminifhed to a much lefs fize, and the membrane of the wing was covered with a kind of fcales, I could not (as I have before faid) follow with my eye thofe minute ramifications. I perceived, however, in many places, an artery and a vein, placed clofe befide each other, and of a fize large enough to admit the paffage of ten or twelve globules of blood at the fame time; and in this artery the blood was protruded or driven forward with great fwiftnefs, and flowed back through the vein, which was a moft pleafing fpectacle to behold.

I could alfo moft plainly perceive in the arteries, the rifing, or pulfation, caufed by the motion which the blood receives from the heart; thefe pulfations were fo rapid that I judged feven ftrokes were performed in a fecond of time.

The worm, or fmall animal which is produced from the fpawn of frogs, and is called a tapdole, afforded me a ftill more diftinct view of this fubject; for, upon placing one of them, which was newly hatched, before the microfcope, I could diftinctly perceive the whole circuit of the blood, in its paffage to the extremities of the veffels, and in its return towards the heart. But I muft here obferve, (as before mentioned) that if this blood had been an uniformly clear liquor, its motion could not by any means have been difcovered; but as it confifted of a very tranfparent fluid, mixed, as it feemed, with globules of different fizes, which were plainly to be diftinguifhed, though they had not, as yet, in this creature acquired any colour, the circulation was thereby rendered very apparent.

When thefe tadpoles were about eight or ten days old, I could perceive a fmall particle moving within their bodies, which I concluded to be the heart; and the fluid which was protruded from it began to affume a red colour.

Upon examining the tail of this creature, a fight prefented itfelf, more delightful than any that my eyes had ever beheld; for here I difcovered more than fifty circulations of the blood, in different places, while the animal lay quiet in the water, and I could bring it before the microfcope to my wifh. For I faw, not only that the blood in many places was conveyed through exceedingly minute veffels, from the middle of the tail towards the edges, but that each of thefe veffels had a curve, or turning, and carried the blood back towards the middle of the tail, in order to be again conveyed to the heart. Hereby it plainly appeared to me, that the blood-veffels I now faw in this animal, and which bear the names of arteries and veins, are, in fact, one and the fame, that is to fay, that they are properly termed arteries fo long as they convey the blood to the fartheft extremities of its veffels, and veins when they bring it back towards the heart. For example, I fee many blood-veffels in the tail of a tadpole taking their courfe, as reprefented in Plate IV. *fig.* 1. ABC, where the pofition of the parts A and C is towards the fpine or middle of the tail, and the part B towards the edge of it. In A B, the blood is driven from the heart, and in B C, it is brought back again, and thus may we fay, that the veffel A B C, is both an artery and a vein, for it cannot be denominated an artery, farther than where the blood is driven in it to its fartheſt extent, that is, from A to B; and we muſt name B C, a vein, becauſe, in it, the blood is returning back to the heart. And thus it appears, that an artery and a vein are one and the ſame veſſel prolonged or extended.

In the part where I ſaw this circulation, the arteries were no larger than to admit a ſingle particle of blood to paſs freely through them: theſe particles, though in this creature they were of a flat and oval ſhape, yet ſometimes by reaſon of the ſmallneſs of the artery, aſſumed a kind of oblong round figure, and when the animal, by being taken out of the water, grew languid, the blood in theſe very minute arteries began to ſtagnate, and when it again acquired motion, many of the globules appeared twice as long as broad, and alſo pointed at their extremities.

In another place, I ſaw a larger artery divide itſelf into two branches, which are ſhewn at *fig.* 2. D E, and each of theſe branches returned back with a curve, as repreſented at E F and E G. Now, if we denominate D E F, and D E G, arteries, becauſe, in them the blood is driven outwards from the heart, it follows that F H, and G I K, muſt be veins, becauſe they each bring it back towards the heart. Again, not far from K, was another ſmaller artery, which is figured at M L; this was united to the vein I K, ſo that the arteries D E G, and M L, together formed one vein at I K. In a word, in this figure, H F is a vein, D E F and D E G, are arteries; G I K and K I L, are veins, and M L is an artery; and yet we muſt ſay, that theſe are only the ſame veſſels continued.

In another place I ſaw three of the ſmalleſt arteries, after returning in a curve, as before deſcribed, unite in one, and thus form a vein three times the ſize of each artery. But all theſe three veſſels with their bendings wherein the circulation was performed did not occupy more ſpace, than could be covered by a grain of ſand.

I often perceived an artery, taking its courſe over, or croſſing a vein, and, if a perſon did not clearly ſee the different courſes of the veſſels, he might conclude that here the circulation was performed or compleated, and this I ſaw not only in the ſmalleſt veſſels, but in thoſe which were ten times larger. This tranſverſe courſe, or current of the veſſels, I had often before obſerved in terreſtrial animals, whilſt I was endeavouring to diſcover the conjunction of their arteries and veins. But, as I became then well aſſured, that this conjunction, or circulation, did not take place in the larger veſſels, but in the very ſmalleſt of all, (for otherwiſe I am perſuaded, that all the parts of the body could not be ſupplied with nouriſhment) and that therefore I ſhould in vain attempt to diſcover ſuch circulation, I, ſome years ago, abandoned the farther inveſtigation of it. For, if we now plainly perceive, that the paſſage of the blood from the arteries into the veins of the tadpole, is not performed in any other than thoſe veſſels, which are ſo minute as only to admit the paſſage of a ſingle globule at a time, we may conclude that the ſame is performed in like manner in our own bodies, and in thoſe of other animals. And if ſo, it muſt be impoſſible for us ever to diſcover the paſſage from the arteries into the veins in the human body, or of any terreſtrial ani-animal; firſt, becauſe a ſingle globule, when lying in one of thoſe minute arteries, has not any viſible colour, and ſecondly, becauſe, in thoſe veſſels which are ſo large as to come within our ſight, the blood has not any perceptible motion.

The particles in the blood of frogs are (as before obſerved) of a flat and oval ſhape, and theſe, when viewed ſingly, appear, as I may ſay, colourleſs; but when two are laid on one another, they appear a little of a reddiſh caſt; and where three are together, the redneſs becomes deeper. This may be explained by *fig.* 3. wherein A repreſents one of theſe oval particles, which, in part, is covered by another particle B; and C is a third particle, covering a ſmall part of both A and B; by which means the part at D, where the particles are three-fold, acquires a ſtill darker colour. But when

I have attentively examined one of thefe oval particles on the edge, as is feen at E, I have found it exhibit a ftronger blood-red than where three particles lay flat one on another.

Among the tadpoles, which I caufed to be taken out of the canals, I perceived a few very fmall fifhes, having their fkins marked with dark fpots, fome of which were of the figures of little ftars. This fpecies of fifh I judged to be of its full fize, becaufe I had never feen any by the naked eye of the fame fhape as thefe appeared when magnified. One of them I placed before the microfcope, and, upon obferving the finny part which conftitutes the extremity of the tail, I plainly faw the fame kind of flender arteries and veins as I have before defcribed, though with more difficulty than in the tadpole, partly, becaufe this fifh did not long continue quiet, and partly becaufe the particles of Blood (which, in thefe obfervations appeared to me no other than globules) were much fmaller than in the tadpole. Thefe arteries and veins were placed near the boney parts, or rifings, which give ftrength to the fin at the tail, and in them I faw the compleat circulation of the Blood ; for, on both fides of each of the before-mentioned boney parts was an artery, which had a bending, or backward turning at its extremity, and thus became the beginning of a vein.

Upon viewing this fifh's tail, at the part where the fin begins, I there faw, to my great admiration, a large artery dividing itfelf into the before-mentioned fmaller ones ; and clofe to it, numbers of the minute veins returning from the fin, and uniting in one large vein. In fhort, here was fuch an agitation, or motion of the Blood driven out of the large artery to the fartheft end of the tail and into the fin, and running back in the fmall viens, into the large one, as is inconceivable.

In order to fhew the fize of this little fifh, wherein I obferved all thefe motions of the blood, I caufed a figure of it to be drawn, as it appeared to the naked eye, and this is fhewn in Plate IV. *fig*. 4. At *fig.* 5, is ſhewn part of the body and the tail of the ſame fiſh, as ſeen through the microſcope. DE is a fin on the back, and L M, another under the belly, near the tail, and FGHIK is the fin of the tail, wherein are to be numbered ſeventeen ſmall bones.

Theſe ſmall bones, contrived by Nature to give ſtrength to the fin, were formed with joints; and I could ſee that they were compoſed of oblong particles, which, probably, were hollow tubes; the pellicle, or membrane, which covered them, and compoſed the greateſt part of the fin, was alſo formed of oblong parts, but theſe things the limner could not perceive, becauſe the fiſh being then dead, they were become inviſible.

I have before ſaid, that on each ſide of theſe boney parts of the tail I had diſtinctly ſeen the compleat circulation of the blood, and this was in thirty-four places, two between each bone; that is, there were in this fiſh's tail ſixty-eight blood veſſels; namely, thirty-four arteries, and as many veins, beſides thoſe veſſels that, probably, were in the ſmalleſt part of the fin, about F or K, which I did not attend to.

To ſhew this circulation more plainly, I cauſed one of the boney parts of the tail to be drawn ſomewhat more magnified, which is repreſented at *fig.* 6, O P Q R. Cloſe to each ſide of this bone lies an artery, which in the figure is pictured at S T and W X, and in theſe veſſels are repreſented the particles of blood, which appear of a round figure. Here the blood was to be ſeen running with a ſwift courſe from S to T, and with the ſame ſwiftneſs returning back from T to V, ſo that S T is an artery, and T V a vein, and yet, both of them but one blood-veſſel, continued and prolonged. In like manner, were the blood-veſſels on the other ſide of the bone at W X Y. But theſe arteries and veins were not at ſo great a proportionate diſtance as here repreſented, for, in many places, they were ſo cloſe as to touch each other.

In other places, and alfo in the two fins D E and L M, I faw the blood not only running along, but alfo taking its whole courfe forward and back again, in manner before defcribed.

Now, if in the tail of fo fmall a fifh, as this which is pictured at *fig.* 4, there are to be found thirty-four diftinct circulations of blood, what an incredible number of them muft there be in an human body! And this being fo, it is no wonder, that, upon the leaft puncture made by a needle, or any other fmall inftrument, the blood iffues forth. Indeed, from thefe my obfervations, I am well affured, that, in the fpace of a finger's nail, in any part of the furface of our bodies, there are more than a thoufand circulations of blood.

Some years after thefe, and other obfervations of the like kind, had been made by me, I accidentally fell into converfation with a certain learned Gentleman, (not a native of Holland) on this fubject of the circulation of the blood, particularly in the minuteft veffels which are contained in a very fmall fpace, and that this circulation could as plainly be feen, as with the naked eye we fee water fpringing up from a fountain, and falling down again; but though I ufed all my endeavours to convince him of the truth of what I advanced, yet this learned Gentleman refufed to give credit to my words, declaring that he could not form any conception of the matters which I related.

This Gentleman's incredulity took up much of my thoughts, particularly upon a time when I had got fome very fmall eels, not longer than one's little finger: and on this occafion I fent for a limner, who I knew was a very curious obferver, and had a very acute fight, judging that he would be able to make a drawing of fome of thofe blood-veffels.

I then put one of thefe fmall eels into a glafs tube, about the fize of a goofe-quill, and placing it before the microfcope, I delivered it into the limner's hands, defiring him particularly to attend to the current of blood which at that time was moft diftinctly to be feen in fome fmall veffels; defiring him, at the fame time, to obferve, that all thofe veffels through which the blood was driven outwards to the extremities, were named arteries, but where the blood, when arrived at the fmalleft veffels, began to take its courfe back again, there they were called veins, although it plainly appeared that the veffels were one and the fame.

The limner could not fufficiently admire this fpectacle of the blood circulating in fuch minute veffels, arifing out of the larger ones; and he was equally in admiration at the blood's returning from thofe very fmall veffels into the larger. And as the eel continued quiet longer than ufual, without moving its tail, I frequently defired the limner that he would, as long as poffible, keep his eye fixed on this current of the blood, in order to imprint the idea on his memory. At length, he put his hand to paper, and made a rough fketch of fome blood-veffels and their ramifications, or branches; and he repeated his obfervation and his drawing, until he had compleatly traced fix feveral blood-veffels, namely, three arteries, and as many veins, with their ramifications, with all the accuracy he was able, faying, he had now fufficient materials to make a perfect drawing, fo as to defcribe the exact proportion both of the larger and fmaller veffels.

In Plate IV. *fig.* 7, and in the fpace between 1, 2, 3, 4, are reprefented fix of thefe blood-veffels, which I directed to be drawn on rather a larger fcale than the firft fketch taken of them, in order that the feveral veffels might be eafier diftinguifhed; therefore this figure fhews them about twice as large as they appeared to the limner through the microfcope.

Thefe veffels were not at the very extremity of the fifh's tail, but a little below it, towards the end of the fin. And that part, or fpot, which the limner faw through the microfcope, and the feveral blood-veffels of which he made the drawing, did not, in my judgment, take up as much fpace as is occupied by a large grain of fand; for though the view of the microfcope might in clude the compaſs of four ſuch grains, yet the part wherein the blood-veſſels were ſeen, did not amount to a fourth of that ſpace; ſo that, within leſs compaſs than that of a grain of ſand, there are found to be in the tail of an eel as great a number of blood-veſſels as are here repreſented between 1, 2, 3, 4.

At the letter A, is repreſented one of thoſe blood-veſſels, which are called veins; B, one of thoſe named arteries; C, is a vein; D, an artery; E, another vein, and F, another artery.

But, in order more clearly to explain the courſe of the blood in theſe veſſels; and to ſhew, at what part, though in fact they are one and the ſame, they aſſume different names, I have in the figure more particularly pointed out, and ſhall now deſcribe one of thoſe veſſels called an artery.

D, is that artery, out of which, at G, proceeds a ſmall branch, which, at H, divides itſelf into two, as H I K: and here we ſee, that the branch G H I is properly to be named an artery, becauſe, as far as I, the blood is driven from the heart, and I K, we muſt name a vein, becauſe, from I to K the blood is brought back towards the heart. In the other branch, which proceeds from H, in the direction H L M, the blood is infuſed into the vein E at M; and ſince at M it firſt begins to take its courſe towards the heart, it follows that at M this veſſel firſt aſſumes the the name of a vein.

In this ſmall artery GH, it is to be obſerved that the limner has been very accurate in deſcribing the exact ſize of the veſſel, and we muſt always bear in mind, that in theſe branchings, or ramifications, the arteries grow ſmaller and ſmaller, and the veins continually grow larger, as they receive the blood from the arteries. Farther, all the minute blood veſſels deſcribed in this figure the limner has repreſented, not by lines, but by ſmall circular dots, ſo as to give an idea of the particles or globules of blood, which he very diſtinctly ſaw, running or paſſing through them.

All the minute veſſels which are repreſented in this figure, of the ſize pictured at H I K, or H L M, are of equal dimenſions, and they are ſo ſlender, that I can ſafely affirm, that if a grain of our common ſcowering ſand were divided into a million of equal parts, each of thoſe parts would ſtill be too large to find a paſſage through theſe minute veſſels. Which being conſidered, we may conclude how exquiſitely ſlender muſt be the veſſels in which the circulation is performed: and if it were not ſo, how could all the parts of our bodies be continually ſupplied with nouriſhment? *

Farther, in the before-mentioned artery D, is another ſmall ramification at N, which depoſits its contents in the vein E at O, and a little higher, at P, is a branch which unites itſelf with the vein E at Q.

At R, may be obſerved another ſmall branch, proceeding from the ſame artery D, which, at S, is joined with a ſmall branch from the artery B, and afterwards both fall into the vein C.

Again, at T, is another ſmall branch, ariſing out of the artery D, which, at V, ſubdivides itſelf into two, and, in two ſeveral places, namely, at W and X, conveys the blood into the vein E, and from the ſame artery another branch ariſes at Y, which, at Z, is divided into two, and theſe are united to the vein C at the places marked *a* and *b*.

At a ſmall diſtance from Y, is another very minute branch at *c*, which is joined to the vein C at *d*.

Farther, at *e*, another ſmall artery branches forth from D, taking the direction *e f*, and at *f* is ſubdivided into two ſtill ſmaller branches, both which join the vein E at *g* and *h*.

* A very eminent phyſician of our own country, (Dr. Mead) expreſſes himſelf in very nearly the ſame words: "Every animal machine is of ſuch a nature, that there is a "ſort of infinity in its conſtituent parts, by which expreſſion I mean, that their fibres are "ſo extremely ſmall, that we cannot diſcover the ultimate ſtamina, even by the aſſiſtance "of the beſt microſcopes. Had it been otherwiſe, aliment could not be conveyed to "every individual part of the body; nor could the neceſſary functions of life be per-"formed." MEAD's *Medical Precepts, in the Introduction.*

A little higher in the artery D, a ſmall artery branches off at *i*, proceeding to *k* and *l*, where it again divides itſelf into two, and joins the vein E at *m* and *n*.

Cloſe to *i*, two ſmall branches ariſe at *o*, and join the vein C at *p* and *q*.

At *r* ariſes another ſmall artery *r s*, which at *s* divides into two ſmaller branches, one of them taking the courſe *s t*, to join the vein C, and the other paſſing by *s u w x*, to join the vein E.

Laſtly, the extremity, or ſmalleſt part of the artery D, is ſhewn at *r y z*, and is united to the vein E at A, firſt ſending off a branch near the letter *u*, which taking the direction *u b*, is united to the vein C at *t*.

Hence it plainly appears, how many various branches or minute arteries proceed from thoſe ſmall blood-veſſels, or arteries, repreſented at B, D and F, and how theſe all unite with the other ſmall veſſels called veins, which are ſhewn at A, C and E; and this alſo proves what has been ſo often mentioned, that all theſe blood-veſſels, though called by different names, are yet the ſame identical veſſels. And if we reflect, that each of theſe very ſmall veſſels muſt be formed with the ſame kind of coat as the larger ones, though of a thinneſs proportioned to its ſize; and farther, if we conſider of what wonderfully fine and inviſible membranes the coats of the ſmalleſt veſſels muſt be formed, and how eaſily the fineſt part of the arterial blood may find a paſſage through thoſe coats, to the end that every part of the body may, from thence, be continually ſupplied with neceſſary and ſuitable nouriſhment; theſe things, I ſay, being duly weighed and conſidered, it ſeems clear that the arterial blood, coming from the heart, muſt contain more ſubtile and fluid parts than when in its paſſage to the heart. For the blood will not be deprived of its more ſubtile juices, while in the larger arteries; to prevent which, I imagine that they are provided with thick and ſolid coats. And here the particles of blood from which its redneſs proceeds, ſwimming in a thin juice, are of a bright red colour; but in the ſmalleſt arteries, ſome of its parts are drawn off for the ſupport and nouriſhment of the body, whereby the blood, when returning in the veins, being deprived of thoſe thin juices, aſſumes a darker red, and as more of the thin juices are taken away, it will appear blackiſh.

The circulation of the blood is repreſented in another view, at *fig.* 8, A B C D E F G H I K, which is a drawing of ſome veſſels ſeen by the microſcope, in the tail of a tadpole; theſe animals are much quieter than eels, and the arteries and veins are as eaſily to be ſeen in them as in any other creature; and in the ſmalleſt veſſels where the period, or the retrograde motion of the blood is performed, its particles are more diſtant from each other than in any other animal.

The veſſel ſhewn in this figure, (which was an artery, wherein the blood was driven forward with great ſwiftneſs from A to B) was rather larger than to admit one of the particles of blood at a time. At B it divided itſelf into two branches, which are repreſented at B C and B E; theſe two branches were at D again united in one, for a ſhort ſpace, and at F they again ſeparated, as ſhewn at F G and F I. Here theſe two arterial branches, making a ſmall curve, or bend, again joined in one at H, forming a ſomewhat larger veſſel, which is ſeen at H K; and at K, this was joined to a ſtill larger blood-veſſel.

Here it is plain, that the veſſels A B C D E F G, and A B E F I, foraſmuch as in them the blood is driven from the heart, to G and I, its greateſt diſtance, muſt be named arteries; and the veſſels G H K and I H K, becauſe in them the blood is returning to the heart, muſt be named veins.

I formerly was of opinion, that in all caſes where by an accidental fall or blow, there were produced livid or purple ſpots upon the ſkin, which proceeded from coagulated blood, this blood (if no exulceration ſhould take place in the part) would by degrees be ſo diſſolved, as to be carried off by perſpiration; but the following obfervations caufed me to alter my opinion in this refpect.

In the tail of this tadpole, I obferved a veffel, of a fize to admit twenty of the particles or globules at once; fo that this was a large veffel, in proportion to thofe which I have before defcribed. A fmall part of it is reprefented at *fig.* 9, L M; and from this, proceeded a minute veffel, which is fhewn at M O.

The current in this veffel, from L to M, was not fo fwift as I obferved in the other veffels, and for this reafon, that, in another part of it, at R, the blood was coagulated, infomuch, that no diftinct particles could be perceived in it, but only an uniform rednefs; but in the fmall veffel M, the current was as fwift as in any of the others.

In confequence of this ftagnation at R, the blood was driven forwards from N to P, with every pulfation of the heart, and inftantly ran back again, in like manner, as if with the naked eye we beheld a fwift alternate or reciprocal motion, like that of a faw.

We know, that water cannot be compreffed into a lefs fpace than it naturally occupies; and this being alfo the cafe with regard to the blood, we muft conclude, that the coat of this veffel, between N and P, and alfo a little below N, was, at every pulfation, expanded in diameter, and, at the intermitting of the pulfation, would contract itfelf, and fo drive the blood back again.

Keeping my eye fixed on the object, I perceived, in a little time, the blood between P and R begin to move, and by little and little, from P towards R, to have the fame alternate motion to and fro, as I have before defcribed. At the fame time, the blood in the veffel N S, where at firft, little or no motion could be feen, the current was now as fwift as ufual. And in the fmall blood-veffel, marked P Q, which was only of a fize to admit one globule at a time, and wherein I could not at firft difcover any motion, the circulation was now reftored; but the particles of blood were few in number, and at a diftance from each other, At length all the blood from P to R, was ſo far rendered fluid, that, at every pulſation, it was driven forward, and then returned back again. In theſe obſervations, about two minutes of time elapſed, and my eye being fatigued, I took it off the object to give it reſt, in which interval, the animal put itſelf into a violent agitation, thereby precluding any farther obſervation.

But, ſince we now clearly ſee, that coagulated blood can, by the pulſation of the heart, in courſe of time, not only be put in motion, but alſo ſo far diſſolved, that its component particles or globules may re-aſſume their priſtine figure, we may fairly conclude, that blood, in any animal, which by a blow or bruiſe, is made to coagulate and ſtagnate in the veſſels, may, in the ſpace of ſome days, be reſtored to motion.

60
75
———
4500 an hour.
24
———
18000
90
———
108,000 a day and a night.
10
———
1,080,000 ten days.

For, ſuppoſing, that in an human body, the blood is driven from the heart ſeventy-five times in the ſpace of a minute (ſome ſay the number of pulſations does not exceed ſixty, but I believe my computation to be neareſt the truth) it follows, that the pulſations in an hour's time, are 4,500, and, in the ſpace of a day and a night, 108,000.

Now, if we find, that the appearance produced by coagulated blood, will, in the ſpace of ten days diſappear from our bodies, and conſider, that, in the ſame ſpace of time, a million and eighty thouſand pulſations are performed, and ſuppoſing, that, at every pulſation, ſo much of the blood is put in motion in the ſeveral veſſels, as is only equal in ſize to a grain of ſand, we may gather how much of ſtagnant blood may be reſtored to motion, in the ſpace of time juſt mentioned.

For example, let us fuppofe, that the quantity of blood, which at every pulfation can be rendered fluid, and reftored to its motion, is no more than the fize or quantity of a grain of fand, and that eighty of fuch grains placed fide by fide do not exceed the length of one inch ; we find then that 512000 grains of fand taken together are equal to a cubic inch, which number is not the half of the number above affigned.

80
80
6400
80
512000

In this blood-veffel, which I have juft mentioned, I could not only very clearly difcern the feveral pulfations, but I could alfo many times in all the arteries, fee to make an exact computation how many times the blood was propelled from the heart in the fpace of one minute.

Now, if we confider that fo great a quantity of blood, as is contained within the compafs of a cubic inch, is very rarely by a blow or bruife congealed in one fpot, we may eafily conceive, that when a coagulation does happen, it may, by fuch frequent propulfions or pulfations as I have mentioned, be at length diffolved, and in all, or moft of the veffels, reftored to the fame current or courfe as before.

At another time, I obferved an appearance of a different nature in the blood-veffels, which was occafioned by my having put a tadpole into a piece of clean paper, whereby a fmall fpot in the very thinneft part of its tail ftuck to the paper, and thereby received a fmall injury, fo that fome blood flowed from the wound, out of an artery which was of a fize to admit about four globules of blood to pafs through it at a time.

The blood thus flowing out, remained collected about the wounded part ; but here another fight prefented itfelf, which engaged all my attention ; for, in this fame artery, at about the half of an hair's breadth diftance from the wounded part, another fmall branch appeared, wherein the blood purfued its courfe in the fame uniform and diftinct manner, as if the artery had remained uninjured.

At *fg*. 10, T V, is ſeen this artery, which was wounded a little above V. The letters V and X indicate the extravaſated blood. V W denote the minute artery in which the blood purſued its regular courſe, though cloſe to the place, at P, it iſſued out from the artery T V.

This ſight at firſt ſurprized me, but my wonder ceaſed when I obſerved that this blood veſſel V W, was united with a large one at W, and of that ſort which, carrying back the blood to the heart, is called a vein. And by means of this laſt-mentioned veſſel, the blood was carried through the paſſage V W, as it were, by a kind of ſuction, with as much ſwiftneſs as it had been before driven from T to V, inſomuch that I was perſuaded, that if the ſmall veſſel V had not been united to the artery T V, but only its orifice had laid in the extravaſated blood, about the ſpot at V, that ſuch extravaſated blood would in a ſhort time have been, as I may ſay, ſucked up and carried away with the remainder of the blood towards W.

I have often reflected on the nature of thoſe very thin tranſparent pellicles, or ſkins, which conſtitute the wings of ſmall flying inſects, ſuch as gnats, flies, moths, and the like; ſome of which I have obſerved to be entirely covered with feathers, others compoſed only of thoſe muſcular parts which ſtrengthen and expand the wing, and others are wholly covered with hairs: and when I conſidered, that theſe hairs, or feathers, are fixed or rooted in regular order in the membrane of the wing, my thoughts were wholly bent to diſcover how theſe wings might be formed.

As to the ſuppoſition which at firſt occured, that theſe membranes were compoſed of a tranſparent viſcous or gummy matter, congealed or hardened to a due conſiſtence, I could not ſatisfy myſelf with that idea, for it ſeemed impoſſible to me, that in that caſe the feathers and hairs could be produced in ſuch regular order; and yet, it was beyond my comprehenſion how ſo thin a membrane could be furniſhed with fuch a number of veins or veffels as would be requifite for the formation of fuch feathers and hairs.

In my endeavours to inveftigate this fubject, I firft examined one of thofe flying infects, whofe wings confift of membranes only, without either hairs or feathers; which membranes are placed between the large veffels and finews, giving ftrength and ftiffnefs to the wings; and upon the examination of thefe, I plainly faw that there were large blood-veffels running among the finews or mufcular parts, from which arofe fmaller veffels, and thefe again divided themfelves into ftill fmaller ones, until at length they became invifible.

I was not, however, content with this, and among other objects, I met with a large green grafshopper, in the wing of which I more clearly perceived not only, that from the large blood-veffels in the wing, other fmaller ones arofe, but I alfo faw that the colour of the blood in thefe large veffels was green; and in the fmaller veffels and their more minute ramifications, I could ftill diftinguifh the blood to have a greenifh caft; but when thefe veffels were again fubdivided into fmaller ones, I could not perceive any colour in them, and the veffels themfelves became fo clear and tranfparent that they entirely efcaped the fight.

Though I could moft plainly fee that the fubftance, or matter, of which this blood was compofed, confifted of globules fwimming in a clear liquor, I moreover cut the wing in two, and out of the veffels collected fome of the blood, which I placed before the microfcope, and obferved that where the globules or particles of it lay in numbers or heaps together, the colour was a lively green, where they lay fo thin as not to amount to the twentieth part of the thicknefs of an hair of one's head, the colour was only greenifh, but where the globules were fingly difperfed, it had no longer any appearance of colour at all, but became tranfparent; and here it clearly appeared to me, that all thefe green globules were contained in a thin tranfparent fluid.

From thefe obfervations I concluded, that the tranfparent membranes which principally conftitute the wings of thefe fmall animals, are as completely provided with blood-veffels, finews, &c. as the bodies of other creatures.

I formerly was of opinion, that in the wings of thefe fmall flying creatures there was no circulation of the blood, for I judged, that in its paffage through fuch exceeding flender veffels, it muft be evaporated or dried up : and the rather, as many of thefe winged infects do not take any food, but only live a few days, and die as foon as they have coupled, and laid their eggs. But if we recollect, that the membranes of their wings are of a hard and horny nature, though exceeding thin, we may conclude, that all the veffels, compofing this horny membrane are fo firm and tough, that, though all the fluid contained in them fhould be dried up by the heat of the fun, the veffels themfelves would not collapfe or fhrink up, as thofe in our own bodies, or the bodies of other animals would do in the like cafe.

I was confirmed in this opinion, by obferving that the blood-veffels in the wings of thefe infects were not of the fame make as thofe in the bodies of the human fpecies and of terreftrial animals, but were compofed of annular parts, or rings, like the windpipe and the veffels pertaining to refpiration in the lungs of animals. And, though we may not be able to difcover all thefe veffels in the wings of infects, yet we may be affured that there is an incredible number of them entering into the compofition of thofe wings. And, fhould we imagine, that thefe veffels by reafon of their fmallnefs or their hard and dry nature, are impervious to blood and juices for the fuftenance of the wing, we muft confider that there is not a fingle hair or feather, how fmall foever it be, which is found upon one of thefe wings, but muft have had in it many fmall veffels neceffary for its production ; for every feather has its quill and every quill muft have a great number of veſſels, in order to contribute to the increaſe of ſuch feather: and who knows whether each of ſuch ſmall feathers may not have been formed out of more than a thouſand veſſels? And when we reflect on the great number of feathers or hairs with which the wing of a fly or moth is covered, we ſhall find it impoſſible to conceive the numbers of veſſels of which theſe inſects, though they appear contemptible in our eyes, are compoſed. Indeed, I am of opinion, that many phyſicians and ſurgeons cannot reckon up ſo great a number of veſſels in a cat or a dog, as I imagine enter into the compoſition of a gnat.

It was alſo at one time my opinion, that the ridges, or thicker parts, in the wings of theſe flying inſects, and which I have named ſinews, were only the boney parts of the wing to give it ſtrength. But when I perceived, that there were large blood-veſſels in thoſe parts, I applied myſelf with all diligence to diſcover, if poſſible, the current of blood in thoſe veſſels.

For this purpoſe, I took thoſe butterflies which proceed from the catterpillar that feeds on the aſpin, the poplar, or the willow; and which, in ſize and ſhape, reſemble the ſilk worm's butterfly. Their wings are, on both ſides, covered with white feathers, and, unleſs theſe are taken off, the membrane cannot be diſcerned. Theſe feathers I wiped from the wing with a ſoft piece of leather, as gently as poſſible, to avoid injuring the wing or hurting the butterfly. And I then applied the wing (while the animal was alive) to the microſcope; but, with all my attention, I could not diſcern the leaſt current of blood in the veſſels, though if there had been any regular motion, I have no doubt but I ſhould have ſeen it, and the rather, as this blood was of a yellowiſh colour; and, upon opening the large veſſels in theſe wings, I have often preſſed out the blood which they contained.

For the moſt part, theſe large veſſels lye in, or near, that boney part of the wing which gives it ſtrength; and I have often obſerved thofe veffels to be placed, not in a right line, or parallel with the boney part, but twifted, with various turnings, in like manner as if one were to fee the inteftines of an animal in the pofture they lie while joined to their membranes.

After this, I accidently met with a large grey moth or butterfly, which in a manner flew into my hand. This butterfly I killed, and cut off the wings, and, having taken off the feathers, I placed them before the microfcope: and here I faw the blood-veffels more plainly than in the wings of the other infects I have mentioned. A part of one of thefe wings I placed before the microfcope, and caufed a drawing to be made, not only of thofe blood-veffels lying in the boney part of the wing, but alfo of thofe which were difperfed over the membrane, and of which the membrane, in part, confifts; in order to fhew, how the veffels lye twifted in various turnings; alfo, how they are compofed of annular parts or rings placed together; and likewife, how, from thefe large veffels fmaller branches arife, which, in great numbers, are fpread all over the membrane.

In Plate IV. *fig.* 11, P Q R reprefents a blood-veffel, with its various branches, fpread over the membrane. A B C D E F G, is a large blood-veffel in one of the boney parts of the wing, wherein is feen, the manner how this veffel is twifted or bent, and alfo, the annular parts of which it is compofed; in conformity with the formation of the blood-veffels in all infects; infomuch that I have feen the blood-veffels in the loufe and flea, to be compofed of fuch annular parts.

In the fame figure, B H, I K, C L, D M, E N, and E O, reprefent the blood-veffels with their branches iffuing from this laft-mentioned veffel, and fpreading over the membrane; and in thefe alfo, the annular parts could be diftinguifhed; but when they became fo fmall, as to appear no larger through the microfcope, than a horfe-hair to the naked eye, then the rings in them could no longer be difcerned. Thefe veffels the limner purfued in his drawing as far as his eye could diftinguifh them, but at length they became fo minute, and fo intermixed one with another, that no true judgment could be formed of them.

In S T V, are fhewn a few of the feathers, which fo exactly cover both fides of the membrane, that no part of it can be feen. W W W, are three larger feathers which were placed on the edges of the wing. XXXXX indicate the membrane, when it was laid bare of its feathers, on both fides, in order to difcover the blood-veffels. And here, though not in regular order, may be feen the cavities or holes in which the quills were fixed, and from which they had their origin.

Farther, I confidered with myfelf, whether or no the blood-veffels confifted of arteries and veins ; but I could not fee any other than one fort of veffels in the wings of all the infects of this fpecies, which I have examined, except that once I thought I faw in the thinneft part of the wing of a grafshopper, that in the larger veffels next the body, another fpecies of veffels was inferted.

The conclufion drawn by me upon the whole was, that there was not any circulation of the blood in the wings of thefe creatures, and that the blood-veffels I have been defcribing, which certainly were arteries, were only defigned to perfect the formation of the wing with its multitudes of feathers, and afterwards, to convey the blood, with an exceeding flow motion, through the veffels, in order to afford a fmall degree of fupport to the wing in its perfect ftate. For, as thefe butterflies, and thofe which are produced from the filk-worm, and many other flying infects which proceed from caterpillars, do not take any food, and do not live any longer than till they have coupled and laid their eggs, it is not neceffary, in my opinion, that the blood in their wings fhould have any circulating or retrograde motion, and befides, the membranes being of a ftiff horny nature, they require little or no nourifhment.

I cannot here omit to mention, that I have heretofore often taken great pains to difcover two kinds of veffels in the leaves of trees and plants in order to afcertain, whether there was any circulation in leaves, but I never could fee more than one fpecies of veffels, namely thofe that convey the nutritive juices to the feveral parts.

But, if we confider, that not only the leaves of trees, but alfo their fruits, do not need any other than thofe nutritive juices, which are requifite to bring them to perfection, we fhall not wonder that when at a ftate of maturity, they are, as it were, fpontaneoufly loofened or fhaken off from the tree, without the leaft appearance of having been broken off; nay, that part of the ftalk which was originally united to the tree, will appear as fmooth as if, with its multitude of veffels, it never had been joined to it.

In a word, I will venture to affert, that neither the wings of the before mentioned flying infects, nor the leaves or fruit of trees, require that kind of circulation of the juices, which we have been confidering.

Of the formation of the Teeth in ſeveral animals; the ſtructure of the human Teeth explained, and ſome of the diſorders to which the ſame are liable accounted for.

HAVING taken great pains to inveſtigate the formation of the elephant's tooth, and examined into the nature of it by every means I could deviſe, I found it to conſiſt only of a collection of tubuli, or pipes, which are exceedingly ſmall, and all derive their origin from the inner part of the tooth, for I never could diſcover any of them lying longitudinally or lengthwiſe in it.

Upon examining that part of the tooth where the boney ſubſtance is but thin, which is where it is united to the head, I very plainly perceived that one end of theſe tubuli took its riſe from the cavity within, and the other end extended to the circumference, which circumference or outſide was compoſed of a kind of ſcaly particles laid one on another, and I conſidered with myſelf whether each ſeries or layer of theſe ſcaly particles might not be the ſubſtance or thickneſs formed in the ſpace of one year.

Purſuing theſe my obſervations in the examination of that part of the tooth where to the eye it ſeems perfectly ſolid, I there found it to have, near the middle, a ſmall cavity, through which cavity I concluded the nutritive ſubſtance muſt be conveyed, for the continual ſupport and increaſe of the tooth. And upon examining the tubuli round about this ſmall cavity, I perceived that they all aroſe from thence, and ſpread themſelves all round towards the circumference. I endeavoured to examine ſtill farther, beyond the part where this cavity ended, in order to diſcover whether from theſe firſt formed tubuli others might not ariſe or branch forth; but this part of nature's work was inſcrutable to me. My conjecture reſpecting the matter however was, that each of the boney tubuli (proceeding from the ſmall cavity before-mentioned) might be compoſed of many folds or coats, and thus not only be diſpoſed to diverge or ſpread into a larger ſpace, ſo as to form the ſubſtance of the tooth, but alſo, by this means, contribute to its ſtrength.

I alſo examined the teeth taken from young hogs, and found them to be likewiſe formed of tubuli ſpreading from the cavity in the center, to the circumference.

After this, I was deſirous of examining the ſtructure of the human teeth, and having for that purpoſe procured a number of the large ones, called the grinders, I found them to be formed exactly in the manner before deſcribed, namely, of tubuli or little boney pipes, cloſely joined together, ariſing at the cavity in the middle of the tooth, and ending at the circumference or outſide. And in order to explain this formation to the Reader as clearly as poſſible, I cauſed the following drawings to be made:

In Plate V, *fig.* 1, at A B C, is repreſented a human tooth, on one ſide of which, with a file, I cut away almoſt the half, not to diſcover the cavity therein, which is well known to moſt perſons, but only to ſhew the manner how the tubuli, of which the boney part is compoſed, take their riſe from the cavity in the center, and terminate at the circumference. But it muſt be underſtood, that theſe tubuli are by no means of the ſize repreſented by the lines in this figure, the ſame only denoting the order in which they lie, for the tubuli themſelves are exceedingly ſmall, and cannot be well diſcerned without the help of the very beſt microſcopes.

In the ſame figure, at G H I, is repreſented another tooth, which is filed down from the upper part of it as far as the before-mentioned cavity, in order to ſhew how the tubuli do here alſo ſpread themſelves round about from the center. All the extremeties of the tubuli which lie near the outſide of the tooth, (as far as they are above the gums, and expoſed to the air) are extremely hard, being as it were the ſolid caſe, ſhell, or covering of the tooth; and if we examine the ſurface of this caſe or covering attentively, we ſhall find one tooth to have forty, another perhaps fifty circles on it, like wrinkles, or gatherings, which in ſome places run in a curved or wavy direction, as is repreſented in the figure at DEF, where a drawing is given of this outſide ſhell, with ſome of the circles marked thereon; and I imagine that the circles which thus appear like wrinkles proceed from hence, that they are the places where the tooth, while growing, is from time to time protruded or thruſt out from the gum.

In the teeth ſhed by children, and likewiſe in thoſe of many young animals, I have obſerved that the ends of their roots are entirely open or hollow; and in like manner I imagine that the roots of the molar teeth or grinders which I have been juſt deſcribing, are at firſt formed in the ſame manner, but that in proceſs of time they become oſſified or converted into a boney ſubſtance, of a ſpongy nature, through which many veſſels paſs, conveying blood, and nutritive juices into the cavity of the tooth; and I alſo conceive that this cavity is filled with nerves and veſſels ſpreading themſelves into ſo many branches, that every one of the boney tubuli is thereby increaſed during the time of its growth, and afterwards, (while the tooth continues ſound) nouriſhed and ſupported. I alſo conjecture that theſe ſmall veſſels thus nouriſhing and ſupporting the boney tubuli do not end at the ſurface of the tooth (I mean, in that part of it which is within the gum) but that the aliment or nutritive ſubſtance has a continued courſe through theſe veſſels, and that the ends of the boney tubuli are again converted into ſoft or pliable veſſels, ſpreading through the gum, and that thoſe veſſels are what principally keep the tooth fixed in its place.

The firſt formation, and ſubſequent ſupport or nouriſhment of the tooth being as before defcribed, we may eafily conceive that the boney tubuli, (being of a folid nature, and incapable of dilatation or fpreading) may happen to be obftructed by fome grofs or concreted matter, and then the fmall veffels contained within the cavity of the tooth muft immediately by fuch obftruction in the circulation of their juices be diftended. This diftention or fwelling will neceffarily excite great pain, for all the veffels contained in the tooth will prefs clofely on each other, forafmuch as they cannot fwell or fpread themfelves as other veffels can, which are not confined within the folid fubftance of a bone. Again, fuppofing thefe boney tubuli to be obftructed, and the obftruction not removed, we may from thence gather the reafon why our teeth partially decay, fometimes on the fides, and fometimes at the tops, the reft of the teeth remaining found for feveral years after.

In order to fhew the proportion which the fize or thicknefs of the tooth bears to its component parts before defcribed, I placed a very fmall piece of this tooth before the microfcope, and delivered that microfcope to the limner, directing him to draw an exact reprefentation of what he faw, (but without acquainting him what that object was). And here I muft obferve, that in this tooth the tubuli appeared to me much larger than I had before obferved in any animal, or in the elephant's tooth.

In Plate V. at *fig*. 2, K L M N, is reprefented * an exceeding fmall particle, or piece of a human tooth, of that fort called the molar teeth, or grinders, as feen through the microfcope. The reafon why in this figure fome of the tubuli there pictured appear of a darker fhade than the reft, is only this, that in that place where they feem darker, there were more of the tubuli lying one

* The Author having juft below informed us, that 120 of the boney tubuli make only the forty-fifth part of an inch, we may, by counting the tubuli reprefented in this figure, judge the natural fize of the fragment, or piece of tooth here magnified, and it will be found to be about the fortieth part of an inch in length and the fiftieth part of an inch in breadth, or of the fize fhewn at X.

behind the other, owing to the piece of tooth being thicker in that part, for this ſmall fragment was ſplit off, and not cut from the tooth.

The breadth of this tooth was almoſt two fifth parts of an inch, and from the beſt computation I could make, I judged that within the forty-fifth part of an inch, I ſaw an hundred and twenty of the tubuli, which amounts, in the ſpace of one inch in length, to five thouſand four hundred: now ſuppoſing this molar tooth, or grinder, before deſcribed, to be of a round figure, the diameter of it would be 2150 times the thickneſs of one of the tubuli of which the ſame is compoſed, and when this number is multiplied into itſelf, the product is 4,822,500. In a word, the proportion of one of the boney tubuli to the ſize of ſuch a tooth, is as one to 4,822,500.

Notwithſtanding I had now obtained a very ſatisfactory inſight into the formation of the human tooth, I was not yet content, but became deſirous to examine into the nature of the ſubſtance, or veſſels contained in the cavity, and for this purpoſe, I procured ſome of the fore-teeth, and the jaw-bone of an ox, which were taken out and brought to me immediately after the animal had been killed; ſeveral of theſe fore-teeth, and ſome of the grinders, I broke, or ſplit open, and with great admiration obſerved, that thoſe veſſels, which, paſſing through ſmall apertures in the lower part of the tooth, filled all the cavity within, conſiſted of ſuch an inconceiveable number of blood-veſſels, and other veſſels, as to ſurpaſs all imagination: indeed, many of them, I obſerved to be as ſmall and ſlender as the tubuli themſelves, of which the tooth was formed; and among them were ſmall blood-veſſels branching out into ſtill ſmaller ones, many of them entirely colourleſs, therefore, I thought it probable that there might be ſtill ſmaller veſſels entirely undiſcernible by our ſight.

All theſe veſſels were incloſed in a membrane, or coat, which was eaſily to be ſeparated from the bone, and, having kept ſome of thefe teeth by me four or five days before I broke them open, (in which time all the internal moifture was evaporated), I obferved in fome places within the tooth, a bloody fubftance which had penetrated into the boney tubuli, giving fome of them a reddifh colour.

It is my cuftom, every morning, to rub my teeth with falt, and afterwards to wafh my mouth, and after eating I always clean my large teeth with a tooth-pick, and fometimes rub them very hard with a cloth. By thefe means, my teeth are fo clean and white, that few perfons of my age * can fhew fo good a fet, nor do my gums ever bleed, although I rub them hard with falt; and yet I cannot keep my teeth fo clean, but that upon examining them with a magnifying glafs, I have obferved a fort of white fubftance collected between them, in confiftence like a mixture of flour and water. In reflecting on this fubftance, I thought it probable, (though I could not obferve any motion in it,) that it might contain fome living creatures. Having therefore mixed it with rain water, which I knew was perfectly pure, I found, to my great furprife, that it contained many very fmall animalcules, the motions of which were very pleafing to behold. The largeft fort of them is reprefented in Plate V, *fig*. 3, at A, and thefe had the greateft, and the quickeft motion, leaping about in the fluid, like the fifh called a Jack; the number of thefe was very fmall. The fecond fort are reprefented at B, thefe often had a kind of whirling motion, and fometimes moved in the direction reprefented by the dotted line C D, thefe were more in number. Of the third fort, I could not well afcertain the figure, for fometimes they feemed roundifh but oblong, and fometimes perfectly round. Thefe were fo fmall, that they did not appear larger than reprefented at E. The motion of thefe little creatures, one among another, may be imagined like that of a great number of gnats, or flies, fporting in the air. From the appearance of thefe, to me, I

* Mr. Leeuwenhoek, at the time of writing this, was upwards of fifty years of age.

judged that I ſaw ſome thouſands of them in a portion of liquid, no larger than a grain of ſand, and this liquid conſiſted of eight parts water, and one part only of the before-mentioned ſubſtance taken from the teeth.

With the point of a needle, I took ſome of the ſame kind of ſubſtance from the teeth of two ladies, who I knew were very punctual in cleaning them every day, and therein I obſerved as many of theſe animalcules as I have juſt mentioned. I alſo ſaw the ſame in the white ſubſtance taken from the teeth of a boy about eight years old; and upon examining in like manner, the ſame ſubſtance taken from the teeth of an old gentleman, who was very careleſs about keeping them clean, I found an incredible number of living animalcules, ſwimming about more rapidly than any I had before ſeen, and in ſuch numbers, that the water which contained them, (though but a ſmall portion of the matter taken from the teeth was mixed in it,) ſeemed to be alive.

Some time after making the preceding obſervations, I received from Sir Hans Sloane, a packet, containing three ſmall maggots, two of which were dead, and the third alive, with a letter, informing me that they were found in a perſon's decayed tooth, from whence they had been expelled by fumigation. Upon examining theſe, I had no doubt that they were of the ſort found in cheeſe, and upon comparing them with ſome living ones which I procured from a cheeſemonger, I found them to correſpond exactly in make and ſhape. Theſe maggots are the offspring of a ſmall fly, which is frequently ſeen in cheeſemongers' ſhops, and lays its eggs in the cheeſe, where the little maggots produced from them find nouriſhment, and are in time converted into flies.

The maggots ſent me by the cheeſemonger, I kept in a glaſs tube, and ſupplied them with food, and in a ſhort time they were converted into flies, which laid eggs, and theſe again produced maggots of the ſame kind as the former. The living maggot which I received from Sir Hans Sloane I kept by itſelf, and it was alſo converted into a fly of the ſame ſpecies.

Theſe maggots when firſt hatched from the egg, are no bigger than a grain of ſand, but afterwards grow to about four times that ſize; they have two ſmall teeth by which they are enabled to gnaw their way into the cheeſe; and as their ſkin is very firm and hard they are not eaſily cruſhed or deſtroyed. Now, it is eaſy to conceive, that the perſon in whoſe tooth the maggots firſt mentioned were found, might have been eating of ſuch old cheeſe, and that the maggots, or the eggs producing them, might have been lodged uninjured in the cavity of the tooth, where, when they began to gnaw they muſt cauſe great pain; and we may alſo eaſily imagine that by the fumigation they might have been driven out of the part.

ON COFFEE.

IN my inquiries into the nature of ſeveral kinds of ſeeds, I examined, among others, thoſe which are called Coffee Beans, which are much in uſe in this country, for preparing the well known drink of that name.

I was firſt deſirous to know in what part of theſe ſeeds the young plant was placed, and for this purpoſe I procured ſome entire coffee beans, incloſed in their original huſk or ſhell.

In Plate V. *fig.* 4, E, F is repreſented this nut, huſk, or ſhell, in which are two of theſe coffee beans, divided by a membrane, or partition: for, that which at firſt ſight appears as a ſingle ſeed, does in fact conſiſt of two diſtinct beans or ſeeds, lying in regular order beſide each other, juſt as we obſerve two kernels in an almond, a filbert, or an apricot.

In *fig.* 5, G H, is ſhewn the nut or ſhell, opened on one ſide, ſhewing how the two beans lie with their flat ſides next each other; G, is that part which was joined to the plant, and from whence the ſeed derived its nouriſhment, and H, is the end where the young plant is formed in the ſeed: *fig.* 6, I K, is a coffee-bean lying with its flat ſide upwards.

I cut a ſlice from one of theſe beans, at the end marked I, and cauſed a figure of it to be drawn, ſomewhat magnified, only to ſhew the place where the young plant lies.

Fig. 7, L M N, is this ſlice, and at O is to be ſeen the part of the bean where the young plant is formed; and here that part which would have grown up into a ftalk or ftem, is cut tranfverfely.

I have alfo laid coffee beans for fome time in water, in order more eafily to take out the young plant, and to give a drawing of it from the microfcope. This young plant, fo magnified, is fhewn in Plate V. *fig.* 8, P Q R S T V. At Q R S T V are three compleatly formed leaves, and I could fee the veffels and globules whereof they confifted very diftinctly in fome of them, efpecially where the leaves did not lie two or three together. A few of thefe globules, compofing the leaf, are reprefented in this figure, at letter T. That part where the root and ftem would fhoot forth is fhewn at P Q V.

After this young beginning of the plant had ftood fome months before the microfcope, I perceived that the leaves were covered with a fort of mouldinefs. This appearance ufually begins by a kind of ftalk; from whence a globule proceeds, and out of that many more, exhibiting together the likenefs of foliage, but the mouldinefs I am now fpeaking of, had a very different appearance, being much more in the fhape of flowers, as is fhewn in *fig.* 8, at a a a a. But I have often feen this mouldinefs, even on the dead bodies or parts of the bodies of infects, and alfo on the fhell of a filk-worm's egg.

Some of thefe beans I placed in a proper chymical veffel over the fire, and obferved, that in the roafting, or burning them, a great great quantity of oily fubftance. and alfo of watery moifture was expelled. The roafted beans I broke into fmall pieces, and after infufing them in clear rain water, I fuffered the water to evaporate, after pouring it off from the groffer parts of the coffee, and then I difcovered a great number of oblong faline particles of different fizes, (but moft of them exceedingly minute) all of them with fharp points at the ends, and thick in the middle.

Afterwards, I took fome of the coffee beans in the fame ftate they are imported to us, and upon ſqueezing, or preſſing them with great force, a larger quantity of the oil was expreſſed than could be imagined, and I obſerved that this oil was very clear and thin.

I alſo cut coffee beans into very ſmall fragments, or pieces, in every direction, and I always found them to be of a very open and ſpongy texture: for, whereas, almoſt all ſeeds conſiſt of a farinaceous, or mealy ſubſtance, (except in that part where the young plant is contained) this ſeed, on the contrary, is formed of nothing but fibres, branching or ſpreading one among another, and the cavities between them, in many places, filled with oil; for when I cut off very ſmall pieces from the bean, I could plainly perceive the oil, and take it out from the part where it lay.

From the middle of a bean, I cut a very ſmall ſlice, and placed it before the microſcope, in order to ſhew the open and ſpongy texture of this ſeed; and in Plate V. *fig.* 9, A B C D, is repreſented this particle, or piece of bean when magnified, the natural ſize of which was no larger than might be covered by two grains of ſand. The parts which in this figure appear cloſed up, and ſome of them to conſiſt of globules, were filled with oil. When a coffee bean is thus cut into ſmall pieces, and the pieces preſſed between the fingers, or ſqueezed between any hard ſubſtances, the fingers, or whatever is uſed in ſuch preſſure, will be much ſtained with oil; (that is to ſay, in proportion to the force applied) and I will venture to ſay, that by a ſingle operation of this kind, more than one thouſand little drops of oil will be expreſſed: it is here to be noted, that the oily particles formed in the coffee bean are not perfectly of a round figure, but in many places they lie together in irregular ſhapes.

This formation of the coffee bean being conſidered, we need no longer wonder, that they cannot be reduced into powder until they have been roafted, or burnt, for, in the roafting, much of the oil is driven off and confumed by the fire, and the branchey, or fibrous particles become weaker or more brittle, and the more they are burnt, or roafted, the more eafily they can be pounded in a mortar.

As to myfelf, who am accuftomed to take this kind of drink every morning for breakfaft, I do not fuffer the coffee beans to be much burnt, and I caufe them to be pounded, or reduced into fuch fmall particles, that they will pafs through a filken fieve, and until they feel between the fingers as fine and fmooth as flour. A proper quantity of the coffee thus prepared, being put into a coffee-pot, I pour on it boiling rain water, and then fet it again on the fire, but not to boil, and after letting it ftand for a fhort time to fettle, this is the coffee I make ufe of.

This is not, indeed, a very profitable way of making coffee, though much more grateful and pleafant to the palate, except to thofe who like the burnt flavour. For, when the coffee beans are violently roafted, they can more eafily be pounded to powder and paffed through a fieve, and the liquor clarifies fooner ; and alfo, by reafon of the burning, the bitter tafte fpreads farther, and produces more of the liquor, efpecially if the coffee be boiled in the water

But, if we judge, that the oil and falts which are found in coffee, are the parts wherein its virtue confifts, and from which we are to expect benefit to our health, we fhall prefer that coffee which is not over roafted, to that which is more burnt, for, in the coffee which I drink, I always obferve a great quantity of oily particles fwimming on the furface, which would not be found there, if the coffee were more roafted, for in that cafe the oily particles are more driven off by the force of the fire.

Many perfons fay, that coffee is not wholefome, unlefs it is made bright and clear before it be drank; but this, I think, is of no confequence, becaufe I am well convinced that the particles of coffee, (excepting the oil and falts, which I have before mentioned to be contained in it,) are of fo hard and inflexible a nature, that they never can be introduced into the fyftem of our bodies.

I have oftentimes endeavoured to bring coffee beans to a ftate of growth and vegetation, but herein I never could fucceed: whether this was, becaufe they had been kept too long, or whether, that at the place of their growth, they had been over dried, to facilitate their exportation to diftant countries, whereby the juices which fhould have nourifhed the young plant were dried away, I cannot pretend to fay.

I have feveral times placed coffee beans in a clean glafs under water, without finding any alteration in the colour of them or of the water, but when they were fo placed that part of them was above the furface of the water, then both the coffee-beans and the water became of a grafs green colour.

I formerly thought that thefe coffee beans were produced by fowing them annually in the manner of our peafe and beans in Europe, but I have been lately informed by a Gentleman who has travelled in the Eaft, that they are the feed or fruit of a tree which grows to about the fize of our lime trees.*

* The coffee-tree is a native of Arabia, from whence in the laft and prefent centuries it has been cultivated both in the Eaft and Weft Indies, but the Mocha coffee is ftill in the greateft eftimation.

ON VINEGAR.

I HAVE obferved, that on expofing a fmall quantity of white wine Vinegar to the air for a few hours, a vaft number of corpufcles, or fmall folid fubftances appear in it, which I take on myfelf to name the falts of Vinegar. Some of thefe are reprefented in Plate V. *fig.* 10; thofe at A appeared to terminate in a fharp point at each end, having in the middle a dark fpot; others were glittering like cryftals, as at B, and thefe were moft in number: others of thefe corpufcles were of an oblong figure, and of a dark colour, with a lucid fpot in the middle, as at C; and fome few of an oval form with an oval bright fpot in the middle, as at D. Among the figures A, B, D, I was convinced that I faw feveral with a cavity or hollow in them, which gave them the appearance of being half dark coloured, and half tranfparent. Others of thefe falts or cryftals laid one on another in clufters, as at E; and laftly, fome there were with points at one end only, like half cryftals, as at F. It is not eafy to defcribe the extreme minutenefs of thefe corpufcles, and fome of them were indeed, fo fmall that they almoft efcaped the view of the microfcope.

All thefe particles, which I name the falt of vinegar, I conclude to be thofe parts of it which excite on the tongue that tafte or fenfe named acid. And, although they appeared to me, through the microfcope, of the fhapes and fizes I have mentioned, yet I concluded that they were all compofed of ftill fmaller particles, of the fame fhape, in like manner as I have often in our common fea-water, or in water wherein common falt is diffolved, when placed before a microfcope, feen many particles moft exactly quadrilateral, or four-fquare, but fo minute that millions of them were not equal to a grain of fand; and thefe, while I contemplated them, would increafe in fize ftill preferving their exact fquare figure. In like manner I conclude, that there are none of thefe fharp pointed falts which I obferve in vinegar, but are compofed of numbers of fmaller particles of fimilar fhape.

Having kept in my parlour for about two months, a glafs, two fingers broad, with a fmall quantity of vinegar in it, expofed to the air, I obferved, at the end of that time, numbers of faline particles fwimming on the furface, and, upon more narrowly examining them, I plainly difcerned, what I had not fo clearly feen before, that thefe faline particles had a kind of cavity in them, as eafily to be feen, as if, with the naked eye we were to look into a fmall boat or a fhip, and which, the longer the vinegar was fuffered to ftand, grew larger: fome of thefe, with the cavity in front, are reprefented at G, and at H fome of the fame feen fideways. I alfo caufed a drawing to be made of a living eel, of that fpecies which is often found in vinegar, whereof the number I faw in this liquor was very great; this is fhewn at L M; and at N O, another eel dead, which I killed, on purpofe that the limner might take it's figure more accurately. Thefe eels (which are invifible to the naked eye) I caufed to be drawn, that by comparing them with the before-mentioned faline particles, the extreme minutenefs of thofe falts might be the better conceived, and it fhould be underftood, that by far the greater part of thefe falts could not be difcovered by the common microfcope, which made the eels vifible. I am alfo defirous to convince thofe of their error, who imagine, that the acid tafte of vinegar arifes from the pungency, or fharp, fenfation, which thefe eels are fuppofed to excite on our tongues, by their pointed tails; for, were this the cafe, many forts of vinegar would be taftelefs, becaufe none of the eels are to be found in them; and in winter time, vinegar would become vapid, or lofe it's fournefs, becaufe thefe minute eels are killed by cold or froft.

I was defirous to obferve the effect of crabs' eyes being infufed in vinegar, it being faid that they abforb or take away its fournefs, and I concluded that this muft be performed by the acute falts before mentioned being altered in figure, or rendered more foft or flexible, fo as to lofe their pungency on the tongue. I took therefore, fome new glaffes, and after mixing in them vinegar with crabs' eyes broken in fmall pieces, I found, that the long pointed falts I have before defcribed, were altered to a kind of oblong quadrilateral figure rifing in the middle in form of a pyramid, fimilar to a diamond when polifhed; thefe are reprefented in *fig.* 10, at P, others were exactly fquare, as at Q, and others of the fhape reprefented at R. But it is to be noted, that thefe particles bore no proportion in point of fize to the faline particles in common vinegar, for thefe laft were drawn from much deeper magnifiers, without the help of which, I could not have difcovered their fhapes. And, what I particularly wondered at was, that thefe faline particles were almoft all of the fame fize, which I never obferved in any other fpecies of falts. After the effervefcence produced by the mixture of the vinegar and crabs' eyes was fubfided, I drank about a third part of a thimble full of the vinegar, and found that it had no acid tafte, but a bitternefs, fo difgufting, as almoft to occafion a naufea or ficknefs.

I have alfo pounded white chalk and mixed it with vinegar, and I found that it produced the fame effervefcence as the crabs' eyes, and the fame change of figure in the faline particles, and that it alfo took away all the acid tafte of the vinegar.

OF THE SCORPION.

THE Directors of the Eaft India Company in Delft, having fent to me a living Indian Scorpion, I put it into a long and wide glafs tube, ftopped at the ends with cork, though not quite clofe; and I prefumed that, on account of the coldnefs of the glafs, the Scorpion would place itfelf on the cork, and fo be preferved longer alive: and I occafionally put it into a thinner glafs tube, in order, as far as I was able, to examine it by the microfcope.

I firft made my obfervations on its legs, the fifth joint of which, from the body, being very tranfparent, I there plainly perceived the blood running in an artery towards the extremity of the foot; which artery, I judged to be the fize of an hair of ones head and clofe befide it, the blood was returning in a vein of the fame thicknefs. Thefe two veffels I deemed to be the principal blood-veffels in that limb, and, though I was well affured, that there were many fmall branches through which the blood was conveyed out of the artery into the vein, and thus the circulation was compleated, yet I could not get a fight of thofe minute veffels.

The blood of this creature not being of a red colour, it may be ranked among thofe animals, which the antients named exfangues, or bloodlefs.

I faw that this Scorpion had two black eyes; placed, not at the extremity of the head, as we obferve in many fmall animals, by which they difcover objects on both fides of them; but thefe two eyes ftood about the eighth part of an inch towards the back part of its head, and feemed defigned for the view of objects upwards. And I difcovered, on each fide of the head, three other eyes, only an eighth part the fize of the before mentioned ones, placed in regular order befide each other, fo that thefe creatures are provided with eight eyes; and, as the two eyes on the top of the head are only fitted to look upwards, fo, thefe eyes placed on the fides are calculated to fupply the defect of the former ones. And herein we fee, with how much perfection and provident forefight, every creature, however difgufting it may be to us, is formed by Nature; and that none of fuch creatures have ever proceeded from corruption, as fome men have imagined, but have been produced by their like ever fince the Creation.

I put two living flies into the glafs with this Scorpion, in order to fee whether it would feize them as its prey; but they appeared not at all frightened at the Scorpion, even fitting upon its body, and the Scorpion was equally indifferent, and did not move itfelf on account of the flies. I afterwards put a fmall lizard, newt or eft; and likewife a fpider and a fly at the fame time into the glafs with the Scorpion; but it appeared equally indifferent to them all; and after I had kept it by me almoft three months, in which time it had not taken any food, it died.

As foon as I perceived that the Scorpion was dead, I took a pair of fmall forceps, and laid hold on that part in which I was perfuaded the poifon was depofited, and brought the fting before the microfcope; then, by a little compreffion of the forceps, I caufed the poifonous matter to iffue forth, which might be thought to be emitted at the very extremity of the fting, but upon examining the fting by the microfcope, I found that on each fide of it, near the point, was a fmall aperture.

I have caufed a drawing to be made of this Scorpion, in order to explain the nature of its fting.

Plate V. *fig.* 11, reprefents the Scorpion itfelf, and at A, is the fting, which the animal, whether in motion or at reft, always carries with its tail bent, or turned inwards, in order, moſt probably, to preſerve the ſting from any injury it might ſuſtain by the blunting of the point, or otherwiſe.

Fig. 12, F G H I, repreſents the ſting, as ſeen through the microſcope, and, between the letters G and H, may be ſeen the aperture which the ſting has, on one ſide; and *fig.* 13, K L M N, repreſents the other ſide of the ſting where the ſame aperture is to be obſerved between the letters L M.

It muſt here be noted, that the prominent part which is ſeen in *figs.* 12 and 13, at letter X, is not to be taken for a ſecond ſting, for in my opinion it ſerves only as a baſe or ſupport, to be fixed on the ſkin, in order that by its help, the ſting may be thruſt in with greater force.

Upon reflecting frequently on the make of this ſting, I conſidered with myſelf, that, if the above mentioned aperture had been at the very extremity, the ſting could not ſo eaſily have been made to pierce the ſkin: I alſo thought, that the Scorpion has not power to expel the poiſon, but that when the ſting enters the fleſh, then the ſides of the oblong cavity in it (which is ſeen in the *figs.* 12 and 13, between the letters G H and L M) are, by the preſſure on the ſting in its entrance (in regard the inner parts of this cavity are of a ſoft and yielding nature) forced inwards, and by that means the poiſon within the ſting is driven out. Now, if the Scorpion had power to eject its venom, I imagine that it would not ſtrike at any object whatever with its ſting, without at the ſame time emitting ſome of the venom; but as this is not obſerved to be the caſe, we muſt conclude, that the poiſon is kept within the ſting, until, by the force applied in piercing the ſkin or fleſh, the poiſon is driven out, and there it will exert its full force upon the juices of the wounded part.

The liquid matter, or poiſon which I before mentioned to have extracted from the ſting by preſſure (though it was in a very ſmall quantity) I put into a clean glaſs, which I prepared on purpofe, in order, if poffible, to difcover the faline particles contained in it, which alone, as it feems probable, do render this liquid poifonous in fo great a degree; but, with all my attention, I could not perceive any thing in it particularly worthy of noting.

This liquid, being in a very fmall quantity, and alfo being fpread very thin, in a fhort time, all the moifture of it was evaporated, leaving a kind of thick gummy matter, mixed with various different particles, to which I could not affign any particular figure. Hereupon, I, without lofs of time, made a puncture on my finger with a needle, and applied a fmall portion of the blood which iffued from the part, to this poifonous fubftance, in order to fee, whether the blood would undergo any alteration by the mixture. But, nothing of that kind appeared, for I could not difcern any difference between the blood which was placed on the poifon, and that which lay near it.

The next morning, I diffected the tail of this Scorpion, and, from each joint, I took out two flefhy mufcles, of a very white colour, each of which was compofed of a great number of very fmall oblong particles, terminating at the extremity of the mufcl where it grew fmaller, thus forming the tendon: on one of thefe mufcles was a kind of veffel, fhaped in the middle like a bladder, and this, I concluded, was deftined to convey the poifon to the extremity of the tail. Thefe flefhy mufcles were furnifhed with annular parts, or rings, ferving to extend and contract the mufcle.

Thofe eyes which were fituated on the upper part of the head, I placed before the microfcope, whereby I faw how perfectly the tunica cornea, or horney coat of the eye was formed; for through it I could fee all the furrounding objects (though wonderfully diminifhed) fo diftinctly, that I could not contemplate the fpectacle without admiration; but this pleafing fight was not of long continuance, for the tunica cornea foon dried and fhrivelled up.

Upon opening the belley, I could not form any judgment of the inteftines, by reafon that they had begun to decay, except that I found twelve eggs, each about the ſize of a grain of millet, of a yellow colour, and in ſhape not unlike a lemon.

In the fore part of the head, and juſt in front of the mouth, I obſerved two teeth, each fixed on a ſhort joint, and they are uſed, as I imagine, by the Scorpion, to grind its food, before it is taken into the mouth. Theſe I ſeparated from the head, and found each to conſiſt of a three-fold tooth, one of which was ſo made, as to fit exactly the cavity between the two oppoſite ones. And, to ſhew the ſtrength of theſe teeth, I cauſed a drawing to be made of one of them. *Fig.* 14, O P Q R, is this tooth, or more properly this three fold tooth, and on it, at P, are to be ſeen ſome hairs; the legs of this creature are alſo covered with hairs.

I alſo placed before the microſcope one of the claws, which are like thoſe of crabs or lobſters, and in *fig.* 11, are to be ſeen at C or D. And I cauſed a drawing of this claw to be made, in order to ſhew the curious formation of it. *Fig.* 15, S T, is the claw, magnified, and on it are plainly to be ſeen a great number of teeth or notches, like thoſe of a ſaw, ſome of them larger than others, and which ſaw-like teeth, I doubt not are ſo formed for enabling the Scorpion firmly to hold ſuch ſmall living creatures as it catches for its prey.

Seeing now, the wonderful make of this animal, though to us it is ſo deteſtible, and indeed ſo noxious; and, conſidering the perfect wiſdom requiſite for the contrivance of its ſeveral parts, we have ſurely ten thouſand times more reaſon to believe that its origin is derived from thoſe which were created at the Beginning, than to adhere to the chimæras and errors of the ancients, ſome of whom have tranſmitted to us in their writings, the notion, that Scorpions are not produced by generation, but from the great heat of the ſun; others, that they are bred from putrefaction in the bodies of crocodiles; and others again, that they are generated in rotten wood, and ſuch like fictions.

ADDITION, BY THE TRANSLATOR.

It may not be unacceptable to the Reader, to fubjoin a quotation from Dr. Mead's celebrated Eſſay on Poifons, and the rather, as the fentiments of our Author, in regard to the nature of the Scorpion's poifon, are exactly fimilar to thofe of the Doctor's, when treating of that emitted from the Viper's fangs; which animal, being much larger than the Scorpion, might afford Dr. Mead a better opportunity of inveftigating the nature of this fubftance, than Mr. Leeuwenhoek could have, in the very fmall quantity which he collected from the Scorpion's fting: and, as we fee that the operations of Nature are performed with the greateft uniformity in cafes which are analogous, it may fairly be concluded, that what Dr. Mead has faid, refpecting the Viper's venom, may be applied to that of the Scorpion, and of more minute noxious animals.

Dr. Mead expreffes himfelf on this fubject, in the following words:

'This venomous juice itfelf is of fo inconfiderable a quantity, that it is no 'more than one good drop that does the execution. And for this reafon, 'authors have contented themfelves with trials of the bite upon feveral animals, 'never effaying to examine the texture and make of the liquor itfelf: for 'which purpofe, I have oftentimes, by holding a Viper advantageoufly, and 'enraging it till it ftruck out its teeth, made it bite upon fomewhat folid, fo as 'to void its poifon; which, carefully putting upon a glafs plate, I have with a 'microfcope, as nicely as I could, viewed its parts and compofition.

'Upon the firft fight, I could difcover nothing, but a parcel of fmall falts 'nimbly floating in the liquor; but in a very fhort time, the appearance was 'changed, and thefe faline particles were now fhot out, as it were, into cryftals 'of an incredible tenuity and fharpnefs, with fomething like knots here and 'there, from which they feemed to proceed: fo that the whole texture did in 'a manner reprefent a fpider's web, though infinitely finer, and more minute; 'and yet withal, fo rigid where thefe pellucid fpicula, or darts, that they remain'ed unaltered upon my glafs for feveral months.*

'I have tried feveral ways to find out, if I could, under what tribe of falts 'thefe cryftals are to be ranged, and to difcover what alterations they make in

* A reprefentation of this, taken from Dr. Mead's work, is given in Plate V. *fig.* 16.

'the blood: and, not without fome difficulty, by reafon of the minute quantity 'of the liquor, and the hazard of experiments of this kind, fome curious friends, 'and myfelf together, made the following obfervations:

'About half an ounce of human blood received into a warm glafs, in which 'were five or fix grains of the viperine poifon newly ejected, was not vifibly 'altered either in colour or confiftence: it then was, and remained undiftin-'guifhable from the fame blood, taken into another glafs in which was no 'poifon at all.

'Thefe portions of blood were feverally mixed with acids and alkalis: the 'empoifoned blood was, after fuch mixtures, of the fame colour and confift-'ence as the other.

'Spirit of nitre, fpirit of falt, and juice of lemons, feverally poured upon 'the fanies itfelf, produced neither fermentation, nor any change of colour.

'Salt of tartar run per deliquium, and the fimple fpirit of harfhorn, dropped 'upon the venom, neither altered its colour, nor raifed any ebullition.

'Syrup of violets mixed with the poifon did not change its colour either to 'red or green.

'The tincture of heliotropium, that is, blue paper, was not altered by the 'fanies ejected upon it; and this, drying, ftill retained its yellowifh colour.

'We caufed feveral animals, dogs, cats and pigeons, to be bit by an enraged 'Viper; which generally died, fome in a longer, others in a fhorter fpace of 'time. But we conftantly obferved, that they all, immediately upon the bite, 'fhewed with figns of acute pain, marks of their life being affected, by 'ficknefs, faintings, convulfions, &c.

'The head of a large Viper lay three hours after it was cut off; it was per-'fectly flaccid and without motion. A pigeon, wounded upon the breaft with 'the fangs of this head, was prefently convulfed, &c. as from the bite of the 'animal, and died in feven hours.

'We contrived a fharp fteel needle to be made, crooked, in fhape not un-'like to the Viper's tooth, with a fulcus or hollow on the convex part, not far 'from the point: into this, we put a drop of the venom, and with it wounded 'the nofe of a young dog. It produced the ufual diforders of vomiting, purg-'ing, &c. but in a lefs degree, and the dog recovered. It was remarkable, 'that upon making the wound the dog cried but little, till the poifon came 'into it; but then he howled, &c. in the fame manner as if bit by the viper 'itfelf. But a pigeon pricked in the flefhy part of the breaft, by the fame 'poifoned needle, fuffered as from the bite, and died in about eight hours.

'We refolved to end out poifon-inquiries by tafting the venomous liquor. 'Accordingly, having diluted a quantity of it with a very little warm water, 'feveral of us ventured to put fome of it upon the tip of our tongues. We all 'agreed, that it tafted very fharp and fiery, as if the tongue had been ftruck 'through with fomething fcalding or burning. This fenfation went not off in 'two or three hours, and one gentleman, who would not be fatisfied without 'trying a large drop undiluted, found his tongue fwelled, with a little inflam-'mation, and the forenefs lafted two days; but neither his, nor our boldnefs, 'was attended with any ill confequence.

'This is no objection to the hurtful quality of this juice: for, as fome chy-'mical liquors ferment with others of a certain kind only, fo thefe poifonous 'falts may affect one fluid of the body, and not another; it is fufficient to the 'prefent purpofe to fay, that the faline fpicula are broken and diffolved in the 'mouth by the clammy falival humour: and if any of them fhould pafs thence 'into the ftomach and inteftines, the balfam of the bile will be an antidote 'there, powerful enough to overcome their force.

'Thefe experiments upon the Viper poifon and the blood, are a fufficient 'confirmation, that the nervous liquor only is affected by this venom; and at 'the fame time afford a convincing proof, how much thofe fcanty principles of 'our chymifts, acid and alkali, fall fhort in explaining the actions of natural 'bodies; fince neither of thefe falts could in any way be found to affect the 'viperine venom.'

Mechanical Account of Poifons, p. 14, & feq. Ed. 1747.

The Doctor's Effay on the Nervous Fluid and the manner in which it is affected by animal poifons, is too long to infert in this place, but the Reader will find it in the Introduction to the work from which the preceding paffage is taken; that is to fay, in the later editions, for it is not to be found in the firft, printed 1702.

Of the Oak-gall, or Gall-nut; that it is not a fruit, but an excrefcence produced on the leaves of the oak, by means of an infect; the manner of its formation particularly defcribed. A fimilar excrefcence produced in like manner on the Thiftle.*

WHILE I was employed in the fummer feafon, to collect acorns from the oak, in order to examine the beginning plant in that feed, I faw with furprize, that the gall-nuts were produced upon the leaves of the trees. This feemed the more extraordinary, becaufe I had fuppofed that they were the fruit of the tree, but now I found that they were occafionally, or accidentally produced on the leaves of the oak. I was convinced of this, partly, becaufe I faw but a few leaves here and there with gall-nuts on them, (in fome of which I found four, five, and even fix galls) and in others I could not find a fingle one; and in the next place, becaufe I faw, that thefe galls were formed upon the large fibres, or veffels in the leaves, which were burft or broken, in the places where the galls were formed; fo that I concluded that fome infect had wounded or gnawed thofe veffels, and that the juices of the tree, flowing out of the wounded part, had extended themfelves in globules and veffels, and thus, as length caufed the formation of the gall-nut.

* This is a literal tranflation of the Dutch word *Galnoot*, ufed by the Author; in the Latin tranflation it is *Galla*, which Ainfworth renders 'a fruit called gall, or oak-apple;' but this is a miftake, for the oak-apple is not the gall, nor is it formed on the leaves of the tree, but at the ends of the fmall twigs; and it is produced, not by a fingle infect, but by a great number collected together, and thofe of a different fpecies from the infect found in the gall-nut.

On my return home, I examined thefe gall-nuts more accurately, and found that each of them had a cavity in the middle, wherein lay a living white worm, which had very little motion: it was thick, in proportion to its length, and lay bent in a circular form, the body of it confifting of thirteen or fourteen rings, as we fee filk-worms and caterpillars, and thefe covered with pointed hairs.

It feemed to me worthy of obfervation, that, from this time, I obferved thefe worms, or maggots, continue alive to the end of December; and that, in gall-nuts which I had gathered in the fummer, and which were fo dried, that I thought they were fhrunk to half their former fize; whereupon I concluded that the worms, for want of fufficient nourifhment, had not arrived at their full growth, fo as to be changed into flies, and had only been fupplied with food fufficient to keep them alive. But, when they had grown to be fomewhat larger than a great pin's head, then I faw the eyes beginning to be formed, which were of a black colour.

After this, I went occafionally into the wood at the Hague, in order to purfue my fpeculations, and obferved that thefe worms were changing into flies; for, I not only could fee their eyes perfectly formed, but I alfo could difcern plainly their horns and feet, and the hind part of their bodies. This infect then lay without any motion that I could perceive, with its feet, fix in number, and its two horns lying in regular order clofe to its body, in like manner as we fee in the aurelia of the filk-worm, before it comes out of its fhell, or covering, but in this animalcule I did not then obferve any fuch cafe or covering; but only the fhape of a fmall fly without wings, the hind part of its body of a round form and of a fhining black colour, and which in a fhort time was provided with two larger and two fmaller wings: and I afterwards found that thefe aurelias had a thin covering, which enclofed the body, but not the feet.

From thefe my obfervations, I concluded, that thefe animalcules were thus produced, namely, by the before-mentioned kind of fly, laying its eggs on the leaves of the oak, where, when the young maggot is hatched, it bites or pierces the veſſels of the leaf, ſo that the juices flow out, and are hardened into globules, ſpreading themſelves, at the ſame time, in a circular form like veſſels, and thus produce what is called the gall-nut, and which juices, while hardening, do incloſe the maggot in the middle.

This newly-formed gall-nut ſupplies the animal with food, for it eats away the ſubſtance of the nut by little and little, round about itſelf, whence proceeds the cavity we find in the middle of theſe galls, and which cavity grows larger, as the animal increaſes in ſize. And it ſeems to me, that unleſs ſome of the large veſſels in the leaves were injured or perforated by one of the maggots I have deſcribed, there could not be any gall-nut formed, for in every nut which I opened, I conſtantly found a maggot (though in an hundred ſuch nuts, I found but two which contained more than one) and this, though one gall-nut was ſixty times the ſize of another.

It is however to be noted, that the wounding or biting the large veſſels in the leaves, does not conſtantly produce a gall-nut; for this is only formed, where a ſufficient quantity of the juices iſſues from the opened veſſels; to this alſo, the heat contributes much, by condenſing or thickening the juice; and hereupon it is my opinion, that where theſe veſſels are opened in the morning, galls will more eaſily be formed than when it happens in the evening; for I ſaw on thoſe leaves on which were gall-nuts, and alſo on thoſe where none were to be ſeen, the leaves and veſſels much eaten into, and the veſſels pierced through, and yet, not the leaſt appearance of the formation of a nut on the place. Farther, I concluded, that many of theſe maggots get their ſuſtenance from the leaves without piercing the large veſſels, for in many places I ſaw the leaves eaten away and in holes.

In further proſecuting my enquiries on this ſubject, I found that the beſt ſort of gall-nuts which are uſed in this country, are brought from Aleppo. Hereupon I conſulted Tavernier's Travels, to ſee what he ſays on this ſubject; and I found, that in his third book, when ſpeaking of his journey to Aleppo, he ſays, 'the 'hills are covered with oaks bearing the gall-nut, and ſome 'of them, beſides gall-nuts, alſo produce acorns.' But, after the preceding obſervations, we are not to wonder, that the ſame oak will produce both galls and acorns, ſince nothing more is wanting for the production of a gall-nut, than ſuch a fly as I have mentioned, from the eggs of which, worms ſhall proceed, which feed upon the leaves of the oak.

To ſatisfy myſelf more fully in this particular, I examined ſeveral of thoſe gall-nuts which are imported to us, and are much uſed by dyers; and in ſome of them I found a dead fly, of the ſame ſhape with thoſe found in the galls of this country, and in others, only a cavity in the middle, with a round hole reaching from that cavity to the ſurface of the nut, and in the cavity a kind of duſt, which I imagined to have been the excrements of the worm while it was in the nut. And I found upon farther proſecuting my obſervations on the galls which I gathered from the trees here, that not only the maggot is able to gnaw the ſubſtance of the nut; but alſo, that the fly has power to perforate it, to open a paſſage for itſelf, though I do not think that the fly uſes the ſubſtance of the nut for food.

In others of theſe Aleppo galls, I ſaw no appearance of any living creature having been incloſed; the reaſon of which I concluded to be, firſt, the maggot in our gall-nut, even when of its perfect ſize, is very tender, and cruſhed with the leaſt touch, and contains nothing in it, but a whitiſh fluid ſubſtance, ſo that if a maggot happens to die in the nut, whether from the juices being too acrid, or the nut too hard, in ſuch caſe, the ſubſtance of the worm may ſo dry away, as to leave no traces behind it. In the next place, a maggot, when grown to a conſiderable ſize, may pierce a large veſſel in the leaf, and afterwards ſhift itſelf to another place, and out of the large veſſel ſo wounded, a gall-nut may be produced without any maggot in it. The gall-nuts which are formed without any inſects in them, are generally the heavieſt, by reaſon that they have not any cavity made in their inſides.

With regard to my preceding obſervations on this ſpecies of fly, I was the more confirmed in my opinion, upon recollection of what I have obſerved of the like kind in divers trees, and particularly the willow; on the leaves of which I have ſeen certain green tubercles or ſwellings, on opening which I have found animalcules within them, ſome of which were alive, and others dead; all which I doubted not were produced by maggots hatched from the eggs of the flies of the ſame ſpecies as thoſe which I had found in ſuch tumors or ſwellings. For it is with me an eſtabliſhed principle, that no living animal, whether worm, fly, gnat, or mite, can be produced from the mere juice or leaf of any tree or plant, nor from corrupted or decayed ſubſtances.

I have cauſed a drawing to be made of theſe galls, as they grow or are produced on the leaves; and in Plate V. *fig.* 17, A B C D, is repreſented an oak leaf, with that ſide upwards, which, when on the tree is undermoſt; for I never ſaw any of theſe galls on the upper ſide of the leaf; the reaſon of which I take to be, that if the maggot was placed on the upper ſide, and expoſed to the ſun's heat but for a ſhort time, it would, by reaſon of its ſmallneſs, be dried up and periſh. On this leaf are ſeen two large galls, and two ſmaller ones, at the letters E, F, G, H.

Fig. 18, 18, exhibit a gall-nut cut in half, wherein, at N, N, appears the cavity, in which the maggot lay; ſome of theſe maggots, of different ſizes, are ſhewn at I, K, L, M.

Fig. 19, ſhews one half of a gall-nut, with the fly in it, which has opened to itſelf a paſſage from the cavity as far as the ſurface of the nut, and at *fig.* 20, is the other half, exhibiting the cavity in the center, formed by the maggot, and the perforation to the circumference made by the fly.

Fig. 21, is the fly bred in this gall-nut, whofe body is not quite fo large as reprefented in this figure, but the wings are of the fame fize as they appear here.

After thefe obfervations, in the month of January, I again went in fearch of gall-nuts, upon the leaves of the young oaks, and thofe which hung near the ground; and I found a great number of them, although the leaves were very much dried: in many of thefe galls I faw the perforation through which the fly had iffued; in others of them I found living flies; and in others, living maggots.

Some of thefe galls I placed in my clofet, and opened them at different intervals of time, and I always found either the maggot in them alive, or a hole, through which the fly had iffued: ten of thefe I kept till the end of April, and upon opening them, I found them all perforated with holes, and the flies which had iffued from them, lying dead.

While I am on this fubject, I can not forbear to mention, that in the autumn there were brought to me a parcel of roundifh fubftances, which were gathered from thiftles, and therefore, called thiftle-nuts. Many of our countrymen carry thefe nuts in their pockets, under a notion that while they wear them, they fhall be free from the diforder called the piles, particularly if every year, they throw away the old nuts and procure frefh ones (which, it is faid, do not grow in our province). And fome fay, that there is a maggot in thefe nuts, and that while it lives, the before mentioned virtue remains in the nut, but upon its dying the virtue is loft.

As foon as I faw thefe fuppofed nuts, I concluded that they were produced, as I might fay, by accident; and that their virtue againft the piles was a mere imagination. And upon examining the nuts, I found that there was not one of them which had not one, two, three, four, and ſome as many as ſeven or eight cavities in it, each cavity containing a ſhort, white aurelia, or cryſalis, formed of many joints like rings; theſe aurelias were almoſt all alive, and I judged them to have been produced from maggots, the offspring of ſome fly or ſuch like inſect, which had laid its egg on the thiſtle; and that thoſe maggots having pierced the veſſels of the thiſtle, while in the flouriſhing time of its growth, had occaſioned a copious effuſion of juices, by means of which a tumor or ſwelling had been formed upon the thiſtle, which had incloſed the maggot, and formed a ſolid ſubſtance round it. And upon further proſecuting this ſubject, to elucidate my own poſition that theſe nuts had been produced by means of maggots, I opened ſeveral of them at different times in the ſucceeding winter, preſerving the aurelias; and at length, towards the end of the April following, they produced a ſpecies of black flies, different from any I had before ſeen, for the hind part of their bodies terminated in a point, forming a kind of ſheath, wherein was contained a ſmall ſting.

I thought it would not be amiſs, to exhibit to the view, the ſhape and make of theſe nuts, in order to ſhew the ſizes of them and of the cavities they contain; and alſo how far, fancy and imagination will go with ſome people.

Plate V. *fig*. 22, 23, 24, repreſent three of theſe thiſtle-nuts dried, and of different ſizes.

Fig. 25, is one of the ſame nuts, cut open on the ſide, where may be ſeen two cavities, one of them, at A, containing an aurelia.

Fig. 26, is the fly produced from this aurelia.

Fig. 27, is a thiſtle-nut cut acroſs, ſhewing ſeven cavities, wherein the aurelia had lain.

INTRODUCTION to the SECOND PART.

As I have entitled this Tranflation, The difcoveries of the Author in many of the Works of *Nature*, a term ufed by himfelf) I fhall take the liberty to lay before the Reader a few words, refpecting the idea we ought to annex to that expreffion.

By the word Nature, here ufed, I underftand that unfeen power whereby different parts of Matter are brought together, and, by their various combinations and modifications, produce thofe bodies or fubftances which we obferve on this terraqueous globe. Matter, is that *Something*, of which Bodies are compofed, and I call it Something, becaufe its primary or original particles are fo minute as to be entirely undifcernible by us; and it is not until they are combined or collected in larger portions that they become objects of our fenfes. This is capable of demonftration many ways: for example, Earth, which, in itfelf, has little either of tafte or fmell, produces herbs, flowers, and fruits, poffeffing an endlefs variety of taftes and odours; and not only fo, but of natures entirely different from each other, the fame fpot of earth which produces wholefome herbs for our tables, bringing forth alfo the moft noxious plants, according to the quality of the feed or plant committed to it: and yet, we cannot trace thefe various taftes and odours, nor thefe wholefome and noxious properties, in plants, to any other original than the fame common parent Earth, aided by fuch fupplies as they receive from the other *elements. Herbs, taken into the ftomachs of animals, are converted

* Water, it is well known, is effential to the growth of plants, neither will they vegetate without a fupply of Air, a fluid eight hundred times lighter than water; and, it is the opinion of Sir Ifaac Newton, that Light, which is beyond all conception more rare and fubtile than air, does enter into the compofition of Bodies.

into the flefhy parts of their bodies, and even compofe the folid fubftances of the bones and teeth: and all thefe vegetable and animal fubftances do, by putrefaction, return to the general mafs of Matter from which they were firft formed, and enter into the compofition of new Bodies. Again, water evaporates, or is carried up into the atmofphere, in particles fo fmall as to be invifible to us; and even mercury or quickfilver, the heavieft of all fluids, upon the application of a moderate degree of heat, flies off in vapour, and, unlefs confined by fome folid body, fuch as a chemift's retort, wholly difappears. Arguing then, from thefe appearances, we muft conclude, that the elementary or original particles of Matter, are not, as fuch, difcoverable by us. And, as far as ocular examination can reach, Mr. Leeuwenhoek has given it as his opinion, that, had he been able, by the help of glaffes, to have difcerned objects, millions of times fmaller than thofe his microfcopes difcovered, he could not have traced Bodies to their original component particles.

Some Philofophers have fpent much time in arguing on the infinite divifibility of Matter, and in propofing ftrange * theories refpecting its inherent properties. But herein, they feem to have exercifed their wits, without much improving their underftandings; for furely, it is of no utility to propound queftions, which cannot poffibly be brought to the teft of experiment. In oppofition to thefe vain fpeculations, how wife, and, at the fame time, how modeft, are the words of Sir Ifaac Newton: † "It feems probable to me, that God in the Be-"ginning, formed Matter, in folid, maffy, hard, impenetrable, move-"able particles, of fuch fizes and figures, and with fuch other proper-"ties, and in fuch proportion to Space, as moft conduced to the end for

* Such as that of fuppofing the cohefion of bodies to be caufed by their particles being formed with little hooks; and, that repulfion proceeds from other particles being made like hoops rolled up, and afterwards expanding themfelves.

† Newton's Opticks, Qu. 31, near the end.

" which he formed them; and that these primitive particles being " Solids, are incomparably harder than any porous bodies compounded " of them, even so very hard as never to wear or break in pieces; " no ordinary power being able to divide, what God himself made one " in the first Creation. While the particles continue entire, they may " compose Bodies of one and the same nature and texture in all ages; " but, should they wear away or break in peices, the nature of things " depending on them would be changed. Water and Earth, com- " posed of old worn particles, and fragments of particles, would not " be of the same nature and texture now, with water and earth com- " posed of entire particles in the Beginning. And therefore, that " Nature may be lasting, the changes of corporeal things are to be " placed only in the various separations and new associations and mo- " tions of these permanent particles; compound bodies being apt to " break, not in the midst of solid particles, but where those particles " are laid together, and only touch in a few points." This seems to be the *ne plus ultra*, or utmost extent of human sagacity, terminating in a conclusion, worthy of that great Philosopher and good Man. In conformity to which, I think we may say, that the particles of Matter are not infinitely, but indefinitely small, or, in other words, so minute as to be singly, invisible to us, though collectively, they are the daily objects of our senses. It now remains to consider the properties of Matter, or, the means by which its particles are brought into action.

The Honourable Mr. Boyle has written an Essay on this subject, wherein he refutes the error of the ancient heathen Philosophers, and their followers among the moderns, the Schoolmen, who figured to themselves, an active, intelligent Being, which they called Nature; subordinate indeed to the Deity, but yet, presiding over the mundane System, and directing its operations. He shews, in a variety of instances, that the supposition of such a Being, is insufficient to solve the different phænomena in the ſyſtem, and, that it detracts from the honour of the Author and Governor of the World: And he gives us his opinion on the ſubject, in theſe words: * "Since the preſent is a "philoſophical enquiry only, we ſhall only, at preſent, conſult the "light of reaſon in the formation of the World, which might proba- "bly be after the following manner. The great and wiſe Author of "things, firſt forming the univerſal undiſtinguiſhed Matter, put its "ſeveral parts into various motions, by which they muſt needs be di- "vided into innumerous particles of different bulks, figures, and ſitu- "ations; guiding and over-ruling the motions of thoſe parts, by his "wiſdom and power, ſo as to diſpoſe them into that beautiful and "orderly frame we call the World; ſome being ſo contrived, as to "form ſeeds, or the ſeminal principles of Plants and Animals. Be- "ſides, he ſettled ſuch laws or rules of local motion, amongſt the parts "of Matter, that, by his ordinary concourſe, the parts of the Univerſe "once compleated, ſhould continue the œconomy of the Univerſe, and "propagate the ſpecies of living creatures." And again, he ſays, "If we ſuppoſe the univerſal laws of motion to be eſtabliſhed, and "that, by their conventions, the ſeminal principles of various things "were contrived, by the local motion of Matter, ſkilfully guided at the "beginning, and that God's ordinary and general concourſe, contri- "buted to perfect the Univerſe, and continue it ſo, there is no need of "any diſtinct powerful intelligent Being to aſſiſt him, as Nature is "repreſented; ſince the Phænomena which occur, will flow from the "mere fabrick and conſtitution of the World."

The learned Dr. Mead has a paſſage on this ſubject of Nature, when applied to animated bodies, which I the rather quote, as it contains a reproof to thoſe viſionary Philoſophers I have mentioned.

† "Whereas the Word *Nature*, is made uſe of by Phyſicians, in

* Enquiry into the received notion of Nature.

† Mead on the Small Pox, Chap. II.

" the cure of all diseases, I will here, once for all, plainly declare my " sentiments of what we ought to understand by that word. That " there is something within us, which perceives, thinks, and reasons, " is manifest beyond contradiction: And yet, the nature of that " *something*, cannot be fully and perfectly comprehended in this life. " Wherefore I shall resign the disquisition of this point to those, who, " while they know too little of, and care less for, things falling under " their senses, take great pleasure in investigating those things which " human reason is incapable of conceiving. However, thus far the " soundest Philosophers agree concerning it, that it is somewhat in- " corporeal. For, how can sluggish Matter, which is, of itself, void " of all motion, be the source and first cause of Thought, the most " excellent of all motions? Wherefore, it is sufficiently evident, " that this first mover within us, is a spirit of some kind or other, " entirely different and separable from terrestrial matter, and yet, " most intimately united with our body."

" Moreover, to me, it seems probable, that this active principle, is " not of the same sort in all; that the Almighty Creator has en- " dowed man with one sort, and brutes with another; that the for- " mer so far partakes of a divine nature, as to be able to exist, and " think, after its separation from the body; but that the latter is of " such an inferior order, as to perish with the body."

" Now this matter, if I am not mistaken, stands thus: Such is the " composition of our fabrick, that when any thing pernicious has got " footing within the body, the governing mind gives such an impulse " to those instruments of motion, the animal spirits, as to raise " those commotions in the blood and humours, which may relieve " the whole frame from the danger in which it is involved. And " this is done in so sudden a manner, that it should seem to be the " effect of instinct, rather than voluntary motion, though it be " effected at the command of the active principle. And, indeed, those

" very motions, which are commonly called natural and vital, as " thofe of the heart, lungs, and inteftines, which perfevere through " the whole courfe of life, even when the will cannot be concerned " in them, as they have their beginning from the mind, fo they are " perpetually under its direction."

Sir Ifaac Newton, in that part of his works above quoted, expreffes himfelf as follows: " All material things feem to have been " compofed of the hard and folid particles above mentioned, varioufly " affociated in the firft Creation, by the counfel of an intelligent Agent. " For, it became him who created them, to fet them in order. And, " if he did fo, it is unphilofophical to feek for any other origin of the " World, or to pretend, that it might arife out of a chaos, by the " mere laws of Nature ; though, being once formed, it may continue " by thofe laws, for many ages. For, while Comets move in very " eccentrick orbs, in all manner of pofitions, blind Fate could never " make all the Planets move one and the fame way, in orbs concen- " trick, fome inconfiderable irregularities excepted, which may have " arifen from the mutual actions of Comets and Planets upon one " another, and which will be apt to increafe, till this Syftem wants " a reformation. Such a wonderful uniformity in the Planetary " Syftem, muft be allowed the effect of choice. And fo muft the " uniformity in the bodies of animals they having generally, a right " and a left fide, fhaped alike, and, on either fide of their bodies, two " legs behind, and either two arms, or two legs, or two wings before " upon their fhoulders ; and, between their fhoulders, a neck run- " ning down into a back bone, and a head upon it ; and, in the head, " two ears, two eyes, a nofe, a mouth and a tongue, alike fituated. " Alfo, the firft contrivance of thofe very artificial parts of animals, " the eyes, ears, brain, mufcles, heart, lungs, midriff, glands, larynx, " hands, wings, fwimming bladders, natural fpectacles, and other " organs of fenfe and motion, and the inftinct of brutes and infects,

" can be the effect of nothing elfe, than the wifdom and fkill of a " powerful ever-living Agent, who, being in all places, is more able, " by his will, to move the bodies within his boundlefs uniform " *Senforium, and thereby to form and reform the parts of the Uni- " verfe, than we are, by our will, to move the parts of our own " bodies."

I hope I may be permitted to add to the opinions of thefe great men, an obfervation, which, I think, muft have occurred to them, though they have not particularly mentioned it, except Sir Ifaac Newton, in the laft lines of the paffage I have quoted from him. The laws of motion which, according to Mr. Boyle, were eftablifhed at the Beginning, and afterwards, continued, by what he calls, " the " ordinary concourfe of the Creator, " and which principles are ftiled by Sir Ifaac Newton, " the laws of Nature," cannot have any force without the fame exertion of power to fupport them, by which they were at firft created. Nor can the incorporeal mind or fpirit, mentioned by Dr. Mead, preferve its activity without the continued influence of the Supreme Mind. For, the cafe is not analogous to what may be fuppofed of a workman, conftructing a machine, which fhall for a length of time continue in motion, without his intervention; nor to that of a mafter, giving directions to his fervants to perform, what they afterwards accomplifh of themfelves. For, in the one inftance, the machine, if its firft mover be a weight, is kept going by the law of gravity, and, if a fpring, by the power of elafticity, both which are entirely independent of the workman; and, in the other inftance, the fervant executes his mafter's commands by virtue of the powers of felf volition and action he poffeffes, independent of that mafter, though, for the time, he willingly applies thofe powers to the accomplifhment of the tafk affigned to him. But, we cannot

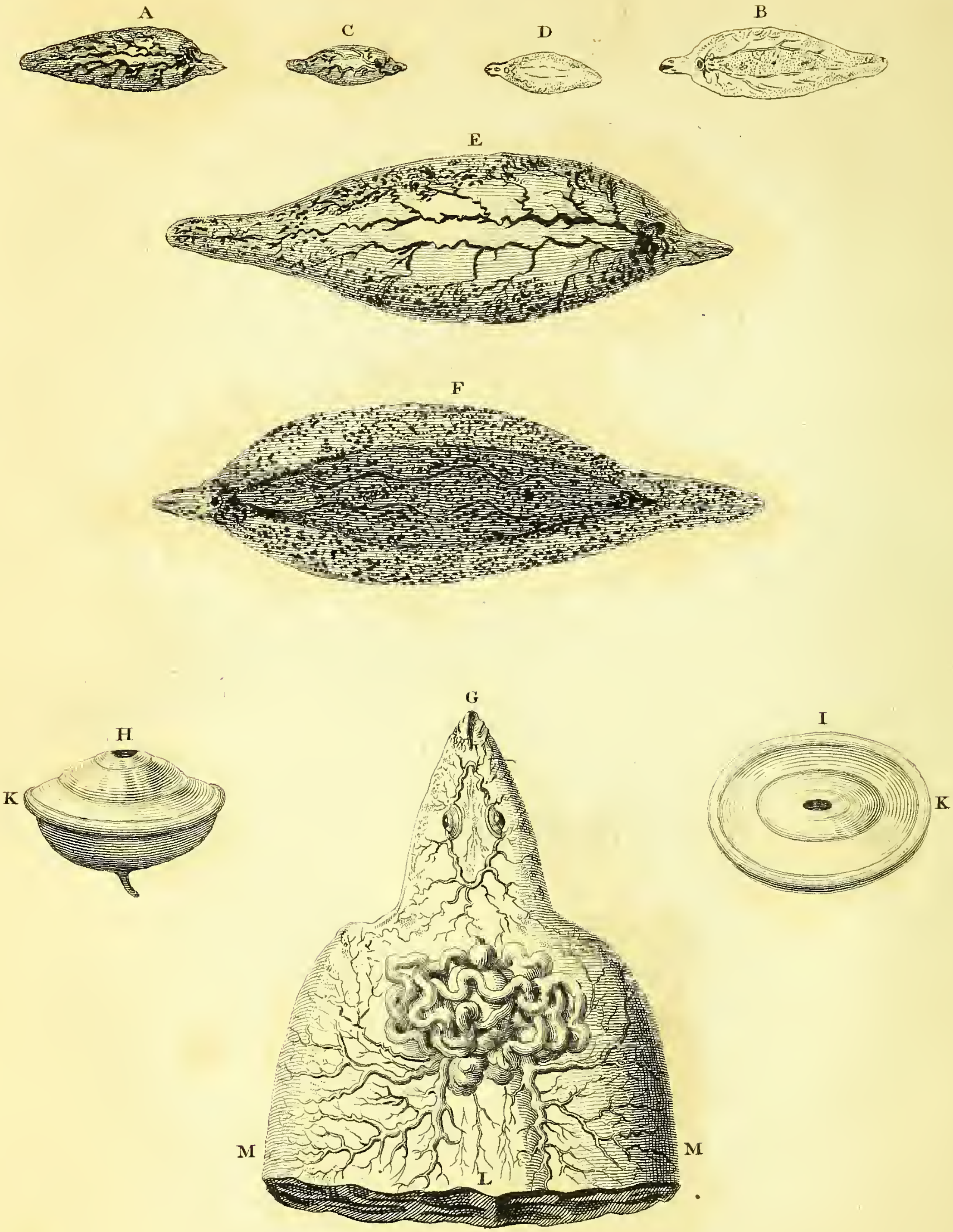
* Senforium, means the feat of confcioufnefs or perception, in animated Beings; and, when applied to the Deity, his Omniprefence makes it to be every part of Space.

conceive any active principle to exiſt, in either Matter or Spirit, without the ſupport of the firſt Cauſe; for this would be to ſuppoſe more than one active independent Exiſtence, which Dr. Clarke has proved to be the greateſt abſurdity.* Upon the whole, when we inveſtigate this ſubject as far as our faculties will extend, we cannot do otherwiſe than reſolve all, that we call the operations of Nature, into the continual agency of the firſt Creator. And, though we are loſt in the idea of ſuch immenſe and inceſſant energy, we are equally ſo, in the contemplation of any other of the Divine Attributes, foraſmuch as finite capacities cannot comprehend Infinitude.

While we poſſeſs theſe ſentiments, and keep the idea of Nature, and the Author of Nature, connected, (which it is not eaſy for a reflecting mind to ſeparate) I cannot, for my part, but approve the † perſonifying figure, which I think more decorous than to name the Deity on every trivial occaſion: and Mr. Leeuwenhoek ſeems to have been of this opinion, for he frequently uſes the expreſſion "de voorſichtig Natuur" *i. e.* provident Nature, but when the wonders he diſcovers excite his admiration, that admiration is always directed to the Creator.

* Clarke's Demonſtration of the Being and Attributes of God.

† The Ancients pictured Nature in a female form, to denote her fruitfulneſs; and, with many breaſts, to typify the abundant proviſion made by her for her different productions.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* *The Author's opinion and reaſoning reſpecting the formation of that ſpecies of fuel which is called Peat*†, *and alſo with regard to the trees dug out of thoſe places where Peat is found: from whence he takes occaſion to propoſe and diſcuſs a queſtion, whether the Sea may not, in proceſs of time, become more elevated in reſpect of the Land.*

I HAVE heard many perſons deliver their ſentiments, reſpecting the manner in which that ſubſtance called Peat was produced in this country of Holland. The general opinion is, that the place where this Peat is found was, in former ages, nothing but a wood, and that the falling leaves and ſmaller branches or twigs of the trees, collecting together on the earth, did in proceſs of time, produce this ſubſtance, which is by us called Veen. It is alſo believed, that thoſe trees, numbers of which are found among the Peat, formerly grew in the ſame place, and were all blown down by ſome violent tempeſt of wind

* In this Eſſay, the Author departs from his uſual method of inveſtigating the works of Nature by the microſcope, and proceeds upon theory. It will be ſeen, however, that he does, in one inſtance, draw a very ſtrong argument in ſupport of his hypotheſis, from microſcopical examination.

† The words Peat, and Turf, are ſometimes uſed promiſcuouſly, though their true meaning is very different. Turf, properly ſo called, as denoting an article of fuel, is compoſed of the thick roots of graſs, pared off the ſurface of the earth on commons, and dried in the ſun. The bark of oak, after it has been uſed by the tanners, made up into ſquare pieces or cakes, and dried, is ſold in London for firing, under the name of Turf. But Peat, of which the author here treats, is found under the ſurface of the earth, ſometimes to a conſiderable depth.

from the North-Weſt, and that for this reaſon, the roots of all the trees ſo dug up at this day do point towards the North-Weſt.

Theſe opinions I have often controverted: for how can it be imagined, that ſo great a quantity of Peat could be produced from trees ſtanding together in a wood; inaſmuch as Peat is in ſome places found collected to the thickneſs of ten or twelve feet, and ſometimes more? Neither can it be conceived, how thoſe large oak trees, which are now found, lying in the midſt of the Peat, could ever have grown to their full ſize in ſuch a ſoil, for, a common ſtorm of wind would have been ſufficient to blow them down.

Again, it is well known, that thoſe trees which are found at a conſiderable depth in the Peat never have on them the ſmall branches on the ſtem, nor any ſmall ramifications on the roots, and all thoſe ſmall light branches of alders and willows which are found in Peat, are not (as far as I have ever known) firm or ſolid in their kinds, but very much decayed, the ſame as if they had been for ſeveral years expoſed to the air, or had died and withered on the trees, or were almoſt rotten. Theſe decayed portions of wood cannot, as I conceive, have grown in the places where they are now found, but muſt have been carried thither by ſome flood, or ſtream of water, and that they either floated on the water, or had lain expoſed to the air for ſeveral years, and therefore may properly be denominated decayed wood; and I remember, that on handling ſome pieces of willow about the thickneſs of a finger, which I myſelf ſaw dug up, I found them as ſoft and flexible as a withered carrot.

Now, if thoſe oak trees, which are found at a great depth in the Peat, had originally grown in the ſame place, ſuch trees would certainly be found with the ſmall branches on their ſtems and roots, if not in the whole, at leaſt in part, and thoſe not decayed, for in the very ſame places there have been found in the Peat, hazle-nuts, with their ſhells entire.

We know that thefe trees lye eight or ten feet below the furface of the Peat, which furface is, in fome places, four feet lower than the fea at low water; how, then, can it be conceived that thofe trees could have grown in fuch low lands, unlefs we fuppofe that the level of the fea was at that time full twenty feet lower than it is at prefent?

To this may be added, what I have myfelf been an eye-witnefs to, that a violent ftorm from the North-Weft has fo agitated that river which we call Hollands Diep, or Haring Vliet, as to tear up from the bottom large portions of a fubftance fimilar to our Peat, but fo light, as to be carried by the waves againft the banks, and there left, fometimes in pieces larger than a cart-load, which fubftance I was told the poorer fort of people carried away for fuel. Now, it is impoffible that this Peat-like fubftance raifed from the bottom of the Haring Vliet, and which, like Peat, is compofed of leaves, fmall fibres of the roots of trees, and other vegetable fubftances (and who knows how deep the bed thereof may be?) could ever have grown in that place.

I once faw Peat taken up from the depth of ten feet, in a watery place, where it had never before been dug. I examined the texture of it, and found it in part to confift of an herb called heath, which herb does not grow in our Peat-lands. And I have alfo feen Peat dug up at a confiderable depth under the fands, not in regular ftrata or beds, but in broken interrupted patches, and fometimes in a large body collected. This Peat I examined, and found that it confifted of leaves of trees, the roots of grafs, the ftalks of leaves, and very fmall pieces of wood; in fhort, there is no vegetable fubftance that grows wild of itfelf, but what, upon an accurate inveftigation, will be found among Peat.

Some years ago, being on a journey at a fmall diftance on this fide of Haerlem, I faw in a meadow by the road fide, a labourer digging in the earth in a cavity as deep as an ordinary man's height; and, being curious to know what he was taking up, I alighted from my carriage, and found that it was Peat which was laid by in pieces to dry for firing.

In the place where this man was digging, the Peat lay only in ſmall parcels, or collected portions, and near the ſame ſpot there was not any token or appearance of Peat. I was at the ſame time ſurprized, to ſee lying on the ſand among the Peat, a certain ſubſtance of a fine blue colour, and I was told, that, near the place, it had been found in a larger quantity, and enough of it collected to fill a ſmall caſk, which had been carried away and ſold.

At another time, in paſſing through the town of Helvoetſluys, I obſerved before the houſes of ſeveral poor people, parcels of Peat piled up to dry, and I was told that it was good fuel, but produced a diſagreeable ſmell, and that it had been dug out in enlarging the dock for ſhips; and on breaking ſome of this Peat in pieces, I perceived in it ſome ſmall ſhining particles, which induced me to carry home a ſmall quantity of it, that I might examine it by the microſcope.

I was informed, that this Peat was dug in a place where there had formerly been a dyke, or bank againſt the ſea, and that the peat did not lye in a regular bed, but only in three places, and that under it was the kind of ſand we call klapzand, all which, upon examination, I found to be as related. Hereupon I concluded, that this ſand, called klapzand, had in former times been the ſea-ſhore, and that the Peat had by floods been brought to the three places where it was now found, and afterwards covered with ſand from the ſea, or that waſhed down the river.

On my return home, I examined this Peat by the microſcope, and found, that the before mentioned ſhining particles were the ſeeds of ſome plant, which, if they had been larger, might have been taken for beans, but theſe were ſcarcely the fifteenth part of an inch in diameter. Other ſhining particles I alſo obſerved in this Peat, which, upon a more accurate examination, I found to be pieces of the ſkins of thoſe flying inſects which are produced by tranſmutation from maggots or caterpillars, who hide themſelves in the earth; and, among others, I ſaw ſome pieces of an inſect of the beetle kind, which, as it frequently creeps into the earth, has its wings covered with a kind of ſhell or caſe for their defence, in like manner as we obſerve in thoſe inſects which are called by children cockchafers and ladybirds.

I alſo diſcovered divers pieces of the bodies of various ſmall animals, in which I could diſtinguiſh thoſe little cavities or ſpots which are obſerved on inſects, particularly on the caſes covering the wings; alſo on ſome of theſe fragments I ſaw very minute hairs, ſuch as the bodies of inſects are generally covered with, likewiſe ſome fragments of wings with hairs on them. I found alſo a kind of ſting of ſome inſect, and at the extremity of it an aperture, ſuch as is ſeen in the ſting of a ſcorpion; in a word, I found an incredible number of particles or broken fragments of inſects of various kinds and ſizes, conſidering the ſmall quantity of Peat in which they were contained, ſo that it may fairly be concluded, that all thoſe inſects had been promiſcuouſly collected together when the earth on which they lay had firſt been waſhed away.

In the ſame portion of Peat were various particles, appearing to the naked eye like the ſtalks of graſs or plants, and ſuch I found them by the microſcope to be, and by it I plainly perceived the tubes or veſſels of which they were compoſed. I alſo diſcovered ſome few particles, which ſeemed to be the huſks of ſeeds, and others which I imagined were the rinds or bark of twigs.

All theſe particles, of the many different kinds I have enumerated, were contained within the compaſs of a portion of Peat not exceeding a cubic inch in ſize.

From theſe obſervations it appears, how incorruptible are ſome ſubſtances, when buried deep under ſand and water, when the ſame ſubſtances being expoſed to the air, and in frequent agitation, are ſo divided and broken that they eſcape our ſight, and then we ſay they periſh; and who knows whether this Peat-like ſubſtance might not have lain for ſome thouſand years under the ſand and ſea water before the place became firm land?

It is well known, that not only in Holland, Guelderland, and Utrecht, but alfo on all the fea-coaft, as far as Holftein, much Peat is found; and if it be true, as is generally believed, that not only England and Scotland were formerly united to Ireland, but that the Orcades, Shetland, and Faro, and the other fmall iflands near them, were formerly united (which iflands being rocks, or rocky on their fhores, are able to refift the force of the fea), and that in thefe iflands this Peat-like fubftance is alfo found, we can without much difficulty folve the queftion, if we fuppofe that thefe larger and fmaller iflands, by violent ftorms and high tides of the ocean, may have been feparated from each other, and that the earth or foil which was then carried away, was covered with various trees, grafs, and herbs; all thefe fubftances floating on the fea, might, by the tides and North-Weft winds, be driven to the places where they now lie; and the trees which we find lying with their roots pointing to the North-Weft, muft of neceffity be depofited in that pofition: for, as the roots of trees are heavier than the upper parts of the ftem, thofe roots muft fink deepeft in the water, and, being dragged along the bottom of the fea, the ftems would be driven foremoft, and caufe the trees, when wafhed on the land, to lye with their roots towards the North-Weft. The heavier fubftances, as fand and clay, which had conftituted the foil fo carried away by the fea, would, by their weight, fink to the bottom, and, taking the fame courfe with the Peat, would be thrown upon it, and produce a fandy fhore, as we now perceive it.

It is further to be confidered, that our rivers, the Rhine and the Maes, do every year bring down with them great quantities of foil, and particularly in the fpring time, becaufe at that feafon, by the fun and rains, the fnow is melted on the tops of the high mountains, and, running over the lands, wafhes away with it great quantities of fand, clay, and earth, and thefe, by reafon of the fwift current of thofe waters, find no reft until the rivers, becoming wider at their mouths, and meeting alſo the flood from the ſea, their current is diminiſhed, and the ſand ſubſiding, produces ſhallows. In theſe ſhallows, the clay and earthy ſubſtances alſo ſettle, becauſe in thoſe places the waters have little motion, in proportion to what they have higher up the rivers, and, by this means it is well known that there is a continual increaſe of dry land in ſome parts of our ſhores.

If we obſerve attentively our ſea-coaſts, we ſhall in ſome places, even thoſe which the ſea daily breaks againſt and waſhes over, obſerve large pieces of black earthy matter, very compact and cloſely cohering, and which lye partly covered with ſand, and partly overflowed every tide. Theſe portions of earthy matter ſo depoſited, produce a ſtrong argument, to convince us that our ſhores thus waſhed up by the ſea, were not merely formed by ſmall quantities of ſoil gradually depoſited, but by large portions or fragments of land. And, who knows how long ſuch fragments of land might, by reaſon of their gravity, lye at the bottom of the ſea before they were thrown upon the ſhore, which, in all probability, could not be effected otherwiſe than by violent ſtorms, and that, many years after the ſhoaly or ſandy bottom was firſt formed.

The magiſtrates of Leyden had it lately in contemplation, if it could have been done, to make a channel, outlet, or opening for water, into the ſea at Catwick, in the place where the Rhine formerly diſembogued itſelf; but they found the undertaking to be impracticable, by reaſon that the level of the ſea was too high at that ſpot. This, at firſt, appeared ſtrange to me, as I could not conceive how the ſea could obtain a greater altitude than in former ages, ſeeing there is not a greater portion of waters on our terraqueous globe, than at its firſt formation. But the difficulty ceaſed in my mind, when I conſidered, what quantities of fine ſand and ſlime, or clay, are continually carried down our rivers, inſomuch as to make firm land, where formerly it was deep water; and further, what large rivers there are in other parts of the world, all which carry great quantities of fuch fand and flime into the fea; whereby, at the mouths of thofe rivers many levels of marfh land are produced, while on the other hand, moft countries far diftant from the fea are mountainous.

If we then conclude, that, by all thefe rivers, a great quantity of fand and earth, and whatever is heavier than the water, is depofited in the fea, it neceffarily follows, that the fea muft from time to time be more elevated. Again, by earthquakes, large portions or tracts of land are buried in the fea, leaving nothing but lakes in their place; and we have inftances of a volcano or burning mountain cafting fo many rocks and ftones into the fea, as to raife iflands where before it had been deep water.

In the year 1692, by an earthquake in the ifland of Jamaica, a large fpace of land was fwallowed up, and converted into a lake; and, at the diftance of thirty miles from the fea, two hills, by the fide of a river were thrown down, caufing the river to take another courfe; from which new channel, a great quantity of earth muft have been carried into the fea: and although the coaft of Norway, and that of Ireland, Scotland, and part of England, are rocky cliffs, yet their rivers muft continually carry much folid or heavy matter with their waters, and, the beating of the waves againft the cliffs, will carry thefe kinds of fubftances into the bottom of the fea, and fo elevate its furface.

To fome perfons this affertion may feem ftrange, as judging that the great extent of the fea bears no proportion to the fmall quantity of earth which the rivers wafh into it; and that therefore, the fea cannot be fo much elevated, as to make any perceptible difference in feveral hundred years.

In order to fet this matter in a true point of view, I have made a queftion with myfelf: Suppofing the mountain called the Peak of Teneriffe, to be funk in the fea, what elevation would it produce in the general ſurface of the water? Now, (conſidering the whole of this globe to be one third part land, and two thirds water) I compute that the whole ſurface of the waters would be thereby raiſed between one fourth and one third of an inch. And, ſuppoſing all the rivers in the world, which are very numerous, (for according to our maps Spain and Portugal only, contain one hundred) do yearly carry with their waters into the ſea ſo much earth as is equal in ſize to one half of the Peak of Teneriffe, the ſea would, in the ſpace of one hundred years be elevated nearly two feet.

This being ſo, it is not to be wondered, that we find our flood tides, in ſtrong winds from the North-Weſt, to riſe higher than they were known to do in former times, and that the Rhine, which heretofore fell into the ſea at Catwick, cannot now have any outlet that way; and laſtly, that on the ſame account, we are obliged to raiſe our dykes higher than formerly. Indeed, we may conclude, that if in a courſe of many years, there ſhould not be more ſpace given to the waters of the ocean, by earthquakes or ſubterraneous fires, producing cavities in the deep, the low lands near the ſea will at length be overflowed.

As to the quantity of land excavated in digging Peat, which ſome may imagine affords room to the waters, the ſpace of earth or ſoil ſo taken away, does not, in my judgment, amount to a thouſandth part of the ſand and clay which is brought down the rivers, and beſides, the places ſo excavated are, for the moſt part, afterwards drained.

On the effects of Acids in the Stomach, and the use of Fish Diet, with a particular description and examination of the liquor or substance named Runnet, which is used in the making of Cheese.

IT is the opinion of many medical persons, that various disorders in the human frame are caused by acid in the stomach, which coagulates the juices; and some condemn the use of acids, and also of fish, as articles of food. But to these opinions I cannot subscribe, for, at a town in my neighbourhood, where the people get their living by fishing, and principally feed on fish, especially when they are on the sea, the men are very robust and healthy, even to a great age; and, with respect to myself, I have experienced, that, when my habit of body has been indisposed, I have been greatly refreshed by eating fish, with sauce composed of a mixture of butter and vinegar, and I never found acid sauces disagree with me. It is also my opinion, that a fish diet is more wholesome than flesh, particularly to those persons who do not use much exercise, because fish is more easily comminuted and digested in the stomach and bowels than flesh; and, as flesh affords a more nutritious substance, such superabundant nutriment is, in my opinion the source of many diseases. And, I think it may be made appear, that the coagulation or curdling of food in the stomach, when caused by acid, is not prejudicial, but rather conducive to health.

In the markets which are held weekly in our town, it is usual to expose to sale, that part of the intestines of calves which is called the Maw; this is falted, and kept in cafks, and, with the pickle in which it is preferved, goes by the name of Runnet. It is purchafed by farmers, and when poured on milk* curdles it, of which curd, cheefe is made. Some of this pickle I purchafed, in order to examine it more accurately, but was obftructed in my enquiry, by the numbers of faline particles in it.

I therefore purpofed to procure from a butcher, fome of the liquor when newly taken out of the maw, as foon as the animal was killed; and I was informed, that if a calf had fwallowed any milk a few hours before it was killed, there would be found in its maw a quantity of coagulated or curdled milk, which it was cuftomary for the butchers to take out and preferve with falt in a jar, (fome of which curd was fhewn to me), in order to fell the fame to the farmers, who found by experience that a fmall portion of this curdled milk, was of more ftrength or virtue for their purpofe, than the liquor in which the maw was pickled.

I then went to another butcher's, where I faw the maw of a calf, wherein, although the animal had not fucked for the fpace of twenty four hours before it was killed, I perceived fome portions of curdled milk, larger than a walnut; thefe I caufed to be wafhed in clean water, and carried them home with me, and I was much furprized to find them as hard to the touch as new made cheefe.

This curdled milk I put into a glafs, and poured on it rain water, fo as to cover it about an inch, and then broke the curd into fmaller pieces, in order that the faline particles, if any there were in it, might be diffolved by the water; and, after it had ftood thus for fome hours, I ftrained the water through a filtering paper, into a new and perfectly clean glafs.

* **Rinnen** in German, and *ronnen* or *runnen* in Dutch, mean to curdle; this gives us the true derivation of the word Runnet.

Some of this filtered water I poured on a portion of wine, in order to fee whether it would have any effect on the faline particles which are in wine, but, after it had ftood feveral hours, I could not perceive any alteration; I therefore determined to try the experiment with vinegar. And, as the vinegar which is commonly fold, is for the moft part adulterated, I took white wine vinegar, which I had kept with marygold-leaves in it for five and twenty years, and was uncommonly ftrong, and mixed with it a fmall quantity of the before mentioned liquor, but I faw no other faline particles in it than thofe which are found in vinegar. I obferved, indeed, feveral globules of oil, which in all probability proceeded from the marygold flowers.

But, when I took a fmall quantity of new milk, and mixed with it a very little of the before mentioned water, on bringing it before my eye as foon as I poffibly could, I faw moft of thofe round particles which caufe its white colour, curdled together, and an inconceivable number of fmaller particles, fwimming among the curdled ones, from whence I concluded, that thefe fmaller particles were of a different nature from the coagulated ones; I alfo faw in the fluid or whey various pellucid globules of different fizes, the fmalleft of which were no larger than globules of blood, and the largeft of thefe pellucid globules were twenty-five times that fize; all thefe I concluded to be thofe particles in the milk, of which butter is compofed.

From thefe obfervations it appears, that this liquor called Runnet, which coagulates or curdles milk, does not take any effect on wine or vinegar, neither of which are adapted to the food of calves.

I was informed by the butcher, that the fame curdling of milk, took place in the ftomachs of fucking lambs; and moreover, that if lambs were taken from their dams and fattened with cow's milk, it would be curdled in larger quantities, by reafon, (as he judicioufly added) that ewes milk has more particles of fat in it than that of cows.

After this, I mixed new milk with a large quantity of Runnet, to fee whether thofe fmaller particles which I have before mentioned to have feen fwimming in the whey, would thereby be coagulated, but they ftill continued to preferve their figure.

Upon examining the before-mentioned filtered liquor by the microfcope, I faw in it an inconceivable number of uncommonly minute particles, to which, by reafon of their exceeding fmallnefs, I could not give any other name than that of globules.

Whether the globules or falts in the Runnet, have fuch an effect on rain water, as to caufe any of its particles to coagulate, fo as to become vifible by the microfcope, I have not yet been able to difcover.

I feveral times tried the experiment of pricking my finger with a needle, and, immediately mixed fome of this liquor with the blood, to fee whether any of its particles would thereby be coagulated: on viewing the fame through the microfcope, it exhibited a curious and pleafant fpectacle of vaft numbers of the globules of blood, rolling one over another, but they were fo far from being coagulated by the mixture, that they feemed more fluid than before.

After this mixture had ftood about the fpace of half a minute, I perceived in it many fmall pellucid particles, which by degrees grew larger, but yet were fo minute, and fo much covered by the circumjacent particles, that I could not clearly difcover their figure; but, to the beft of my judgment, they were irregular faline particles, appearing all of different fhapes, and adhering together, in like manner as we obferve in fugar-candy. Now, whether this appearance was compofed of falts in the blood, or falts in the milk, or both, I am not able to difcover.

I feveral times applied a drop of the before-mentioned filtered liquor to my tongue, and I judged it to have more of a bitter than an acid tafte; whereupon I confidered, whether its property to curdle milk, might not be derived from the gall.

I therefore went to a butcher's, to fee whether the gall was not emptied into the maw, but I found that the gall bladder did not difcharge its contents into the maw, but farther down, where the bowel grows narrower; this gall bladder I caufed to be cut off fo as to leave the veffel through which the gall paffes, joined to the bowel, and having bound both ends of thefe with a thread, I inflated the gall-veffel with wind, but I found the parts to be fo contrived that not the leaft portion of water, or even of air, could pafs out of it into the maw.

When fome of this Runnet had ftood with a little water on it in a glafs, for the fpace of two days, it acquired as acrid a fmell, as we perceive in four curdled milk.

I at one time, received from a butcher, the gall bladder of a calf, which was entirely void of gall, whence I fuppofed that its contents had been fpilled by accident, but I afterwards underftood that no gall had been in it, and that the like appearance was often obferved.

But, what fhall we fay, when we fee in how high eftimation tobacco is held, and acids altogether condemned; as if all our bodies were exactly of the fame difpofition or conftitution.

For my part, I have for many years been ufed to fmoke tobacco for the cure of the tooth-ach, but I have often found that before I fmoked half a pipe, I was fo fick, as to be obliged to lie down near the fire, and fo much difordered, that I could not even endure to be fpoken to; whereas, on the contrary, every kind of acid, whether ufed in food, or taken by itfelf, agrees perfectly well with me. In fhort, we can much better judge for ourfelves as to what agrees or difagrees with our conftitutions, than pretend to advife other people what is good diet, or the contrary.

With regard to the curdled milk, which I have mentioned to be taken out of the calf in hard pieces, it feems to me probable, that the milk at firft was but lightly curdled, and that the frequent contractions of the bowel where it lay, which in the courſe of nature are performed many times in a minute, were the cauſe of its being found in that ſtate.

Seeing now, how powerfully coagulation is performed in animals, we may conclude, that ſomething of the ſame kind muſt take place with the food in our own ſtomachs, in order to render the ſame nutritive to us. And who can tell, how far ſuch coagulation may take place, not only with milk, but alſo with wine, vinegar, ſalt, and other parts of our food? This, however, is certain, that if a ſucking child caſts up the milk, on account of having ſwallowed more than its ſtomach can contain, ſuch milk, though juſt before taken from the breaſt, is in a curdled ſtate; conſequently we muſt conclude, that coagulation in our ſtomachs is a neceſſary part of the animal œconomy.

If milk in the ſtomachs of ſmall animals was not curdled, it would in a few hours paſs through their inteſtines, and afford but little nouriſhment to their bodies. And, in this opinion I have been confirmed by the experience of the butchers, from whom I find, that when the excrements of calves or ſucking lambs are thin and fluid, they thrive but little, and, that at thoſe times, no curdled milk is found in their ſtomachs.

I am aware, that theſe my obſervations, may diſpleaſe ſome perſons, as thinking that herein I am going out of my province; but, thoſe conſiderations weigh little with me, foraſmuch as every judicious perſon knows, that Phyſicians themſelves, in many things proceed merely by gueſs, and therefore, I aſſume to myſelf the liberty of offering my conjectures on this ſubject.

ADDITION BY THE TRANSLATOR.

Almoſt all the arts, which contribute to the ſupport or comfort of human life, have been the reſult of long and repeated experience. I will inſtance in the two moſt neceſſary articles of food, which are bread and beer, reſpecting which, a celebrated writer of the laſt age thus expreſſes himſelf:—" The arts of " brewing and making bread have, by ſlow degrees been brought to the per- " fection they now are in, but, to have invented them at once, and, * *à priori*, " would have required more knowledge and deeper inſight into the nature of " fermentation, than the greateſt Philoſopher has hitherto been endowed with ; " yet the fruits of both, are now enjoyed by the meaneſt of our ſpecies."

Cheeſe, however, another principal article of food, at leaſt among the poor, was moſt probably brought into uſe, *à priori*, by adverting to the change made in milk, from a fluid to a ſolid, in the ſtomach of the calf, and by imitating nature in the manner deſcribed in the preceding Eſſay. To preſerve the concreted or hardened ſubſtance, in a wholeſome ſtate, for a length of time, human invention added ſalt, and, by theſe two eaſy operations, is produced that, which is now a luxury to the rich, and a ſupport to the poor.

How the change in milk, by the mixture of Runnet, is produced, Mr. Leeuwenhoek's induſtry, we ſee, has not been able to diſcover ; we can only therefore admire the manner in which nature operates, to produce this effect. For, there is no other known ſubſtance that ſo effectually curdles milk, and, though the taſte of Runnet is of itſelf very nauſeous, yet none of this diſa-greeable taſte is imparted to the curd ; on the contrary, that which is called cream cheeſe, or new cheeſe, being merely the curd, without any mixture of ſalt, is of a ſweet and delicious taſte, and is produced as a dainty at our tables.

* The expreſſion, *à priori*, means, in logic, or in practice, to argue or to act upon known and eſtabliſhed principles, from whence a certain concluſion or effect enſues ; *à poſteriori* means, where, arguing from the effect, we trace it backwards to its cauſe.

Of the Snail or Insect found on the Vine, also on the nature of Sage, and whence its virtue proceeds; with some observations on the manner in which different animals emit their poison.

A Gentleman of some consequence in this country, upon a certain time, put into my hands, a parcel of small whitish eggs, together with some dry earth, in which they were found; and desired that I would endeavour to discover what species of animal would be produced from them. The axis of these eggs was nearly equal to one fifteenth part of an inch.

One of these I dissected, and found in it a thin fluid, mixed with round particles, or globules; the rest of them I put into a glass, but their contents in a few days entirely evaporated, and the shells, which were very brittle and tender, upon the liquid they contained being exhausted, became shrivelled, so that no living creature proceeded from them.

The following year, the same gentleman brought to me some more of those kind of eggs, which I treated in the same manner as the former, but with no better success.

In the month of July, in the third year, I received from the same person a larger parcel of those eggs, which were mixed with about an handful of moist earth.

Seeing this, I began to consider, that perhaps, the reason why the liquor being evaporated from the former eggs, had thereby prevented their producing any living creature, was, that in dry earth they became barren, and that in their nature they required to be kept moiſt; conſequently, that if I treated them in the ſame manner as the former, I ſhould never obtain my wiſh to diſcover their ſpecies. I therefore put theſe, and the moiſt earth wherein they lay, into a glaſs tube, about ten inches long, and three quarters of an inch wide, one end of which I had cloſed together by heat, and the other I ſtopped with a cork, by which means whatever moiſture might evaporate from the earth, would be confined by the glaſs, and, there condenſing, the greater part of it would fall back on the earth, and keep it, and the eggs, always moiſt.

This tube I placed in my cloſet, ſo as to be continually in the way of my notice, and, after ſome days, I ſaw, to my great ſurprize, two ſmall * Snails, of that ſpecies which infeſt the branches of vines, (and which are called by us Wyngaart-ſlakken, Vine-ſnails or Vine-ſlugs) on the inſide of the tube, and which had crept out of the earth contained in it.

I then took out of the tube an egg, or rather what was now become a ſmall Snail, with part of the egg ſhell adhering to it, and put it into a ſmaller tube, in order to examine it by the microſcope more accurately; and thereupon I perceived in one of the horns a very rapid motion, performed in a veſſel, apparently an artery, and which I judged to be about one fourth part the ſize of an hair. This motion was not an uniform or continued one, but by fits, or pulſes, and, ſo quick, that I judged the juices in the veſſel were propelled forward, three times within the period of one pulſation in the human body; and I concluded, that this veſſel muſt certainly be an artery, and not far diſtant from the heart, becauſe the quick pulſations I have noted, could not, otherwiſe, have been ſo diſtinctly ſeen.

The next morning this ſmall Snail was dead; as I gueſſed, for want of food, for the others of the ſame ſize, which were in the larger

* Mr. Leeuwenhoek has not given a figure of this animal.

tube with the earth, continued alive; the next day more of the fame kind of Snails came out of the eggs, and the third day many more.

I often contemplated one of thefe Snails, while adhering to the infide of the glafs tube, and, with great pleafure, I faw through its fhell (which was fo pellucid as to tranfmit the light) a part of its body not larger than a grain of fand, and of an oval fhape, which alternately was contracted and extended, each alternate motion being performed in the fame fpace of time as is required to pronounce diftinctly a word of four fyllables. This little point or corpufcle, I deemed to be the creature's lungs, and the reciprocating motion, that of refpiration.

I have formerly often diffected thefe kind of Snails found on Vines, chufing for that purpofe the largeft I could find, in order, if poffible, to difcover the manner of their generation, and whether any young ones were to be found in them, but hitherto without any fuccefs; and now, almoft by accident, and with little trouble, I plainly perceived that thefe creatures were propagated by laying eggs.

It has frequently been matter of great wonder to me, to obferve in the fpring, young Snails of this fpecies on the Vine branches, when I could not conceive, how they could have been bred and brought forth fo early in the feafon. But, fince it now appears, that they are produced from eggs, the difficulty ceafes, becaufe we can eafily conceive how thefe animals may be hid in the earth all the winter in the egg, and break out from thence, as foon as the firft warmth of the fpring returns.

I have likewife often obferved full grown Snails of this fpecies, whofe fhells were covered with earth or clay, as if they had been newly dug out of the ground, and never could fatisfy myfelf as to the caufe; but this is alfo now accounted for, becaufe, as they muft creep into the earth to depofit their eggs, it is natural to fuppofe that fome portions of earth or clay may be left fticking to their fhells or horns. And, if any perfon fhould wonder how thefe creatures can creep into the earth, I can fatisfy him in that point, from my own experience; for I have frequently feen, after I had picked feveral of them off the tree, and not only thrown them on the ground, but preffed them with violence into the earth, by ftamping on them with my foot, yet, in a fhort time, if their fhells efcaped unhurt, they would find their way out again.

In the month of Auguft, I invited the friend I have mentioned, to my houfe, and acquainted him with the manner I had treated the eggs he had fent me, and fhewed him the Snails which they had produced, with which he was greatly pleafed; and told me he had rather fuppofed, that the fpecies of lizard commonly called Efts would have been the produce. The next day, he brought to me a very large Snail of this fpecies, the furface of whofe fhell was covered with moift earth, juft as if it had newly crept out of the ground; and he informed me, that, while he was bringing it, he perceived it lay an egg. Hereupon, I put this Snail into a glafs tube, about ten inches long, and wide enough to give it full liberty of moving about; and within half an hour it laid feven eggs, which I perceived fticking to the glafs, and in two hours time as many more; but, when I next examined it, I found that in creeping about the glafs it had broken them all, and in two days it died, as I fuppofe for want of food, without laying any more eggs.

The fmall Snails, which, as I before mentioned, were produced from the eggs, did not live above two or three days, and I perceived that the fhells from whence they had iffued were very white, but the remainder of the eggs which had not produced any young ones, and were barren, were of a dark colour, and of a watery appearance.

It being now demonftrated by the foregoing obfervations, that thefe Snails are produced from eggs, the old eftablifhed error muft be abandoned, which thofe adopt, who dream that thefe creatures are produced from corruption, or the decayed leaves of trees; and thence conclude, that, if ſuch leaves are not taken out of gardens, theſe Snails will be bred from them. Whereas, we ought rather, on conſidering the matter, to ſay, that if the leaves which fall in autumn are left in gardens, the eggs depoſited by theſe Inſects in the ground, the ſurface of which is covered with ſuch leaves, will be the better defended from the winter's cold, and conſequently more of thoſe animals will be produced in the following ſummer.

A certain Author, of the name of Kircher, having publiſhed to the world, that he had, by his microſcope, diſcovered on the leaves of Sage ſomething like a ſpider's web, woven by ſome ſmall inſect, and having thereupon founded an aſſertion, that thoſe who ſhould eat of Sage leaves, without waſhing them, would be poiſoned, I was requeſted by ſome learned friends, to examine into the truth of this aſſertion.

I had many years before this time, frequently inſpected the leaves of Sage, and always found that they were, in many places, covered with ſmall globules, but I never perceived on them any animalcules, nor their eggs, even by the aſſiſtance of the microſcope.

Upon this occaſion, I procured ſome Sage, not only the green ſort, but that, which, becauſe its leaves are yellow at the edges, is called variegated Sage. This I examined by the microſcope, and perceived the leaves to be covered with many capillary or hairy parts, too ſmall to be diſcerned by the naked eye; and ſo cloſely ſet together, that there was not a place in the leaves, of the breadth of an hair without them, and, I cannot give them a better name, than capillaments, or ſmall hairs, becauſe, like the hairs of animals, they all terminate in a ſharp point. And I ſuppoſe, that Kircher had imagined theſe capillaments to be the webs of ſpiders.

At the extremities of many of theſe capillaments, I perceived certain globules, which, through the microſcope, appeared no larger than grains of fand feen by the naked eye; and thefe globules feemed to me to be filled with an oily fubftance. But I could not difcern the leaft trace of any living animalcules on the furface of the leaves, and I am certain, that, had there been any fuch, though an hundred millions of degrees lefs than a grain of fand, they would have been vifible by my microfcope.

This oil, wherein the virtue of Sage confifts, is produced on every leaf of it in fuch abundance, as no one would believe, but from experience; infomuch that one can fcarcely touch a leaf of Sage, but an incredible quantity of oily particles will adhere to the fingers.

My admiration was greatly excited, by obferving that the greater number of the capillaments I have mentioned, were formed with three joints, and fome, which ftood on the veffels of the leaves, with four. Thefe joints I do not remember to have feen in the capillaments on any other leaf, but whether that is to be attributed to my want of attention, I do not know.

When Sage is dried, its leaves exhibit a whitifh colour, and that is caufed by thefe capillaments, which, lying thick one on another, do, by their tranfparency, produce that whitenefs.

This fame Kircher, in his writings, gives it as his opinion, that Sage, and alfo Fennel, are very wholefome herbs, but, that in them is produced a maggot, which, being inadvertently eaten, will caufe grievous fymptoms, and even death itfelf; and he moreover pretends to have found by experience, that there is no plant which does not breed fome maggot or moth; but furely, if he had been provided with a good microfcope, and had underftood how to ufe it in the diffection and examination of minute animals, he never could have broached fuch abfurdities.

For my part, it is my fixed and fettled opinion, that no leaf, no tree, nor any root, ever did, or ever can, produce or breed any animal endued with life and motion. But, a fmall animal may lay its eggs, or depoſit its young, on the leaf or fruit of a tree, which young one, when depoſited, or when hatched from the egg, may make its way into the leaf or fruit, and there find nouriſhment to promote its growth.

It is an eſtabliſhed axiom among Philoſophers, that, nothing can come of nothing; how then can a being or ſubſtance void of motion, produce a creature endued with motion and life? And this is certain, that, whenever we diſſect or examine ſmall animals, the wonderful fabrick of their bodies, both externally and internally, ſtrikes us with aſtoniſhment.

As to the opinion, that venomous animals do ſhed their poiſon on fruits or leaves, I do not ſee that this can be ſaid of the Scorpion, nor that poiſonous ſerpent called the Rattle Snake, neither of the Spider, nor the Indian Millepeda, becauſe, as far as I can underſtand, they have not power to hurt, by ſpitting or voiding their poiſon on any object, becauſe they cannot caſt it to any diſtance, but they do miſchief, by injecting it into a wound made in the fleſh. But, it is poſſible for the Frog and Toad to infect plants with their venom, for I have more than once obſerved thoſe animals, when irritated, eject a kind of water, in a ſtream, from their poſteriors, which water poſſeſſes an extraordinary corroſive acrimony. This property was firſt experienced here, by a reſpectable perſon, who, in fiſhing for Jack, uſed young frogs for a bait; and once, while he was fixing a frog to his hook, the animal on a ſudden ſcattered a little of this liquor into his eye, which produced an excruciating pain in the part.

I have often taken notice of a large dog, who was very eager in the purſuit of mice, which he would ſwallow whole, without chewing. He was alſo very fond of hunting frogs and toads, and, when he had killed them, by biting, he uſed to throw them away; but at thoſe times his mouth was entirely covered with froth or foam, which I attributed to the liquor emitted by them. This was moſt particularly the caſe, when he caught a toad, for then, he appeared almoſt mad, violently ſhaking his head, and, great quantities of froth or ſlaver iſſuing out of his mouth ; but he was accuſtomed, before he began to bite the toads, repeatedly to take them in his mouth, and daſh them againſt the ground.

This virulent liquid in frogs and toads, they do not, in my opinion, emit, except upon extraordinary occaſions, when they are irritated, for it is a natural inſtinct in all animals, carefully to preſerve that, which Nature has given them for their defence. So the Scorpion, whoſe weapon of defence is his ſting, does, while creeping or running along, carry the point of the ſting turned inward, towards his body, in order to preſerve it from injury.

This ſagacity, and the other faculties we obſerve in animals, cannot be ſuppoſed to be produced ſpontaneouſly, nor that, with the creature it is bred from corruption or putrefaction, but, we ought to lay it down as a certain poſition, that theſe faculties implanted in animals, at the Beginning, have been, by a conſtant ſucceſſion, tranſmitted to their offspring ; foraſmuch as we are not to ſuppoſe that any new animal, or ſpecies of animals, is created at this day. In a word, the make and ſtructure of every creature, and the powers implanted in it, muſt, in my judgment, be aſcribed to God alone, the Creator of the Univerſe.

On Wheat, and the manner of its vegetation; the nature of the ſeveral component parts of that grain explained, and their figures deſcribed as ſeen by the microſcope.

ALL ſeeds contain in them the rudiments, or firſt beginning plants, of their reſpective ſpecies; that is, the part which, in the progreſs of vegetation, ſhoots upwards, and forms the ſtalk or ſtem, and that, which penetrates downwards into the earth, and is called the root. Seeds do alſo, for the moſt part, contain a farinaceous or mealy ſubſtance, which affords nouriſhment to the young plants until the roots are of a ſufficient ſize for extracting ſupplies from the earth, to continue and perfect their growth.

Among many other ſeeds, I have particularly examined the grains of Wheat; and, in them, the young plant I have mentioned, before it began to vegetate, having firſt either put them in water for a ſhort time, or held a few grains in my mouth, merely to moiſten the outward membranes, whereby they could the eaſier be taken off. And, having ſeparated the two external membranes which cover the young plant, I took it out from the grain, and placed it before the microſcope, when it appeared to me to be compoſed of nothing elſe than a collection of aſcending veſſels, with ſome flexures or bendings in them, and ſome minute tubercles or pimples, which pimples I conceived to be only cauſed by the evaporating of the moiſture.

In Plate VI. *fig.* 1, ABCDEF, is the whole of this beginning of the plant, magnified : E F D, are the parts or points from whence not only three diftinct roots will grow, but they are alfo the beginnings of three feveral fpires or ftalks of Wheat ; for the minute protuberances which appear at F A, and C D, are two diftinct plants : fo that, from every grain of Wheat (which is well worthy of obfervation) there will arife, not merely a fingle ftalk, but three diftinct ones, which are formed in the feed itfelf. And as, when fpeaking of artichokes, we call the principal or uppermoft fruit, the parent artichoke, and the others chicken artichokes, fo, in the inftance before us, we may properly name the uppermoft plant, which appears at B, and whofe root projects lower than all the reft at E, the parent plant, and the two fmaller ones, at F A, and D C, the two chickens or fuckers.

In order to form a computation of the proportionable fize of thefe firft formed plants, I placed them befide an entire grain, which I judged to be four times their fize both in length and thicknefs, whence it follows, that each grain of Wheat is fixty-four times larger than the three feveral young plants formed in it, and which are to receive nourifhment from it, in the beginning of their vegetation.

I cut off a piece of this young plant, by a tranverfe fection, acrofs the part where the three vegetative principles I have defcribed are fituated, or at the place in the figure from F to D, only to fhew how, and in what order, the roots (or that which is the place or fource of the roots and plants in this feed) do lie in refpect of each other ; and alfo, to point out the multitudes of veffels formed in them.

In *fig.* 2. A B C, is the firft or outward membrane or covering, which enclofes both the plant, and the whole circumference of the grain of Wheat, and is compofed of nothing but veffels extending lengthwife, and which, being cut tranfverfely, appear in this membrane as they are fhewn in the figure, particularly at B, where may be feen a few of thefe veffels, prefenting part of their fides to the eye. The fecond membrane or covering, is in part fhewn at D E F.

The reafon why thefe membranes appear at fo great a diftance from HIK, the three young plants, is, that this grain of Wheat was very much dried, and therefore, in the cutting, the membranes were eafily feparated from the farinaceous part, where the young plants are placed; but when the plants and the mealy fubftance, lying in the fpace marked by the letters DHIKFGD, are a little moiftened, they very foon fwell fo much, as to fill up the whole fpace HEKI. This, however, is the cafe in but few grains of Wheat, for, when the young plants, and the fubftance wherein they lie, contract in drying, the membranes which inclofe them contract likewife, they being, generally, all clofely united or adhering together.

At the letters H I K, are fhewn the three beginning ftalks, or roots, of the future plants, as cut tranfverfely; and, in thefe, the veffels would have been much more confpicuous than here reprefented, had it not been, that in the cutting them (although the knife I ufed was very fharp) they were filled up or ftopped; but, though by moiftening, and then cutting them, the veffels appeared more diftinct, yet, no fooner did the moifture evaporate, than they contracted themfelves in fuch an irregular manner, as to be much lefs confpicuous than at firft. And, as to thofe which were vifible, the limner continually complained, that it was impoffible for him to reprefent in his drawing, the multitudes of flender veffels which he faw.

The fubftance wherein the young plants of Wheat are contained, (which is very little in quantity) appears of a different colour from the mealy part of the grain, by reafon, that the globules which compofe it, are not, fingly, fo pellucid, and therefore do not, altogether, appear fo white, as the meal which compofes the greateft part of Wheat. And thefe two fubftances are divided from each other, by a third, of a ftill brighter colour than the white meal, as in the figure is fhewn at D G F.

If, in this figure, I had caufed the whole circumference of the grain, thus cut tranfverfely, and magnified, to be delineated, it would have occupied too much fpace in the paper ; and therefore, I only included fo much of the mealy part of the grain, as is expreffed between the letters, a, D, G, F, c.

I have given a figure of the veffels compofing the external fhell, hufk, or covering of Wheat, becaufe, contrary to what is generally obferved, they do not end in a tubular fhape, but grow out into a kind of hairs.

Fig. 3, G H I K L M reprefents a very fmall piece of this outward hufk, which, when ground, and feparated from the meal, is denominated Bran. Here, not only are to be feen the multitudes of veffels whereof it confifts, but alfo, how at their extremities, they grow out beyond the grain, and terminate in hairy points, as at I K L.

The fecond membrane, lying within the firft, exhibits a curious fpectacle, on account of the tranfverfe courfe of the veffels, in a different direction from the former; and at *fig.* 4, A B C D E F, is fhewn an exceeding fmall particle of it, wherein, though it is no more than can be covered by a grain of fand, the wonderful courfe of thofe numerous minute veffels is plainly to be feen. And, as it is truly faid, that nothing is made in vain, we cannot fufficiently admire this, and fimilar objects, when viewed by the microfcope.

In the fame figure, at D and E, may be feen fome of thofe globules which compofe the mealy fubftance of Wheat, lying within, what feemed to me at firft, an exquifitely thin pellicle, like a third membrane, but was, in reality, only the finer part of the meal.

I many times endeavoured to trace in the young plant, while in the feed, the veftige or firft formation of the ear, but all my endeavours, even with the affiftance of my microfcopes, were fruitlefs, though I was well affured in my own mind, that it did there exift : at length, to fatisfy myfelf, if poffible, in this refpect, I took a fmall brafs box, and almoft filled it with that fort of white fand called fcowering fand, on the furface of which I placed, upright, about fixteen grains of Wheat, and, after ſtrewing more ſand on them, to about the thickneſs of the back of a knife, I moiſtened the ſand with rain water ; and, becauſe the weather was extremely cold, it being in the midſt of winter, I carried the box about with me in my pocket.

At the end of four days, ſome of the grains had put forth ſhoots to the breadth of a finger : one of theſe ſhoots, I cut off cloſe to its root, and, opening it, I took out the middle part of the plant, wherein, by the help of the microſcope, I perceived ſome minute leaves, and, from their appearance, I was well aſſured that the ear between them had increaſed in ſize, though I could not diſtinctly perceive it.

After carrying the box and the remaining grains in my pocket four days longer, I opened it again, and, taking out from one of the ſhoots that part which conſiſted of the innermoſt leaf, immediately incloſing the ear, I placed it before the microſcope, directing the limner to make a drawing of it, as it appeared to him. This is ſhewn at *fig.* 5, A B C D, where A B D, is the young ear, and B C D, the inner leaf incloſing it.

At the end of four days more, being the twelfth day, I opened another of the grains, and, having ſeparated the young leaves a little aſunder, I was much more confident than before, that I diſcerned the ear ; this alſo I cauſed to be drawn from the microſcope, as at *fig.* 6. E F G H.

From theſe obſervations we may be fully aſſured, that warmth and water, will, of themſelves alone, promote the growth of plants. And alſo, that God, the all-wiſe Creator of the Univerſe, does not create any new ſpecies of Things on this Earth, but that, at the Beginning, he ſo ordained and conſtituted all things, that, his Creation being perfect, the ſeeds of plants, when come to maturity, ſhall produce or contain in themſelves (however undiſcoverable by us) the part or vegetative principle of the future plant, which, in its due time will be produced, and that, in all reſpects conformable to the original plant. And this, I take to be a certain truth, which prevails not only in plants, but in all living creatures whatſoever.

I was deſirous to examine, whether in the vegetation of corn, there would be as great a number of radicles proceed from the firſt root, as I had obſerved in graſs, and for this purpoſe, I took a glaſs tube, about half an inch in diameter, and three inches long; having ſtopped this at one end, I filled it rather more than two third parts with dry ſand, which I moiſtened with rain water, and preſſed it gently together to keep it in its place, and then depoſited it in three grains of Wheat, ſtopping alſo the other end.

This glaſs tube I frequently carried in my pocket, and in three or four days, the Wheat began to put forth roots. On the ſeventh day, the roots were ſo far grown, that I could moſt plainly diſcern them to be compoſed of wonderfully minute tubes, each of which was formed with joints, as are to be ſeen in reeds or ſtraws.

The diameter of theſe roots was, as near as I could compute, about the ſixtieth part of an inch, and, at the extremities, they were obtuſe or rounding, like the ends of thoſe quills which are taken out of the wings of birds: the ſurface of them was very ſmooth and ſhining, without any appearance of radicles iſſuing from them, excepting near the grain, where numbers of exquiſitely minute radicles were to be ſeen.

On the eighth day, the young germ or ſhoot had grown to the length of three quarters of an inch, the roots were alſo ſo far grown as to reach the bottom of the tube, whereupon I took out the cork, and they then protruded themſelves out of the tube, and I hoped to have diſcovered in them, whether there were the ſame joints in the ſmall radicles as in the larger roots; but, in the ſpace of half a minute, the moiſture in them was ſo evaporated, that they became contracted into irregular ſhapes.

With regard to the fize of thefe exceffively minute radicles, I made the following eftimate, as far as my eye could judge. Suppofing the diameter of them to be as 1, that of the larger root from which they proceeded muft be confidered as 20, and confequently, 400 of thefe flender radicles taken together were equal to the fize of the larger root. Now, the diameter of this larger root being, as before obferved, the fixtieth part of an inch, 3600 of thofe roots will be equal to a cylinder of an inch diameter; and if this number be multiplied by 400, it follows, that 1,440,000 of the fmalleft radicles are altogether equal to a cylinder the fize of an inch.

This being the cafe, we may naturally conclude, that when any plant is pulled up by the roots, fuch flender radicles as thefe, not only efcape our fight, but muft almoft all be broken off, unlefs the earth or moift fand which furrounds them adhere to, or is taken up with them.

After thefe very flender radicles I have defcribed, had remained in the tube three or four days, thofe parts of them which did not touch either the fand or the glafs, and were expofed only to the air within the cavity, were fo dried up and contracted into irregular forms, that they appeared like parcels of wool, or the threads of fine linen tangled together.

In the month of April, I took up in a field, which in the preceding autumn had been fown with Wheat, fome of the young blades or fhoots, with their roots, and the earth adhering to them: and upon examining thefe, I obferved nothing vifible, except the largeft fhoot or parent plant, which was by far the largeft, and had fhot up much the higheft. To fhew the fize of this plant, I caufed a drawing to be made of it, which is to be feen at *fig.* 7, WXYZ; and in this plant the blade being fhot up to the height of about four inches, the joints, or knots in the ftalk, were already formed, the young ear lying at the end next to the root, at W.

This plant, reprefented at *fig.* 7, I cut open, and took in pieces, until I perceived the fmalleft leaves of all, which as I may fay, furrounded the ear; thefe alfo I took off, and then the ear itfelf was vifible, which, viewed through the microfcope, appeared as at *fig.* 8, AB.CDE. But, I did not deliver this Object to the Limner, until I had diffected feveral of the young plants, and found, that they were all exactly of the fame figure.

At the expiration of nine days from this time, I examined more of the young blades of Wheat, but did not perceive any change in the ear worthy of note, except that it was grown fomewhat higher from the root, and that the joints or knots in the ftalk, were more plainly to be diftinguifhed.

The ftems or ftalks of Wheat, which, after the grain has been threfhed out from the ear, are denominated Straw, appear to the eye wonderfully fmooth and fhining, the outer coat of them being compofed for the greater part, of veffels incredibly flender, with here and there a few larger ones intermixed; the inner part is compofed of larger veffels, all which I have reprefented as nearly as poffible to Nature, in the following figure.

Fig. 9, ABCDEF is a very fmall piece of Straw, cut tranfverfely, and feen through the microfcope: any perfon, by confidering what proportion the arch, or curved external part of it, marked AF, bears to a circle, and, comparing the fame with fo much of the known diameter of a Straw, may eafily conceive the natural fize of the particle here reprefented.

ABEF, is the bark or outer coat, compofed of the veffels before defcribed; GGGG, are the veffels of which the inner part for the moft part confifts; they are of four, five, and fix fides, according as, at their firft formation, their fhape is accommodated to thofe adjoining them.

HHHH, are veffels intermixed with the laft mentioned ones, and containing in them ſtill ſmaller veſſels ; in theſe veſſels I have ſeen the juices (at the time the Wheat ſtalks are growing) running with a wonderfully rapid courſe ; and, through the joints or valves in thoſe veſſels marked G, the juice was carried upwards, which juice was for the greateſt part compoſed of globules ; and when theſe globules came to paſs the valves where the paſſage through the veſſels is very narrow, they aſſumed an oblong figure, until they came into a larger ſpace, when they reaſſumed their priſtine globular ſhape.

Fig. 10 repreſents theſe aſcending veſſels cut longitudinally, and ſeen through the microſcope, being the ſame which in *fig.* 9, are marked GG : at HH, are the valves I have mentioned, and, in thoſe parts, the paſſages through the veſſels are the moſt narrow or confined of all.

The ſtalks of Wheat, are formed of none other than perpendicular or aſcending veſſels, and that, in my judgment, is the reaſon, why they are furniſhed with a kind of joints or knots, at certain intervals, in order to give ſtrength to them ; and that, without ſuch joints, the ſtalk would not be able to ſupport the ear, which is its fruit. This is alſo the caſe with graſſes, and likewiſe with reeds, for the ſame reaſon ; and it alſo obtains in the bodies of ſome trees. In theſe northern parts, indeed, all trees are provided with horizontal veſſels, whereby they have a ſufficient ſtrength ; but, in the warmer climates, where many of the trees have no other than perpendicular veſſels, ſuch as is the cocoa-nut tree, the want of horizontal veſſels is compenſated, by numbers of theſe kind of joints, formed at ſhort intervals, through the whole length of the tree.

The farinaceous or mealy part, of which the grains of Wheat are principally compoſed, conſiſts of thoſe minute globules I have before noticed. Theſe globules are, ſingly, tranſparent, and lie cloſely compacted within a kind of membranes, ſo exquiſitely thin and tranſ-

Z

parent, that, in fome places, their texture is not to be difcerned. A very fmall particle of one of thefe membranes, as it appeared upon the grain being cut longitudinally, is fhewn at *fig.* 11, EFGH; within thefe membranes the globules of meal are inclofed, as it were, in cells; and, at H, fome of thofe cells are reprefented, filled with the globules of meal: the natural fize of this figure, is no more than can be covered by a common grain of fand.

The globules of meal, are of very different fizes, fome being more than an hundred times larger than others, and fome fo fmall, that they almoft efcape the view of the microfcope. In order to give the reader fome general idea of their minutenefs, I took one of the larger grains of that fort of pellucid fand, ufed in fcowering or grinding; this grain of fand, together with fome of the globules of meal adhering to it, I caufed to be drawn from the microfcope, as at *fig.* 12, ABCDE. In the fame figure, FGH denote a fmaller grain of fand adjoining to the former. IKLM are fome of the larger and fmaller globules of meal, lying near the grains of fand.

I had at firft imagined thefe mealy particles to be quite globular, but I afterwards found, that I had been miftaken in that refpect; and that they were not perfect fpheres, each of them having a kind of creafe, chink, or indenting, like that which we fee in the grains of Wheat, which had at firft efcaped my notice, partly from the extreme minutenefs of the particles themfelves, and partly from their different pofitions with refpect to the eye.

Upon viewing thefe mealy particles, and the indentings in them I have mentioned, I began, not without wonder, thus to reafon with myfelf. Certainly thefe particles of meal were not compofed by a concretion or collection of ftill fmaller particles, placed fide by fide, as is obferved in fome liquors, fuch as wine and beer, whofe particles coagulate, and grow together in maffes, which, in the former we call dregs, and, in the latter tartar; but the particles of meal muft be formed in another manner, that is, not by coagulation, but by growth. And the membranes which inclofe them in cells, muft be provided with fo many veins or veffels, that every particle of meal may have its feparate vein, whence it derives its fubftance and increafe, in like manner as the eggs of fifhes are nourifhed by a ligament or veffel, which is obferved not only in the larger fifh, but in thofe very minute eggs which are feen in vaft numbers on fhrimps. Now, if the particles of meal, which, though not ftrictly fpherical, may yet be termed globules, had not acquired their growth in that manner, it fhould feem that they could not obtain that globular figure.

When we confider the tranfparency of every one of thefe globules of meal, we may well exclaim, How wonderful is this formation, and how clofely compacted muft be the fmalleft particles of which each globule is compofed, to give it that tranfparency !

I next proceeded to examine, whether thefe particles of meal might not be globules, inclofed in a certain thin membrane, as we fee is the cafe with all feeds ; but I cannot be confident, that I ever did bring this to my ocular demonftration. I then broke the globules in pieces, and imagined that I faw fmaller ones inclofed in them, but herein I found myfelf miftaken, for, thofe globules which I faw fcattered among the pieces, were fome of the very fmalleft mealy globules, collected in fmall parcels.

I then ufed my utmoft endeavours, to difcover the internal hidden make of the globules of meal, wherein, at length, to my great fatiffaction, I fucceeded. I placed fome of them on a clean glafs, and mixed them with a very fmall drop of water : when they were by this means feparated, I poured on them two more drops of water, and brought the glafs fo near to the fire, that in the fpace of a minute, the water was all evaporated. Then, bringing them before the microfcope, I perceived, that their globular form was changed into flat fhapes, of different fizes, according to the different magnitudes of the globules themfelves. Many of them had a little rifing in the middle, which I judged to be that part, through which they had received their growth and increafe.

This convinced me, that the globules of meal in Wheat, are covered with a fkin or fhell, in like manner as the Wheat itfelf, for, by the compreffion and flattening of the figures in the above experiment, they would have been diffolved or feparated, had they not been confined by fome fuch covering. I then concluded, that the chinks, creafes, or indentings I have noted in thefe globules, were in thofe parts where their fkins had a kind of feam or joining, fo that when warmed and moiftened, their fkins had burft open at thofe places, and the globules fubfided into a flat fhape, as before mentioned.

From this obfervation, I was induced to examine the grains of Wheat themfelves, in order to inveftigate, how, and for what purpofe they were formed with thofe indentings, chinks, or creafes.

For this purpofe, I cut pieces off the grains, by a tranfverfe fection, and examined thofe pieces by the microfcope, when I found, that the fhell or hufk takes its courfe into the middle of the grain, and, on each fide, returns in a curve or bending to the chink, by which means, the hufk, when the grain fwells upon being moiftened, can expand itfelf into a greater fpace.

Hereupon I was led to confider, that, whereas fowls, turkies, partridges, pigeons, and other birds who feed on corn, cannot with their bills, break or grind the grains of Wheat, Rye, and Barley, but take them into their ftomachs entire, where, by reafon of the hardnefs of the hufks, they cannot be broken; feeing this, I fay, I confidered, that thefe kinds of grain muft have been fo contrived and formed by the all-wife Creator, that, without the hufks being broken in pieces and digefted, their contents may be diffolved: which is thus performed, namely, that by the moifture and heat in the ftomachs of thofe animals, the outward hufks, or fhells, may be expanded and burft open, and the meal which they contain, having by this means a paffage opened to quit its covering, may be diffolved, digefted, and converted into nutriment.

To inveftigate this more fully, I took a glafs tube, about the fize of a finger, and clofed at one end; into this I put fome grains of Wheat and Barley, with a fufficient quantity of water, and then applied fo much heat to it, as, in a fhort time, made the water boil. Then, upon examining the Wheat and Barley, I obferved, that their hufks, which before, had been as it were clofely folded or clofed together, were not now, broken or torn afunder, but, in the places where the grains had been contracted and turned inwards, the parts had now receded either way, caufing the hufk to gape open, fo that, in fome of the grains, a part of the meal was vifible, and in others the whole contents were laid open. Some of the grains of Wheat, however, I obferved, which had fwelled to three times their original fize, the hufks remaining entire.

After this, I examined the dung of fome hens, which, in the time of a deep fnow, were kept fhut up in a coop, and fed with nothing but barley, which, it is well known, they fwallow whole. And, in the dung of thefe fowls, I was much furprized to find nothing obfervable, except a great number of pieces of the hufks of barley; and I was at a lofs to comprehend, how fo great a quantity of meal as thofe hufks had contained, could have entered into the bodies of thefe fowls, confidering that they were all full grown.

Farther, I infpected the dung of many fparrows, in which I found a great number of very fmall hairs, clofely compacted together, in a kind of regular order; together with many fragments of the hufks of Wheat and Barley. I at firft wondered what thefe hairs might be, till I recollected the hairy or reed-like parts at the extremities of the grains of corn, which I have before defcribed, and found thefe to be the ſame, for, in them I could perceive a kind of ſtreak or hollow, which is obſervable on thoſe hairs. Theſe ſparrows, I underſtood, during this ſeaſon, when the ground was every where covered with ſnow, ſought their food in the corn market, where they picked up the grains which, in handling and viewing the corn, had fallen to the ground.

In order to exhibit to the eye, the manner in which the huſks of Wheat are folded or cloſed together, I cauſed a drawing to be made from the microſcope, of a piece cut from the grain tranſverſely; but firſt, to ſhew the poſition of the chink or indenting, I ordered the limner to draw a figure of the entire grain, in its natural ſize. This is ſhewn at *fig.* 14, wherein the fiſſure, chink, or indenting, is denoted by the letters N O. The line P Q, indicates the part from which, with a very ſharp knife, I cut ſeveral ſlices.

Fig. 15, A B C D E, repreſents a part or ſlice of the huſk of Wheat, incloſing the meal, cut off as above mentioned, and viewed through the microſcope. A, is the part near that place in the grain, where the young plant is ſituated. G H F K I, are the two bendings inwards of the huſk, in a kind of circular courſe, the intent of which formation doubtleſs is, that, when the grain ſwells upon being moiſtened, the huſk may expand itſelf, and ſtill preſerve the meal in its place: and by inſpection of the part F, it will be ſeen, that the huſk is not cloſely united where the two bendings or flexures meet, to the end, that when the meal expands itſelf ſtill more, the two ſides of the huſk may recede from each other, and produce an opening at that place.

I have already deſcribed the ſize of the globules of meal, by compariſon with larger and ſmaller grains of ſand. I alſo cauſed ſome of theſe globules to be drawn, as ſeen through a microſcope of very great magnifying power; firſt, to ſhew more diſtinctly that they are formed with a chink or crevice on them, next to exhibit to view the fmaller globules, mixed with the larger, and finally, how the chink or crevice appears on them. Thefe are fhewn at *fig*. 16, LMNOP QR.

I have frequently repeated the experiment of placing a portion of thefe globules of meal, no larger than a grain of fand, upon a clean glafs; and, after pouring a drop of water on them, brought it to the fire. After the water and globules were heated, and the moifture was evaporated, the globules affumed a flat fhape, very like that of cakes, which is reprefented in *fig*. 17, STVW. Moft of thefe had a little rifing in the middle, being the place, as I before mentioned, where, in my judgment, they were fupplied with juices in their growth. And I have often feen the very fmalleft of the globules undergo the fame alteration in their fhape as the larger ones. In thefe obfervations I found a portion of meal, no larger than a grain of fand, mixed with a fmall drop of water, fully fufficient to exhibit the change of fhape before noted; for, if more of the meal is ufed, the particles lie fo confufedly heaped on one another, that they cannot be diftinctly feen, and, it is fcarcely to be conceived, that a portion of meal, no larger than a grain of fand, fhould confift of fo many particles as are pictured in *fig*. 17.

I have often examined a fmall piece of bread, taken from a loaf made of fine flour, after the hufk or bran had been taken from it. The particles of meal in this fmall piece of bread, appeared very much like thofe reprefented in *fig*. 17, with this difference only, that the particles in the bread, lay much more irregularly, and appeared more mis-fhapen, with ragged points and rifings; a true reprefentation of all which is to be feen at *fig*. 18, ABCDE.

ADDITION, BY THE TRANSLATOR.

WHOEVER perufes Mr. Leeuwenhoek's Works, will find difplayed in them much found philofophical knowledge, of which fome inftances appear in the preceding Effay. Thefe I fhall quote, in order to explain tho feparts in them, which may appear difficult to fome of my readers. In page 171, the author tells us, that the fubftance inclofing the young plants of Wheat, appears of a different colour from the mealy part of the grain, by reafon that the globules which compofe it are not, fingly, fo pellucid, and therefore do not, altogether, appear fo white, as the meal; and in p. 179 he reflects, with admiration, how clofely compacted muft be the fmalleft component particles of the globules of meal, to give them that tranfparency. To thofe, who are not converfant in optics, it may appear ftrange, that the moft tranfparent bodies have the fmalleft pores, and, that a collection of fmall tranfparent globules fhould altogether exhibit a white colour, but this is according to the eftablifhed doctrine of light and colours, of which Mr. Leeuwenhoek appears to have been fully informed.

As to the firft, Sir Ifaac Newton has fhewn, that it is not the largenefs of the pores of bodies which makes them tranfparent, but the equal denfity or continuity of their parts; which, he fays, appears from hence, that all opake bodies immediately begin to be tranfparent, when their pores become filled with a fubftance of equal or almoft equal denfity, with their parts: thus paper, dipped in water or oil, linen cloth fteeped in oil or vinegar; and other fubftances, foaked in fuch fluids as will intimately pervade their little pores, become more tranfparent than before.

As to the fecond, white being a compofition of all colours, a collection of tranfparent globules, which, from their furfaces reflect the light in all directions, will produce whitenefs by that reflection. This is feen in the froth on liquids, and particularly foap-fuds, which is nothing but a compofition of minute globules of water, made tenacious by the foap.

Of the Cocoa Tree, and its Fruit, commonly called the Cocoa-nut.

I HAVE faid, that ftraws, reeds, and many other ftalks of plants, were formed of none other than perpendicular veffels, whereas the ftems or bodies of all trees growing in our climate, at leaft as far as I have ever underftood, are likewife provided with horizontal veffels ; the ufe of fuch laft mentioned veffels being, in my judgment, to convey the nutritive juices to the exterior parts of the tree. Now thefe horizontal veffels impart fuch ftrength and firmnefs to the timber or trunk, that the moft fpreading trees are enabled to refift the violence of the wind.

But ftraws, reeds, and other ftalks which are deftitute of horizontal veffels, require fome other means of fupport ; for, if all the veffels, from the earth up to the fummit of the ftalk, were difpofed only in uninterrupted parallel lines, the ftalks would be fo weak and flexible, that they could neither refift the wind, nor be able even to bear the weight of their own fruit. Therefore, thefe kinds of ftalks, are ftrengthened by a fort of joints or knots, at intervals, which prevent the over much bending of the ftalk ; and the joints are placed at fuch diftances that the fpaces between each will allow the bending, only fo much as to recover itfelf.

What has been faid of the joints in ftalks growing in thefe regions, I confider as applicable to fome forts of trees in the Indies ; and, upon feeing fome of thofe Indian trees defcribed in drawings, I immediately concluded, that the Cocoa Tree was of the number.

After feveral endeavours to obtain a fpecimen of this tree, I at length procured from a certain ſea captain, a piece of one, about a foot long, and ten inches in diameter. The bark of this wood was ſound, but the wood itſelf ſo decayed, that it crumbled into powder under the fingers, excepting only a very ſmall part. The capillary or hairy parts which run lengthwiſe on the inſide of the bark, were tolerably ſound, but they ſeparated from each other, as eaſily as if they had never been firmly united, which made me ſuſpect, that, if there ever had been any other parts to connect them, they were decayed.

I perceived that theſe capillary or hairy parts, grew out of the bark, and that many of them were divided into two; and I alſo perceived in each of theſe capillaments many veſſels. Among theſe capillary parts were others, ſome firm and ſolid, others in the nature of veſſels, but the greater part of them much decayed.

Theſe capillary parts, were covered by the external ſolid bark, which bark was, in ſome few places, thicker than in others, but, at the knots or joints, the bark was remarkably thick and ſolid.

This bark, cut tranſverſely, I examined by the microſcope, and found it chiefly to conſiſt of roundiſh threads, about the thickneſs of an hair, and theſe again compoſed of oblong filaments, hollowed on the inſides. Many of theſe latter did not take a ſtraight, perpendicular courſe, but turned inwards towards the body of the tree. Farther, I obſerved, intermixed among them, a kind of ſubſtance, conſiſting of roundiſh globules, connected in a ſort of regular order. Theſe parts, compoſing the external ſubſtance of the tree, were ſo cloſely united together, that it might be thought the tree had not any bark on it. From all theſe obſervations, I was led to conclude, that this tree receives its growth and increaſe from the bark alone. And I perceived certain roundiſh parts, which ſeemed to iſſue in a right line from the bark inwards, as if they were deſigned for no other uſe, than to convey the nutritive juices in that direction.

If, however, we could be furniſhed with a piece of this tree, cut while alive and growing, our obſervations might be much more accurate. And, indeed, I was not without ſuſpicion that this piece of wood had been cut from a dead tree, though one of the ſeamen aſſured me, that the decay which I have before mentioned, happened to it on board the ſhip.

In order to place before the reader's eye the form of the joints knots, or bands, whereby the body of the Cocoa-tree is ſtrengthened, and which as it were, ſurround it throughout with a ſort of girdle, I cauſed a drawing to be made of this piece of wood, on a contracted ſcale; from which drawing will be ſeen, how firmly thoſe trees, which have no horizontal veſſels, are ſtrengthened by theſe kind of bands, ſurrounding them in an oblique direction.

In Plate VI. *fig.* 1, A B C D E F G H I K L M, repreſent this wood drawn ſmaller than the natural ſize. C M, C L, D L, E K, F K, F I, indicate the poſition and courſe of the knots or bands, that is, that they do not go in a ſtraight line round the tree, but ſometimes approach to, and ſometimes recede from, each other, which approach and receding are ſhown at K L. And, this oblique courſe of the knots, bands, or cinctures, contributes more to the ſtrength of the tree, than if they encircled it in the form of hoops.

By cutting and examining this wood, in the manner I have deſcribed, I fully ſatisfied myſelf in the particular wherein I wiſhed to be aſcertained, namely, that the Cocoa Tree has no horizontal veſſels. And there is moreover a circumſtance to be noted in theſe kinds of trees, that they have no branches except at the very tops, and therefore, are not ſo ſtrongly acted upon by the force of the wind. Nor are the branches which they have, perennial, but they every year fall off, and are replaced by freſh branches, which grow on the tree at the ſame time with the fruit.

I alſo cut tranſverſely a piece of the wood, in a part where it was ſound, in order to ſhew, as accurately as poſſible, the make and texture of this wood, when viewed by the microſcope.

Fig. 2, O P Q R, repreſents a very ſmall particle of the Cocoa wood, cut tranſverſely, and magnified, wherein are to be ſeen ſix of the larger of the perpendicular veſſels, two of which, ſurrounded by a great number of ſmaller veſſels, are to be ſeen at T T. Of theſe larger and ſmaller veſſels, the capillary or hairy parts I have mentioned, and which are very tough and ſtrong, are compoſed. But theſe veſſels do not all aſcend in an exact perpendicular direction, but creep upwards in a kind of oblique courſe, one among another, by which poſition they contribute to the ſtrength of the tree. And when one of theſe veſſels or threads divides itſelf, each divided part, though it preſents the figure of a ſmaller filament, is yet in truth a perfect veſſel. Theſe ſmaller veſſels, intermixed with the larger ones, I have cauſed to be repreſented in the drawing.

Theſe larger veſſels ſeem connected together by a kind of veſicles, which, I imagine, while the tree is alive and flouriſhing, are filled with ſome kind of liquid. Theſe veſicles are not diſpoſed in any orderly or proportionate manner, but in ſome places they may be ſeen heaped together to the number of five and twenty, and in other places, between two capillaments, will be found only a ſingle veſicle.

Such of theſe capillaments as are next to the bark of the tree, are exceeding ſmall, in compariſon of thoſe nearer the middle; and, to exhibit them to the reader, I cut off a piece of the wood next to the bark, and cauſed it to be drawn from the microſcope, which drawing is copied at *fig.* 3, A B C D. In this figure, A D is an innermoſt bark next the wood, being a very thin ſkin, and the capillaments next to it are the ſmalleſt of all, whereas thoſe more inwards, grow larger and larger. But, though theſe innermoſt capillaments are the largeſt, they are ſtill compoſed of thoſe exquiſitely thin and hollow filaments I have mentioned, the hollows or cavities in which I have caufed to be reprefented by a fort of points or dots. The black fhade in this figure, denotes minute veffels furrounding the others, which by reafon of their exceeding fmallnefs could not be reprefented in the drawing.

Thefe veficles, which I have mentioned to adhere to the capillaments, as they appear, when cut by a ftraight fection, are fhewn at *fig.* 4, E F G H. In thefe veficles there appeared fome fmall particles, concerning which, however, I could not pronounce any thing with certainty.

After I had made the preceding obfervations, I received from a friend who obferved how defirous I was to inveftigate the nature of the Cocoa wood, a piece of that wood which he had procured from the ifland of Curaçoa. This was feven inches in diameter, and about four inches long: in the middle, it was compofed of the before mentioned larger capillary parts, but, on the outfide, and about an inch from the furface, it was fo hard, that in attempting to fplit it, I broke a fteel wedge in pieces, and I do not remember ever to have met with fo hard a wood.

Between the bark and the folid part of this wood, I faw fome capillary parts creeping along, and which were of the fame nature as thofe pictured in *fig.* 1, between G and N, and thefe capillaments, I was informed, are made ufe of to be twifted into ropes and cables.

I obferved, that wherever the knots or bands in the bark approached each other, as at F K, there the capillaments grew out of the bark: fometimes I obferved one or two branches rife out of one of thefe capillaments, and thefe again fubdivide into fmaller ones, hollow within, and which capillaments I judged might in time unite and form veffels of the fize pictured in *fig.* 2, at T T. And if fo, it follows that the Cocoa tree receives the addition to its bulk from the bark, contrary to what we fee in the trees of this country, the bark of which receives its increafe from the wood.

I alfo cut this wood from Curaçoa tranfverfely, and examining it by the microfcope, I found it to agree in all refpects with that reprefented in *fig.* 2, with this difference only, that where this wood was harder than the former, there the capillaments were fmaller, and alfo exceedingly tough.

But as the veficles in the former wood, which are reprefented at *fig.* 4, EFGH, were in this latter much harder, and alfo fmaller than the former, I cut fome of them by a ftraight fection, and caufed a very fmall particle of them, when magnified, to be drawn from the microfcope, which is to be feen in *fig.* 5, at 3 LM2. Thefe veficles, I perceived were of a more firm and folid texture, than thofe in the other piece of wood, and they had in their centers a black fpot, which was a fign that they had had a cavity in them: fome of thefe veficles I cut in fuch thin flices that they appeared tranfparent.

While I was bufied in this part of my inveftigation, I happened to cut one of the afcending veffels, which in *fig.* 2, is denoted by T, but which here is fhewn between IK 3 2 N. And, though the fmaller veffels furrounding it, could not, by reafon of their minutenefs, be otherwife expreffed, than by ftraight lines, yet this larger veffel plainly appeared to be formed of a kind of annular parts, running round each other in a fort of fpiral form. And, though I had obferved this formation of the veffels in many other forts of wood, yet I could not till now, venture to fay, that thefe veffels were formed in that manner, becaufe I had hitherto loft my time and labour in endeavouring to diffect them accurately. But now in this object, where the veffel fpread or opened itfelf a little, at the place marked N, I plainly faw the fpiral formation, which difcovery gave me great pleafure.

I proceeded ftill farther in the examination of this larger veffel, and I found it to be compofed of, at leaft, five fmaller ones, which were placed in regular order, befide each other, and each feverally formed in the fpiral manner I have mentioned. All thefe are fhewn in *fig.* 6, O P, and in the fame figure, at P Q, is to be feen the part which I before mentioned having feen, as defcribed in *fig.* 5, at N.

This circuitous figure of the veffels, may be exactly compared to a brafs wire, twifted round a fmall rod, and the fame kind of formation I have frequently, as I have before mentioned, feen in other woods. And even in a ftraw I once obferved, by the microfcope, one of its larger veffels to be formed, much in the fame manner as this I have defcribed at O P. And, when we confider the fubject, we cannot, in my humble opinion, conceive any form fo fuitable for thofe veffels to raife the juices upwards.

The fame gentleman from whom I received the laft mentioned piece of Cocoa wood, fent me alfo two Cocoa nuts, inclofed in their feveral fhells or coverings. From one of thefe I cut fo much of the outer covering, as to exhibit the inner fhell to view ; and I caufed a drawing to be made of both, on a contracted fcale, which is to be feen at *fig.* 7, A B C D. The diameter of this external cafe or covering was nearly five inches and three quarters, meafured by the fcale B D, which is five inches long.

This external hufk or fhell fo firmly adhered to the inner one, being connected to it by multitudes of veffels, that I found it a work of confiderable labour, to tear it off. The inner fhell was four inches in diameter, and, having cleared it from all the veffels adhering to it, I replaced it in the half of the cafe or hufk, as is to be feen in the drawing.

I have often been told, that the filaments of which this external hufk or bark confifts, are of fuch a length that they are twifted into cables, and alfo wove into fail-cloth. I proceeded, therefore, to examine the texture of this hufk or bark, when I found, that not a tenth part of it confifted of thofe filaments, but that, from them proceeded a certain fubftance, like a collection of vefícles, which vefícles, while the fruit was living on the tree, had been filled with juices, in like manner as thofe parts which, collected in great numbers, from the fubftance of the pear called the Sugar pear, do proceed from the veins or veffels in that pear.

To convey a true idea of the formation of this external coat, hufk, or covering, of the Cocoa-nut, I caufed a drawing to be made from the microfcope of a very fmall piece of it, as is to be feen in *fig*. 8, M N O P Q. Here, N P Q denote the capillaments, which may more properly be called veffels; they are each inclofed in a larger one, which larger one is compofed of numbers of minute veffels.

It is well known, that all fruits, and even the fmalleft leaves, are covered with a fkin, which, that it may prevent the exhalation of the juices, is of a very clofe texture. This external coat or hufk of the Cocoa-nut has that kind of fkin, which, as it appears through the microfcope, is exhibited in *fig*. 9, A B C D E F G H, where are fhewn as exactly as may be, the veffels running along this fkin, and connected with the internal part of the hufk, as for example, as B D E, A E, and H G. A branch proceeding from the veffel B E, is reprefented at C D.

In the fhell of the nut, pictured at *fig*. 7, there are three parts fomewhat refembling eyes, two of which point towards each other, the third contains the young plant, which, when the kernel begins to vegetate, fhoots out through that cavity. And this young plant in its vegetation receives nourifhment from the kernel, through thefe perforations I have called eyes, until it is able to draw its nourifhment from the earth, and this, without there being a neceffity for the fhell of the nut to break or open. The vegetation of the chefnut is performed in the fame way, contrary to what is obferved in the feeds of nuts, plumbs, and the like, the fhells of which, as the vegetation of the kernel advances, divide and open themfelves.

Moreover, I cut off feveral pieces from the hard fhell of the Cocoa-nut, fome of them longitudinally, fome tranfverfely, in order to fhew the texture of it, as feen by the microfcope, This is reprefented at *fig.* 10, IKLMN, in the inner part of which is a vein or veffel dividing itfelf into many fmaller ones.

I next proceeded to examine a thin membrane or fkin, which lines the infide of this hard fhell. An incredible number of veffels which may be feen by the naked eye, are difperfed through this membrane; the hard fhell is of a dark colour, verging towards a black, and the membrane of a faint afh colour. I have often placed pieces of this membrane before the microfcope, and could not, without admiration, behold the almoft incredible number of fmall oblong parts therein, which were heaped one on another, in fuch various manners that I could not conjecture for what ufe they were defigned; but they all confifted of fpiral parts, fuch as are defcribed in *fig.* 6, at O P. Thefe parts were fo exquifitely flender, that upon comparing them with a vein taken from the breaft of a flea, which I had ftanding before a microfcope, I found that the vein (which was alfo of a fpiral form) was about four times as large as thefe component parts of the membrane, and I could not fufficiently wonder at the multitude of thofe fpiral parts,

I have alfo often placed before the microfcope, thofe capillaments which in breaking the fhell I found adhering to it by one of their extremities, merely for the pleafure of contemplating the object; for, a capillament no larger than an hair, would be feen to confift of twenty filaments, the fmalleft of which I judged to be lefs than the thread fpun by the filk worm. So that, if we would compute the whole number of thefe filaments in a fingle nut, we muft not reckon them by thoufands, but by hundreds of thoufands.

That which is the kernel of this nut, and is commonly called the Cocoa-nut, is a very white fubftance, about half an inch thick, clofely joined to the whole interior part of the fhell; the remainder of the cavity contains a watery juice, which is what I never obferved in any other feed, when come to maturity. For nuts and chefnuts are entirely compofed of folid parts, which we call the kernel, though before they come to maturity the matter inclofed in them is no more than a watery and flimy fubftance.

Upon this head, I reafoned with myfelf; that before the inward fubftance of the Cocoa-nut is full grown and ripe, the fhell becomes harder than thofe of any fruit known in the northern climates; and I concluded that when the fhell is grown perfectly hard, it cannot be afterwards increafed in fize, nor can the kernel it contains receive any addition to its fubftance: and therefore, that part of the nutritive juice which is of a watery nature, and cannot be converted into kernel, muft remain in the center of the nut.

I afterwards fell into converfation with two mafters of fhips, who had vifited both the Eaft and Weft Indies, and had been often employed in collecting Cocoa-nuts. They informed me, that when the fhells of the nuts were fo foft that they could be cut with a knife, there was nothing to be found in them except a lymph, or thin liquor, of a very pleafant tafte, which information confirmed me in the opinion I have before related.

At another time, upon a different inveftigation of the Cocoa-nut, I preffed from the pulp or white fubftance of it, fuch a quantity of oil as fixed me in aftonifhment.

After this, upon opening a Cocoa-nut which I had kept for the fpace of feven months in my cabinet, I obferved thofe three foft places in the fhell which are called eyes, and from one of which the young plant ſhoots forth, to be covered, and, as it were, ſealed up, with a ſubſtance like roſin or pitch.

To give a more perfect idea of the nature of the Cocoa-nut or kernel, after I had bored the ſhell near the place where thoſe parts I have likened to eyes are ſituated, and poured out the juice contained in the cavity, I broke away the ſhell ſo far as was ſufficient to ſhew the inſide of the nut, that it might be expreſſed in a drawing.

Fig. 11, O P Q R, repreſents the Cocoa-nut or kernel as it appears, incloſed in the ſhell, which ſhell is denoted by P Q R. At P R, are ſome of thoſe capillaments, which in great numbers, are found united to the ſhell, and, as they are in fact, no other than veſſels deſtined to convey the nutritive juices, they penetrate into the interior part of the ſhell, and there impart nouriſhment to the fruit. Farther, many very ſmall veſſels take their courſe through the hard ſhell, and theſe, as I found by the microſcope, were compoſed of other veſſels incredibly ſlender, the ſmalleſt of which were of the ſpiral formation deſcribed in *fig.* 6, O P.

S T V, denote the nut itſelf, properly ſo called. W X Y is a cavity within it, which contains the ſap or juice I have mentioned, which is very pleaſant to the taſte, and of a nouriſhing quality. A drop of this juice I put into a very clean glaſs, in order, when the watery parts of it were exhaled, to examine the remainder, and therein I did not find any ſaline particles, but it had the appearance of a ſyrup, which did not evaporate, being more of a fixed nature.

This kernel is connected with the hard ſhell by infinite numbers of veſſels, and on the ſide next the ſhell is alſo covered with a thin ſkin, through which multitudes of veſſels take their courſe; they are of the ſame ſpiral figure as before mentioned, and lye cloſe together, and they are not much thicker than the hair of a man's beard. Whence it appears that the kernel is formed and nouriſhed from theſe very ſlender veſſels.

Upon examining this nut or kernel by the microſcope, I found that its ſubſtance is not, like other ſeeds, incloſed in ſmall membranes, but conſiſts of multitudes of minute tubes, which take their riſe from the hard ſhell, and reach to the cavity, within the kernel, where the juice I have mentioned is collected. They are not all of an equal ſize, nor are they of a round figure, but rather of ſix ſides, which ſhape is well adapted to permit their lying cloſe together and in regular order. Some of theſe are turgid with a certain ſubſtance, which in part evaporates; others of them contain globules which I judged to be chiefly filled with an oil.

Theſe ſmall tubes, which in *fig.* 11 are to be ſeen at W, I cut tranſverſely, and cauſed a drawing to be made of a very ſmall portion, as viewed by the microſcope, which in *fig.* 12 is expreſſed by *ABCD*: the ſmall points, or dots in this figure, denote ſome very ſmall particles, which I obſerved in theſe tubes.

Moreover, I cauſed a drawing to be made of that part of the nut or kernel, where I judged the young plant to be ſituated, in the ſhape it exhibits when ſeen by the eye alone, without the microſcope. This occupies but a very ſmall part of the kernel, and is ſituated in a part where its ſubſtance is thinneſt. A drawing of this, of the natural ſize, is to be ſeen at *fig.* 13, ABC DEF, and HEG is the part which in my judgment contains the entire young plant.

From this part I cut ſome very thin ſlices at that end of it which in *fig.* 13 is neareſt to the letter E. For I was deſirous to examine whether any thing would there be found bearing any ſimilitude or reſemblance in figure to the future ſtem of the tree. Some of theſe ſlices I placed before the microſcope, and cauſed a very ſmall portion thereof to be drawn, that it might not take up too much ſpace in the paper. This is repreſented in *fig.* 14, at *EFGHI*. In this figure *IEF* denote the ſkin or covering, incloſing what I take to be the plant. The remainder of the figure repreſents aſcending veſſels, and which, as far as I could diſcover, were filled with an oil. Thoſe parts which appear like larger veſſels, and are indicated by *K K K*, were ſhining and tranſparent, and were compoſed of other veſſels, ſo ſmall as to exceed all belief.

Upon cutting this part marked HEG, not far from the end, next H, I was aſtoniſhed to find that this was not, wholly, the young plant, but chiefly its caſe or incloſure, the young plant itſelf, which was contained in it, being not much larger than a grain of ſand. One of the pieces thus cut off I placed before the microſcope, and delivered it to the limner, directing him to make a drawing of the object which preſented itſelf to him, as nearly as it was poſſible for his art to imitate it. This ſlice, which had been cut lengthwiſe, thus depicted, is ſhewn at *fig.* 15, IKLM.

I took great pains to examine many Cocoa-nuts before I could be certain that what in *fig.* 15, is marked IKM, was really that part of the young plant which would penetrate downwards into the earth, and become the root, and that what is deſcribed at KLM was that part which would grow upwards into a tree; but I am now ſatisfied that this is the caſe, and that the parts laſt mentioned are the leaves, which in this young plant are already formed.

I many times endeavoured to ſeparate theſe young plants from the integuments incloſing them, but always in vain; becauſe that part which in *fig.* 15 is denoted by IKM, firmly adhered to thoſe integuments. All I could do therefore, was, to cut the young plants in pieces by a longitudinal ſection; in doing which, however, it often happened, that the object preſented three or four ſhapes to the view, by reaſon that I had ſometimes cut the plant directly through the middle, and ſometimes on one or the other ſide. To ſet this alſo before the reader, I have given two drawings of the pieces ſo cut, omitting only the integuments or circumjacent parts inclofing them.

The firft is, of a plant which I had, as I believe, cut exactly through the middle, and it is fhewn at *fig.* 16, NOPQ. Here, NOQ, is the part which would become the root, and OPQ, that which would grow upwards into a tree. And, in this young plant, are plainly to be feen the leaves with which it is naturally furnifhed.

The other, is of a plant which I judged, had not been cut through the middle ; for which reafon it did not appear fo large as the former, nor were the leaves equally confpicuous. This is exhibited at *fig.* 17, RSTABZ. The place of the future root in this plant is marked by RSZ, and that of the ftem by SABZ.

Although I frequently repeated thefe experiments, it was only twice that I could obferve the upper part or future ftem of the plant, in drying, feparate itfelf from the circumjacent parts. This feparation I have caufed to be expreffed in the fame *fig.* 17, at SABZ, and at TY.

I have generally obferved, that the young plant, in that part which, in *fig.* 13, is noted by EHG, occupied not more than one half of the fpace there reprefented, and lay near the part marked H. But, at one time, I faw the young plant occupy only a third part of the fpace ; whence it follows, that fuch fpace or cavity was nine times as large as the plant it contained.

Farther, I twice obferved the young plant to lie, not precifely in the middle, but rather on one fide of the before mentioned cavity, whence I concluded, that it had begun to vegetate while in that part, for I faw that the circumjacent parts had in that place begun to feparate from each other, fo that, had the vegetation continued, the plant would have found its way out of the fhell. This feparation of the parts is reprefented in *fig.* 17, at AWB.

Moreover, I thought it right to give fome reprefentation of thofe extended parts which furround the upper part of the young plant, or, more properly fpeaking, the whole of that plant.

Let us fuppofe then, that I have cut off a fmall flice of that part which in *fig.* 13 is pictured between G and H, and, that in *fig.* 17, a fmall part of the circumference of this flice, and of the fkin inclofing it, are defcribed at VWX. By T, and by V W X Y, that fubftance is expreffed, in which the young plant, or rather the upper part of it, is as it were, inclofed and wrapped up. The parts of this fubftance, exhibit the appearance of fmall veffels, which lie difpofed in fuch ftraight lines, that they naturally feem defigned to convey nourifhment to the plant. But, in the part pictured at H, in *fig.* 13, and where there will be found a kind of fwelling, thefe veffels are ftretched out to fuch a degree of finenefs, that none of the parts within them can be diftinguifhed without the greateft attention.

As the kernels of Almonds, Walnuts, Peaches, and Plumbs, which are inclofed in fhells, are denominated the feeds of their refpective trees, fo the Cocoa-nut, or fruit of the Cocoa tree, ought to be reckoned among the feeds of trees. In the feeds, however, of the trees I have firft mentioned, whofe fhells are all formed with a feam or joining, thofe fhells, when the vegetation proceeds, and the kernel fwells, open at the feam, and the young plant in the kernel, having more fpace afforded it, can expand in its growth, and ftrike its root into the earth. But the fhell of the Cocoa-nut has not any feam or joining, being of an equal ftrength and thicknefs throughout, therefore its vegetation muft be provided for in a different manner; and this I conclude to be as follows. The moifture in the Cocoa-nut being inclofed and confined on every fide, when it begins to be agitated by that inteftine motion, produced by heat, muft neceffarily expand itfelf with great violence, and, by that expanfion, the part which contains in it the young plant, is by degrees, as the plant increafes in fize, driven out of the fhell through the aperture before noted.

Thofe, who have lived many years in India, affirm, that there is no tree fo beneficial, or which produces fo many conveniences to mankind, as the Cocoa; and that it is converted to upwards of fixty different ufes by man. The nut not only fupplies him with food and drink, but from the nut is alfo extracted a liquor not much unlike the fpirit diftilled from barley, and from the fame nut vinegar is made. The tree itfelf furnifhes mafts for fmaller veffels, and the capillaments or filaments which furround the nut are partly wove into fail-cloth, and partly twifted into cables, which are ufed even for large fhips. If the trunk of the tree be pierced with a fmall incifion, there will flow from the wound, every day, a quart of excellent liquor, and this operation may be performed twice in the year; the trees, however, which are thus treated, are deprived of their fertility for that year.

If we compare the fize of the Cocoa-nut, with the very fmall plant it contains, we may fafely fay, that the nut is above one hundred thoufand times larger than the plant, and we may thence conclude that this nut, and the pleafant liquor it contains, are deftined by nature, or which is the fame, by Providence, for the ufe of man, and to fupply many of his wants.

On HOPS.

Of the Hops which grow in the Low Countries, thofe from Liege are preferred to ours here in Holland, and, I doubt not, with reafon, becaufe the territory of Liege is one degree and an half more to the fouthward than Holland, confequently the Hops will fooner come to maturity there; befides, in the lands about Liege the foil is deeper than ours. The following are the obfervations I have made upon this plant.

I examined by the microfcope, thofe leaves of the Hop, which compofe the pod, or cafe, containing the feed; which leaves, being remarkably thin, afforded me a very pleafant object to behold, the veins or veffels fcattering themfelves in all directions about the leaves, and, in fome places, uniting again. Some of thefe veffels, I perceived to be filled with a red fubftance, others were of a fpiral figure, refembling thofe veins which I have obferved in the leaves of tea.

Many of thefe leaves, I obferved to have a fmall feed adhering to them, at that part, where the footftalk of the leaf had been joined. And, indeed, I think, that thefe fmall leaves thus bearing the feed, are fo formed, that each fhall produce one feed, but, it is my opinion, that the feeds, when the leaves do not grow to perfect maturity, cannot ripen.

Many of the feeds I diffected, and found nothing in them, except the young plant, which was chiefly compofed of the part that would in time become the root. There were, however, two leaves formed in the plant, but nothing elfe remarkable, except an immenfe number of fmall veffels or veins, difperfed throughout the beginning root.

All thefe feed pods or leaves, chiefly in that part through which they had received their growth and increafe, were covered with exceeding minute globules, glittering with a beautiful yellow, like gold. As far as my eye was able to judge, thefe globules were in diameter about equal to the thicknefs of an hair of one's beard, but fome of them not fo large. I do not confider them to be the fruit of the Hop, but, fome matter or fubftance, iffuing from the plant, fuch, for example, as if it was turgid with a fuperabundant quantity of juices, or, that the heat of the fun might fome days be remarkably intenfe, and that by the very great quantity of juices, or their extraordinary expanfion, they had burft through the veffels. Many of them I broke, and I did not think that they were covered with any fhell or coat, farther than that their external furface being hardened in drying, exhibited fomething of that appearance. They contained only a limpid oil, of a glittering yellow, and alfo other globules, much fmaller, but more folid, and which with the oil, filled up the cavity of thofe firft mentioned globules.

This appearance of globules, on the furface of the leaves, I think very fimilar to what I obferved fome years ago, at a houfe where I was upon a vifit; the back part of which houfe, was covered with a vine, facing the fouthern fun. The young fhoots of this vine, I obferved to be, in many places, covered with tranfparent globules, and I judged them to have arifen from the fuperabundant juices, which, by the heat of the fun, had been brought forth in fuch plenty, that there was not a paffage for them through the narrow veffels of the branches, fo that they might be abforbed by the grapes. And the warmth on this vine feemed to me, to be farther augmented from this circumftance, that the ground which covered the root, was very curioufly paved with fmall different-coloured pebbles, without an herb or blade of grafs appearing between them. And the juice, thus expelled from the branches, was infpiffated or thickened on their furfaces into globules.

Upon examining the globules on the Hops by the microfcope, I found, that the part which might be called their coat or fhell, was not fmooth, but rough, and in wrinkles, occafioned, as I concluded, by this, that the juice which iffued from the plant, and formed itfelf into globules, had, in part evaporated, whereby the outer furface or fkin of thofe globules, contracted into wrinkles.

Thefe yellow globules, when broken, and put into a clean glafs, I fuffered to ftand in the glafs for fome days, and then applied myfelf to examine the oil. I found that great part of this oil, had collected itfelf into thin oblong particles, and, in fuch numbers, that I could not but filently wonder at the fight. Where this oily fubftance lay much difperfed, there, the oblong particles I have mentioned, did not exceed in length the diameter of a very fine thread of wool, but, where the oil was collected in larger quantities, they were four times that fize. In fome places, I obferved oblong particles, with twelve points, iffuing, as it were, from a center, with one of their ends terminating in a point, the others, blunt or obtufe.

Now, we may lay it down for a certain truth, that thofe pellucid and oblong particles, which I have mentioned to be intermixed with the oil, although, by their minutenefs, they efcape our fight, are really a fpecies of falts, and that the bitternefs which Hops impart to beer, is produced by thofe falts. And we may alfo be affured, that thefe minute falts, although they may be a thoufand times lefs than what can be feen by the microfcope, do yet, agree in fhape and figure, with the larger falts of the fame fpecies compounded of them, in like manner as we obferve in common falt, in nitre, or falt petre, and in many other falts. The fame may be obferved, in that kind of fugar called fugar-candy ; for, upon this becoming damp, on being expofed to a moift atmofphere, when it afterwards dried, I have heard women complain of its having loft its bright colour. Upon examining into the reafon of this, I found, that the furface had been in part diffolved by the moift air, and when, in drying by the fire, it again became hard, an incredible multitude of fmall particles, very many of which agreed in fhape with the larger parts, had collected upon the furface, and this collection of minute particles, clouded the brightnefs of the fugar-candy.

But, to return to the falts in Hops; how will thofe philofophers get over the difficulty, who obftinately contend, that bitternefs is caufed by a fort of minute hooks in the falts, which by their punctures produce that tafte we call bitternefs?

I have often laid a fingle leaf of the Hop, fuch as I have defcribed it, upon my tongue, and held it there the fpace of half a minute; for I was defirous to try the experiment, whether fuch a fingle leaf, which is frequently covered with the yellow globules I have defcribed, could excite a fenfe of bitternefs. And, it is not without wonder, I declare, that fuch a fingle leaf, upon being ftrongly compreffed between the tongue and the palate, fpread all over my tongue a very bitter tafte, and indeed, much ftronger than I expected.

Not content with thefe obfervations, I placed a parcel of thefe oily globules, fome of them pounded or bruifed, fome of them entire, in two feparate glaffes, and, with all the attention I was able, I examined them by the microfcope, but I did not find any particular kind of particles in them.

I then placed the glaffes in my cabinet, and, that no kind of filth or dirt might become mixed with the oil, I covered them with paper. After twenty-four hours had elapfed, I examined them very attentively, and, in fome few places, I perceived fome of thofe oblong particles I have before mentioned, which were very fmall and thin, and after twenty-four hours longer time, a much larger portion of fuch falts was difcoverable. Thefe obfervations were in the winter, when the weather was not favourable for fuch enquiries; but, had they been made in a milder feafon of the year, I doubt not, that the falts would have been formed more fpeedily, and in greater plenty.

I think it might be worth while, in the fummer-time, to examine the flowers and bloffoms of various trees, particularly thofe, of which bees appear the fondeft, by which examination it might perhaps be difcovered, what kind of fubftance, if any, and of what qualities or properties, iffues from fuch flowers, and adheres to their furfaces.

At one time, in the month of October, I was informed by a Hop Factor, that the Hops in that year, were of an excellent quality, whereupon I procured fome of the feed pods, of that year's growth. Upon examination, I found each of thefe feed pods to contain thirty or even forty feeds. When I had ftripped the feeds of the fmall leaves or integuments furrounding them, I obferved, that the young plants within them contained, in proportion to their fize, abundance of oil. I farther noted, what I have already mentioned, that each young plant had two leaves, and thefe in proportion to the minutenefs of the plant, were remarkably long. Thefe leaves lay in each feed compacted and twined together, much like the fpiral folds in the fhell of a fnail; and, when I laid open the folds, I faw within them, ftill more leaves, but exceffively minute, and which indeed, I could not difcover in all the feeds. From hence it appears, that the feeds of the Hop differ from moft of the larger fort of feeds, and do not contain in them any fubftance to nourifh the young plant, which plant therefore is more perfectly formed than that in the larger feed of the Chefnut.

As to thofe beautiful globules which I have before mentioned to have obferved, thofe, in this fpecimen of the Hop, were dried, and rather fhrivelled. Having broken them, I put them into a glafs, and breathed on them with my warm breath two or three times, whereupon the oil diffolved into a wonderfully fluid fubftance. The glafs I then placed, where no duft could reach it, and, upon examining it the next day, I faw fuch a multitude of falts of different magnitudes difperfed about the oil, as it would almoft exceed belief to relate. Moft of thefe falts were pointed at each end, but many of them were fo minute, that their figure could not be known or judged of, but by reference to the larger ones adjoining to them. In fome of my obfervations on this oil, I found the falts to appear in it, at the expiration of only half an hour after it had been put into the glafs, and they increafed in number and fize every hour, the fmaller growing larger, and the oily liquor evaporating; and I found that this fpecimen of the Hop plant, contained twice as many falts as were in the former one.

I obferved one thing which feemed ftrange to me, namely, that many of thofe oblong falts which I had faid were pointed at both ends, did not extend in a ftraight line, but were fomewhat bent or doubled together; but, whether thefe falts fo bent into a bow-like figure, do, for that reafon, excite the motion or fenfation in our tongues, which we denominate bitter, I leave to be examined by others.

On COCHINEAL.

WHEN I firſt applied myſelf to inveſtigate the nature of Cochineal, I concurred in the general opinion which then prevailed, that it was the fruit of ſome tree; and, having at the requeſt of the Honourable Mr. Boyle, further proſecuted the examination, each ſingle piece, or fruit, as I then thought it, appeared to contain one hundred or upwards of what ſeemed to me to be very ſmall ſeeds, ſhaped like eggs, each incloſed in its particular membrane; theſe objects, however, I could not bring into view, until the Cochineal had lain in water for ſome hours, and then, the outer ſkin being taken off, theſe apparent ſeeds, which were very ſoft, preſented themſelves; many of which were incloſed in the membranes I have mentioned, which ſeemed to be their natural coats or coverings, and were twice as large as the ſeeds themſelves: the membranes were filled with a watery ſubſtance, of a lovely red, but the ſeeds were of a dark red or tawny colour. The ſeeds themſelves, upon being diſſected, appeared to conſiſt of nothing but very minute globules of a red colour.

The remainder of the Cochineal, or that part of it which incloſed all theſe ſeeds, was compoſed of very thin membranes, which were alſo of a red colour, except that a very ſmall quantity was to be ſeen, of a certain colourleſs ſubſtance, which, to me, had the appearance of an oil. And to give an idea of the general appearance of the figure of Cochineal, I know not any manner of expreſſing it, better than by compariſon, with a parcel of dried black currants, with their ſkins and ſeeds.

regard being neverthelefs had to the different fizes of the currants, and the Cochineal. Laftly, when I divided the membranes or feeds of which Cochineal appeared to confift, into as thin portions or particles as I was able, thofe thin particles, did not, as I may fay, exhibit any particular colour.

The preceding obfervations I communicated by letter to Mr. Boyle, from whom I received an anfwer, to the following effect: that he had underftood from a Governor of Jamaica, that Cochineal was produced from the fruit of the fig-tree, when in a ftate of decay, at which time, there proceeded from thence, certain maggots or aurelias, which changed into flies ; that thefe flies fettling on the trees were there killed by making fires under the trees, the fmoke of which caufed them to fall down ; after which, they were ftripped of their heads, the fore parts of their bodies, and their wings, and the remainder preferved for ufe, fo that Cochineal was properly, and in truth, the hinder part, or tail of a fly, and confequently, that my obfervations were fo far correct, that the fubftances I had feen were really eggs, fuch as are found in the hinder part of the filk-worm's moth.

To this I replied, that, in my preceding obfervations, it was impoffible for me to judge, that Cochineal was an animal fubftance, becaufe there was nothing to be feen in it, that refembled an animalcule, and that I had concluded, if it had been an animal, it would have been devoured by thofe minute animalcules, called mites ; and I added, that in confequence of the information communicated by the Hon. Mr. Boyle, in his letter, I had repeated my obfervations, the refult of which as I communicated them to him, is as follows.

On this renewed inveftigation of the fubject, I was fully convinced, that every fingle grain of Cochineal, was part of an animalcule, from which, not only the head, the fore part of the body, and the wings, had been broken off, but that alfo the legs, and that part of the body to which the legs are joined, had been thrown away, fo that nothing was left, except the animal's hinder part; and I imagined, that the colourlefs fubftance I before mentioned, and which is to be obferved in the chinks or creafes in every grain, is fome preparation, applied to the Cochineal, when it is collected for fale, to defend it from the mites, which otherwife would deftroy or devour it.

Thefe creafes or rings, in every grain of Cochineal, I imagine are, the articulations or joints, in thofe kinds of maggots or caterpillars, which afterwards change into a flying infect: And I did not doubt, that, at the proper feafon, when a fimilar kind of infects could be found in this country, I fhould eftablifh that fact, allowing only for the difference in fhape and colour between them, and thofe which conftitute Cochineal.

After this, I examined a large parcel of Cochineal, and in it I found feveral of the fhells or coverings of the wings, which fhells were of a black colour, with each a red fpot in the middle. Many infects are provided with thefe kinds of fhields, fhells, or cafes, to defend their wings and the hinder parts of their bodies, which are very foft, from injury; and, when they prepare to take their flight, they erect thefe fhields or cafes upright, and fpread their wings.

In this parcel of Cochineal, I alfo found among the grains, fome fragments of aurelias, which I concluded had been formed from the maggots or caterpillars of this fpecies, and, in one of them was a piece of a maggot, which, in part, feemed to have been devoured by mites.

The children in this country, are accuftomed, in the fpring time, (when the white nettles, or, as they are commonly called, the blind nettles, are in bloffom) to go in fearch of a fpecies of fmall flying infects, called by them lady-birds, which, for the moft part, are to be found on thofe nettles. The fubject now before me, caufed me to turn my thoughts on thefe infects (though they are fmaller than t' fe whofe bodies conftitute Cochineal) and I employed fome children, at the proper feafon, to collect fome of them for me; judging that, when ftripped of their wings with the cafes, and their heads and feet, the remainder would be found to refemble Cochineal.

Thefe lady-birds, as they are called, I killed with the fmoke of fulphur, and afterwards dried them; and when I had taken off the red fhells or cafes which cover the hind parts of their bodies, I found under them two red wings, the extremities of which were folded together, becaufe, being longer than the cafes, they cannot otherwife be covered by them. I alfo took off their wings, feet, and heads, and then I found, that the cavity which is feen on every grain of Cochineal, is on the back or upper fide of the animalcule, and is caufed by the drying; that part of the grain which appears with a kind of rifing, is the lower part or belly. As to thofe grains in Cochineal, which have fmaller cavities than others, I conclude, that they muft have been the female infects, whofe bodies, being filled with eggs, do not admit of their contracting in fo great a degree; and though the hind parts of the bodies of thofe infects which compofe Cochineal, do fomewhat differ from thofe of the lady-birds, yet, I was now, more than ever, affured, that, not only the infect which produces the Cochineal, but alfo thofe others I have juft mentioned, are formed from maggots or caterpillars. For, if we confider the nature of all thofe flying animals which are bred from caterpillars, maggots, or, what are called gentles, we fhall find, that all thofe annular parts, articulations, or circular creafes, which are in the caterpillars, maggots, and gentles, are alfo found in the flying infects bred from them; and in the fame number. To inftance in the gentle, from which the common fly is bred; if we examine the fly, and confider its head to be compofed of one of the annular parts, or articulations in the gentle, we fhall find that the breaft to which are joined the fix feet, contains three diftinct articulations, and the hind part of the body five more. In a word, the body of the fly is divided into nine ſeveral parts, joints, or articulations, and ſo many alſo are found in the gentle. This gives the reaſon, why we muſt not ſuppoſe, that the rings or creaſes which we ſee on the grains of Cochineal, are accidentally produced in the drying, for they were compleatly formed in the maggot, from whence the flying inſect iſſued, the hinder part of whoſe body conſtitutes that ſubſtance named Cochineal; of which, if we examine the grains, we ſhall find them to contain ten articulations; and the fore part of the inſect's body, which includes the head and feet, and the wings with their caſes, being compoſed of four joints or rings, it follows, that the Cochineal inſect is formed of fourteen joints, rings, or articulations.

After I had left the grains of Cochineal in water, for the ſpace of twenty-four hours or upwards, I obſerved, that the cavity, which had been cauſed in them by the drying, was ſwelled and extended to its original ſhape, ſo that the grains appeared exactly to agree, in form and make, with the hinder parts of thoſe inſects, whoſe wings and bodies are covered with ſhells or caſes.

An account of fome pieces of Amber prefented to the Author; alfo of a fubftance refembling burnt paper, reported to have fallen out of the clouds in Courland.

A Pruffian Gentleman, by profeffion a phyfician, on a certain time, earneftly requefted me, by letter, to receive a vifit from him, and, with the fame letter, tranfmitted to me, fome fmall pieces of Amber, which, he faid, were fent as a prefent to me, from fome perfons of note in Pruffia.

In thefe pieces of Amber were feveral fmall animals, namely, a Fly, a Gnat, a Spider, and an Ant. In the two firft of thefe creatures, I not only plainly faw the wings, but, by the microfcope I could difcover the feathers and hairs on them, and alfo thofe protuberances or appearances like coral beads, of which the eyes of thofe infects are compofed ; I alfo faw the hairs, and nails or claws on all of them, as plainly as if they had been placed before the microfcope, without any intervening medium. In one of thefe pieces of Amber, I faw a little piece of ftraw, in which I could diftinguifh the tubes or veffels of which ftraw is compofed.

The manner how thefe animalcules became inclofed in the Amber, and the nature and compofition of Amber, are equally unknown to me ; and I cannot fubfcribe to the theories or opinions of others, which do not feem fufficiently fupported, nor am I at prefent particularly called upon, to make any farther enquiry into this matter.

The fame Gentleman, among other fubjects of converfation, told me, that in Courland, there had been found in a field, fomething refembling burnt paper, being as much as two or three fheets in quantity, which it was reported had fallen from the clouds; that he had procured a piece of it, which he had examined by the microfcope, but could not form any fatisfactory judgment refpecting it. And, finding me defirous of feeing this pretended paper, he afterwards fent me a piece of it.

I had not had this fuppofed paper in my poffeffion half an hour, before I obtained, by the help of the microfcope, fo much infight into its nature, that I judged it to be a vegetable production, of a fort which grows in the water; and I concluded, that if the fact was, as reported, that it had fallen from the upper region of the air, it had been carried up thither by what is called a water fpout; though I am much more inclined to believe, that by fome heavy ftorm of rain, or the melting of fnow, (if the country is mountainous) the ponds or ditches might have overflowed, and carried with their current this vegetable production while green, leaving it on fome field of grafs or arable land, and there, by the fun and wind, it might be very much dried, fo as, in fome meafure, to refemble burnt paper: moreover, I was well affured, that I had feen this kind of fubftance in confiderable quantities in ponds, ditches, or canals, in this country; my only difficulty was, to difcover, how it acquired the black or apparently burnt colour before mentioned.

To fatisfy myfelf in this refpect, I went to fome ftagnating pieces of water in the neighbourhood of this town, where I had feen this vegetable, which is an aquatic plant or weed, in great abundance, fome of it I brought home with me, and fpreading it open between pieces of thick paper, I laid it before the fire to dry. I then perceived that where many pieces lay heaped one on another, their natural green was changed to a blackifh caft; but, where the pieces lay fingly, they preferved their green colour.

After this, I examined the before mentioned imaginary paper more accurately, and I faw very diftinctly, that it was exactly of the fame make and texture, with the pieces of green plant or weed I had gathered; and, upon examining this laſt, when in the ſame ſtate as I took it out of the water, I ſaw by a common magnifier, what ſeemed to me like very thin threads in it, much finer than hairs; they were round, and their membranes or coats very tranſparent, and they were filled with great numbers of green globules, of different ſizes, the moſt of them about the ſixth part as large as a globule of the human blood. And though this green weed, when I firſt laid it to dry, was in parcels heaped together, to the thickneſs of one's little finger, yet, when dried, it was no thicker than common paper, whence may be gathered, what a vaſt quantity of watery particles are contained in this aquatic plant or weed.

In a word, this ſuppoſed paper from Courland, which is there reported to have fallen from the clouds, and the green weed or leaf, prepared by me in imitation of it, are, in their component parts, ſo exactly alike, that they may be ſaid to be one and the ſame. For, in divers of the filaments or threads of the firſt, I could perceive the membranes compoſing them to be the ſame as in the ſecond, and, in an hundred places, I could perceive theſe filaments to be furniſhed with joints, which were alike formed in each ſpecimen.

Theſe obſervations ſhew, how far conceit and imagination will lead ſome people, and who knows, how many perſons may have pieces of this imaginary paper, treaſured up in their cabinets as great rarities?

Of the herb Periwinkle, wherein the opinion that it does not bear any ſeed, is refuted.

I WAS induced to turn my thoughts to the conſideration of the herb Periwinkle, from an opinion which is entertained, that, though it bears a flower, it does not produce any ſeed. I therefore procured ſome bloſſoms or flowers of this herb, as they grew on the ſtalks, for I was well aſſured, that no flower is produced by any plant, which, when it falls off, is not ſucceeded by ſome kind of ſeed. And, upon examining by the microſcope theſe flowers, and the remains, as I may ſay, of ſome of them, which adhered to the ſtalk, in the places where the flowers had fallen off, I very plainly ſaw, that theſe remains were formed for the particular purpoſe of producing ſeed; for, in ſome of them, I ſaw two or three ſeeds, though very minute.

An acquaintance of mine, a reſpectable perſon, gave me ſome of theſe flowers, which he had gathered from a plant, growing in a place, where the rays of the ſun ſeldom penetrated: and the ſame perſon, paſſing by a houſe, where this plant was placed as an ornament, and obſerving that there were ſome ſeeds on it, he brought me a few of thoſe ſeeds with the ſhells or pods incloſing them. Theſe ſeeds were of a dark colour, oblong, and much larger than I expected to have ſeen, and they were incloſed in a ſtrong and tough ſhell. They were not much ſhorter than coffee berries, though the coffee berries are four times as thick; and laſtly, the ſeeds of the Periwinkle are diftinguifhable by the fame kind of creafe or chink, as is to be feen in coffee berries.

Six of thefe feeds, I fteeped in water for feveral hours, in order that I might be able to cut them, through the hard fhell or hufk, into very thin flices ; and, upon placing thofe flices before the microfcope, I faw, in every feed, the young plant concealed. I faw likewife, in feveral of them, the two leaves with which thefe kind of young plants are generally provided, and thefe fmall leaves, which, in diffecting the feed, I had cut through, appeared fomewhat of a flat fhape : I alfo could diftinguifh the veins and veffels in thefe leaves. Upon repeating the experiment, I cut through that place in the feed which partly fhoots upwards into a ftalk, and partly penetrates downwards into a root. And here, I could difcern the veffels, deftined to convey the juices upwards or downwards, to thofe refpective parts of the plant. In fome of thefe feeds, however, the young plant was not compleatly formed.

After this, I cut the outer hufk or fhell, and the farinaceous fubftance which furrounded the young plant, into very fmall pieces lengthwife, in order to take the young plant, whole and entire out of the feed. And having fucceeded therein to my wifh, I clearly perceived in the plant the two oblong leaves I have mentioned, with their veffels and veins ; and I farther faw, that the fides of the leaves, which lay next each other, were fomewhat flat, the outer fides of them rounding. The veffels on the fides of the leaves, on account of their opacity, I could not perfectly diftinguifh. The young plant, inclofed in the feed, I judged to be fixteen times fmaller than the feed itfelf.

The young plant in the feed of this herb, Periwinkle, is remarkably long and flender ; the plant itfelf does not rife up into a ftalk, but creeps along on the ground. And, as in this refpect, it is fimilar to moft plants of the vine fpecies, which are by nature what is called creeping, and therefore are uſually trained againſt ſome ſupport; ſo, the young plants, in the ſeeds of the Periwinkle, and in that of the Vine, I mean, what is contained in the grape-ſtone, are of a ſimilar ſhape, though the ſeeds themſelves, are wholly of a different figure: and, as to the circumſtance, that ſeeds are ſeldom found in the Periwinkle, whence the notion of its being entirely deſtitute of ſeeds, ſeems to have proceeded, I gueſs this to be the reaſon, that, it is generally planted in the moſt obſcure and unfavourable places, where it receives very few of the ſun-beams.

Moreover, I examined the mealy ſubſtance which ſurrounds the young plant, and found it to conſiſt, in part, of veſicles, of equal ſizes, but much larger, than the veſicles which are found in the cocoa-nut. When I ſtrongly compreſſed theſe mealy particles, I obſerved many oily parts, of a globular form, and ſo large, that they ſeemed to be compoſed of many receptacles of that oil.

Finally, I placed ſix of the Periwinkle ſeeds in moiſt ſand, which I put into a ſtrong and large glaſs tube; this I carried, for the ſpace of an entire month, in my pocket, where, in the day-time, the natural heat of my body was imparted to them; and, at the expiration of that time, I took out one of the ſeeds, but, I did not perceive any alteration in it. I therefore kept the remaining five ſeeds in the ſand, taking care, that they ſhould always be moiſt. And, at the end of another month, I again examined them, but found their figure unaltered, though the ſeeds were grown ſo ſoft, that, they might be broken with one's nail only. I then took the young plants out of the ſeeds, and I could not obſerve in them any tendency towards decay or diſſolution, nor any advance towards vegetation or increaſe.

*Of the root named * Pareira Brava.*

SEEING, in the Philofophical Tranfactions of the Royal Society of London, the Root named Pareira Brava, very much extolled, on account of the medicinal virtues it is faid to poffefs, I was induced to publifh the obfervations I had made on that root.

A gentleman of fome confequence in this country, produced to me a piece of this root, adding, that it was difficult to be met with, and was very highly valued, for that a few grains of the powder, adminiftered to a fick perfon, would be found of fingular benefit.

In order to examine this wood by the microfcope, I obtained from this gentleman a fmall piece, from which I cut off about the quantity of a grain, and this again, I divided into ftill fmaller flices, fome by a longitudinal, and fome by a tranfverfe fection. I then, by the help of the microfcope, difcovered, that the wood contained many very large pores, in fome places difpofed fingly, in others, two or three placed adjoining to each other. I next, put thefe very thin flices into a perfectly clean glafs, and poured water on them, in order to feparate from them, the falts they might contain, which I was very defirous to examine. Then, upon applying the microfcope, I obferved great numbers of exceffively minute, glittering particles difpofed throughout the water. Thefe particles were of various and peculiar fhapes, very like thofe falts which I have often

* This is the root of an American convolvulus, (the *ciffampelos Pareira* of Linnæus), brought to us from Brazil. The reader will find it defcribed in the New Edinburgh Difpenfatory, being an improvement of Dr. Lewis's.

found in ſea-fiſh. Then, becauſe I imagined that theſe particles, as far as I could judge by my eye, were no other, than abſolute ſalts, I immerſed ſome of them in burnt wine, to ſee whether they would be diſſolved in the wine. But, all of them preſerved their ſhapes unaltered, ſome of them exhibiting on the glaſs, a triangular figure, and ſome being perfectly ſquare. But, it was my opinion, that theſe ſalts, had been incloſed in certain veſicles in the root, and, when extracted from them by the water, had concreted into the ſalts I have deſcribed ; for, I had obſerved the Pareira Brava to be furniſhed with many of thoſe veſicles.

Not having fully ſatisfied myſelf by the examination of this piece of the Pareira Brava, I endeavoured to purchaſe ſome of the root in our town, but I found, that the very name of it was unknown here ; however, in a neighbouring town, where it had been in uſe for about a twelvemonth, I procured an ounce and a quarter, and, upon comparing this with the former ſpecimen, by the help of the microſcope, I found them to correſpond exactly.

This laſt-mentioned root, was a piece, ſplit lengthwiſe, and, as near as I could judge, of five years growth : it was half an inch in thickneſs, and the texture of it appeared to me of a wonderful make.* I divided a ſmall piece of it, into very minute fragments, and, putting them into a clean glaſs with ſome rain water, I cauſed the water to boil, until more than half of it was boiled away, the remainder I took off the fire, judging, that the ſaline particles, were, by this boiling fully incorporated with the water. In this water, however, I diſcovered nothing by the microſcope, except ſeveral very ſmall and thin membranes ſwimming on the ſurface : I therefore expoſed ſome drops of it to the air, in order, that the evaporation of the moiſture might cauſe the ſalts to concrete. But, in a ſhort time,

* The author has not given a figure of this root.

there appeared ſuch a membrane or film on the ſurface of the water, that nothing could be diſtinguiſhed in the fluid, except ſome exceſſively minute particles ſwimming in the water in ſuch multitudes, that, if ſome of them had not collected together in the form of ſalts, I could not have diſcovered them. And, I could not ſufficiently admire, that from ſo ſmall a fragment of the root, ſuch a quantity of ſalts had paſſed into the water.

After this water had ſtood undiſturbed for ſome time, and the films on it were ſubſided, I put a drop of it, about the ſize of a pin's head, into a clean glaſs, and mixed with it ſome blood, which, by the puncture of a needle, I drew from my finger. Whereupon I ſaw, that the globules of blood from whence its redneſs proceeds, were, upon being thus diluted, more ſeparated and ſcattered than I remember to have ever obſerved. There was alſo this remarkable appearance, that moſt of the globules had a kind of ſinus or cavity in them, the ſame as if one had a bladder filled with water, and by preſſing a finger on the middle of the bladder, made a cavity or furrow in it. And, when the globules, after aſſuming a flat ſhape (for when they are ſomewhat diſperſed or ſeparated, their extreme ſoftneſs cauſes them to become flat) got ſomewhat cloſer together, they put on an oval figure, and then, the cavities I have mentioned, alſo became ſomewhat oblong. But, when globules of blood are concreted or coagulated, they exhibit the appearance of a ſolid body, the component parts of which, cannot be diſtinguiſhed by the eye, except that, in the coagulated parts, they ſeem rather to differ in ſize.

Now, having ſo often experienced as I have done, how very ſoft are the globules of blood, and how ſpeedily, when ſlightly in contact, and expoſed to the air, they coagulate, I cannot, in any manner, comprehend, how it is, that thoſe globules when in the veins and arteries, where they ſo ſtrongly propel and compreſs one another, do not coagulate. Still leſs can I comprehend, why, when the ſkin, or the arteries, are compreſſed with the hand, the blood itſelf does not become thicker.

After this, I cut the root into many ſmall pieces, both longitudinally and tranſverſely, in order to inveſtigate, whether thoſe minute ſalts, which I deemed to be in the root, could be there diſcovered. For, I was perſuaded, that there were in the root, ſome kind of veſicles, full of a certain humour or moiſt ſubſtance, and, that upon the evaporation of the moiſture, the ſaline particles which abounded in it, concreted together, as I have mentioned above.

Having now plenty of the root, to purſue my experiments, I found, that more than one-third part of it, conſiſted of veſicles, ariſing at the inner part of the root, and tending towards the exterior. In theſe veſicles, lay certain minute ſalts, collected as it were in cluſters, ſo that frequently, ſix or ſeven appeared together, in a circular poſition: and, where theſe cluſters were longer than broad, I judged that, at leaſt there were twenty ſalts in every cluſter.

Theſe particles, in my opinion, when firſt formed in the root, are larger; but, that in the drying, they become ſo cloſely compacted together, that they each aſſume different ſhapes, ſome being triangular, ſome quadrangular, &c. which I have alſo obſerved, in moſt things when heaped together promiſcuouſly. From hence, at length I gathered, that theſe ſmall particles, were no other than very minute ſalts.

For my farther ſatisfaction herein, I took ſome of theſe very minute ſalts out of the membranes or veſicles containing them, and after wetting them with rain-water, I put them into a very clean glaſs, and placed them over a burning coal, in like manner as I have practiſed in experiments on the globules of meal. I then obſerved, that theſe particles, which, for the preſent, I will call mealy particles, and which, before, were globular, now aſſumed a flat ſhape of a circular figure. So that, theſe particles may, perhaps, without impropriety, be deemed farinaceous or mealy parts; for, as I have faid, their globular form was changed to that of flat and circular, but of different dimenfions. This experiment I often repeated, and always found the event alike.

Having never before, found thefe collections of particles furrounded by a membrane in any other wood, but only in certain feeds, I was not content with the examination of this root, Pareira Brava, but applied myfelf to the infpection of other roots, fuch as that of the China root*, in which, I not only found the fame kind of fubftance, or particles, as in the Pareira Brava, but, the particles were fo very large, that I could very plainly perceive in them, the fame kind of chink, furrow, or creafe, as I have in another place mentioned, to have obferved in the grains and meal of wheat. And, as to all thefe mealy particles, in both the fubjects I have mentioned, I could perceive them, when brought to the fire, uniformly alter their figures, from a globular, to a flat and circular fhape.

Now, fince it appears, that the particles in the laft-mentioned root, have in them thefe chinks or creafes, and, that when wetted and afterwards dried, they change their figures as before related, we may reafonably conclude, that the very minute particles which abound in the Pareira Brava, have alfo the fame kind of chink, or furrow, though fuch furrow is to us invifible.

Let us now fuppofe thefe very minute particles, which I call mealy ones, contained in the root of the Pareira Brava, to be adminiftered as a medicine, and by the heat and moifture of the body to be diffolved: let us farther fuppofe that the particles, fo diffolved, are, by the continual motion and agitation of the body, in order, that they may perform their office of reftoring health, comminuted and broken into other particles of inconceivable tenuity

* This root is very minutely defcribed in Dr. Aftruc's Treatife on the Venereal Difeafe.

and finenefs. We do indeed, hereby gain fome infight into the manner of Nature's operation of healing; but, in what particular manner, the particles, fo attenuated, do act in the accomplifhment of her purpofe, will, if I miftake not, for ever remain undifcoverable by human powers.

Farther, I took a portion of the root, in quantity about five grains apothecary's weight, and placed it on the fire, in order to draw from it the oil and volatile fpirit it might contain. When this was burnt to a coal; in order to difcover its fixed falts, I poured on it a little rain water, which water becoming very turbid and foul, by reafon of the burnt matter, I ftrained it through a filtering-paper, and placed portions of it on feveral pieces of clean glafs, to the end, that the watery parts might evaporate. Neverthelefs, there ftill remained fomething of a vifcous matter, from whence I concluded, that fome parts of the root had efcaped the fire: this was all that occurred to me worthy of note in this experiment.

A certain phyfician, in converfation on the fubject, fuggefted to me, that if the coal of the root was burnt to a white afh, the falts would certainly be difcovered. But, though, in attempting to effect this, the glafs on which the pieces of root were placed, always melted by the violence of the heat, the pieces of wood were never burnt to afhes.

Hereupon, I placed fome pieces of the Pareira Brava root, on a piece of charcoal, fuch as the goldfmiths ufe, and directed the flame of a large candle againft it, by the blaft of a blow-pipe; by which means, the root was almoft all confumed to a white afh: this, I caft into a fmall quantity of water in a glafs, and filtering the water, which was very turbid, I let it fall drop by drop on different glaffes, made perfectly clean. One of thefe glaffes I placed on a burning coal, in order to evaporate the moifture, for, at that time, the atmofphere was very damp, and rainy. When this drop of water was evaporated, ſuch a quantity of ſalts appeared, that I was aſtoniſhed at the ſight; for they lay heaped together, in like manner as, in a wood, the twigs and ſmall branches are ſeen ſpread on the ground. After they had remained thus for a ſmall time, though within an hour, they diſſolved into moiſture: I found the ſame effect to follow breathing on them.

Now, what ſhall we ſay of this moſt extraordinary and intimate union of theſe ſalts with the root? For, it has been obſerved, that though the glaſs melted by the vehemence of the heat applied to it, the ſalts in the pieces of root, which lay on the glaſs, were not expelled; though afterwards, when ſurrounded by a ſtronger heat, they were ſeparated from the wood.

When we find theſe things upon experiment, we cannot but reaſon thus with ourſelves; How wonderful is the make and texture of this root, and how powerfully may the ſalt which is thus cloſely united to it, act as a medicine on the human body! For my part, if I may ſpeak my opinion, it is, that the make of theſe ſalts is not to be altered by the power of fire.

Again, upon conſidering whether the charcoal, which I had uſed in the preceding experiment, might not poſſibly have ſome foulneſs or extraneous matter on it, which was imparted to the root whilſt burning, I placed ſome pieces of the Pareira Brava on a ſilver plate, and, when they ſeemed to be quite burnt to aſhes, and were glowing hot, I threw them into ſome rain water, which had been boiled in a clean veſſel well tinned, and only uſed to boil water for the making of tea or coffee. This water, after ſtraining it through filtering paper, I placed in four ſeparate glaſſes, and ſuffered it to remain there all night. The next day, the atmoſphere being dry and clear, I examined them by four ſeveral microſcopes, and found, that the greateſt part, but not the whole, of the water was evaporated. The event of the experiment was, however, the ſame as in the laſt, namely, that an innumerable multitude of the ſalts before deſcribed, were to be ſeen, and that more diſtinctly than before.

On the formation of the cryſtalline humour of the Eye, in various animals, birds, and fiſhes.

THE cryſtalline or tranſparent body or ſubſtance, (which is commonly called the cryſtalline humour) of the Eye, is, in conſiſtence or hardneſs, almoſt the ſame as a preſerved nutmeg. When I firſt began to make my obſervations on it, I cut off, with a ſharp razor, ſome ſmall pieces or ſlices, and found it to conſiſt of a ſort of ſcaly particles, laid one on another, in a kind of circular form, taking their origin from the center, and all of them then ſeemed to me, to be compoſed of cryſtalline globules. After I had left this cryſtalline ſubſtance, for the ſpace of three days to dry, it became ſo hard, that it flew into pieces before the edge of the knife, after the manner of roſin. Upon again examining its nature and compoſition, I perceived, not only the ſcaly formation, and in the circular direction I have mentioned, but I diſcovered, that each of the ſcales or coats was compoſed of parts, lying in a circular poſition, and in regular order, in reſpect to each other. In other words, the formation of the cryſtalline humour, may be compared to a ſmall globe, or ſphere, made up of thin pieces of paper, laid one on another: this will ſerve to give an idea of the ſcales or coats above mentioned, and, ſuppoſing each paper to be compoſed of particles or lines, placed ſomewhat in the poſition of the meridian lines on a globe, extending from one pole to the other, this may explain the nature of the component parts of thoſe ſcales or coats.

After theſe firſt obſervations, I employed myſelf, more narrowly to examine, the eyes of oxen and cows; for, I thought, that I had not then, inveſtigated the formation of the cryſtalline humour, ſo accurately as I ought to have done.

I, therefore, firſt ſat about examining that pellicle or thin membrane, wherein the cryſtalline humour is incloſed, and by which it is, as it were, ſeparated from the other humours, compoſing the ſubſtance of the Eye. I was then, well aſſured, that I ſaw this membrane to be compoſed of threads or filaments, though afterwards, notwithſtanding the greateſt attention that I could beſtow, I could not diſtinguiſh ſuch filaments.

In this examination, I ſometimes, but not often, obſerved, that the ſmall fibres compoſing the filamentary ſubſtance of the external coat of the cryſtalline humour, were united to the before mentioned membrane; whence I concluded, that this membrane was eſſential to the cryſtalline humour, in order to ſmooth any inequalities that there might be in the filaments of its external coat, and make its round ſurface perfectly even.

I alſo conſidered with myſelf, whether this membrane might not be formed, for the purpoſe, occaſionally, by its compreſſion, to alter the figure of the cryſtalline humour; that is, to make its rounding ſhape flatter at times, as the purpoſes of viſion might require; and, if ſo, this part of the Eye which has hitherto been called the cryſtalline humour, ought rather to be named, the cryſtalline muſcle of the Eye: and yet, I cannot affirm with certainty, that I have clearly ſeen this membrane to be compoſed of filaments intermixed one among another, though, I am well aſſured that it cannot be formed in any other manner; for, I have always found every kind of thin membrane which I examined, to be of a filamentary or fibrous make. With regard to this, now under conſideration, I perceived, when viewing it ſideways, that it was compoſed of a kind of ſtreaks perfectly tranſparent, which I concluded to be, ſome lymphatic veſſels, deſtined for the nouriſhment of the cryſtalline humour; but when I followed with my eye, thefe ftreaks, or lymphatic veffels, to the part where they joined the cryftalline humour, they became fo flender, that they vanifhed from my fight.

With regard to the before mentioned fcales or coats, which compofe the cryftalline humour, I found them to be fo exceedingly thin, that, meafuring them by my eye, I muft fay, there were more than two thoufand of them, lying one on another. For, when I had ftripped the cryftalline humour of the membrane in which it was inclofed, I found, that its axis or diameter where it was thickeft, (for it is not a perfect globe, but fomewhat flattened) was equal to two third parts of an inch; therefore, from the center to the circumference, is one third of an inch; and, as I have found by repeated experiments, that fix hundred hairs of a man's head, are in breadth equal to an inch, two hundred of them conftitute the third of an inch. Now, I have feen, that where ten of the before mentioned fcales or coats lay clofe, one on another, they were not, altogether, equal to the diameter of an hair; therefore, if thefe ten be multiplied by two hundred, it follows, as I have before mentioned, that the cryftalline humour is, in its fubftance or thicknefs, compofed of more than two thoufand fcales or coats: and laftly I faw, that each of thefe coats or fcales was formed of filaments or threads, placed in regular order, fide by fide, each coat being of the thicknefs of one fuch filament.

In order to explain to the reader, the nature of this formation of the cryftalline humour, that is, how it is compofed of fibres or filaments, I have, in the following figures, reprefented thofe filaments by lines drawn in a circle, as accurately as I was able; firft premifing, that in Plate VIII. *fig.* 1. ABC reprefents the cryftalline humour, in an ox's eye, of its natural fize; B, is the place in that part of the tunica cornea, or horny coat of the eye, through which the rays of light pafs. In the following figures, the natural dimenfions are increafed, in order that the filaments of which the fcales or coats are compofed, may be exhibited more diftinctly.

In Plate VIII, at *fig*. 2, is reprefented the furface of the cryftalline humour, pictured at *fig*. 1, but, which is here to be confidered, as if that figure did prefent a circular fhape to the eye. In this figure, are many lines to reprefent the courfe or direction of the filaments, but, it muft not be fuppofed to give a true reprefentation of their numbers, the circumference of the cryftalline humour of an ox's eye, containing more than twelve thoufand of fuch filaments. For, ten of thefe filaments laid fide by fide are, (as before obferved) not equal to the diameter of an hair; and the whole axis or diameter of the cryftalline humour being, as before noted, equal to four hundred hair's breadth, it confifts of four thoufand filaments in diameter. And, by the common rules of arithmetic, whereby we find the circumference of a circle, of a given diameter, it will be found, that the circumference of the cryftalline humour in an ox's eye, confifts of $12571\frac{3}{7}$ filaments.

Hence we may collect, how exceffively thin thefe filaments are; and, we fhall be ftruck with admiration, in viewing the wonderful manner they take their courfe, not, in a regular circle round the ball of the cryftalline humour, as I firft thought, but, by three different circuits, proceeding from the point L, which point, I will call their axis or center. They do not, on the other fide of the fphere, approach each other in a center like this at L, but return in a fhort or fudden turn or bend, where they are the fhorteft, fo that, the filaments of which each coat is compofed, have not in reality, any termination or end. To explain this more particularly, the fhorteft filaments MK, HN, and OF, which fill the fpace on the other fide of the fphere, conftitute a kind of axis or center, fimilar to this at L; fo that, the filaments MK, having gone their extent, and filled up the fpace on the other fide, in like manner as is here fhewn by the lines ELI, return back, and become the fhorteft filaments, HN. Thefe filaments HN, paffing on the other fide of the fphere, again form another axis or center,

4

and return in the direction O F, and the filaments O F again, on the other fide of the fphere, collect round a third center, and thence return in the direction K M ; fo that, the filaments which on this fide are the fhorteft, on the other fide are the longeft, and thofe which there are the fhorteft, are here the longeft.

In order to exhibit more clearly to the view, the nature and difpofition of thofe filaments, conftituting each fcale or coat of the cryftalline humour, I have given a figure of them, as feen fideways, and which, in the plate, is expreffed by lines ; but it muft be obferved, that in thefe figures, the cryftalline humour is reprefented as if it were of a fpherical form, and, in the defcription I call it a fphere, as being more intelligible in the defcription, though in truth, it is not perfectly globular, as I have before noted.

In Plate VIII. *fig*. 3, R T P S W Q, is defigned to reprefent one of the coats of the cryftalline humour, allowing for the difference in fhape as before noted : P, and Q are axes or centers, one of which, P, in *fig*. 2, was fhewn at L ; the filaments coming from the point P, (which in *fig*. 2 is L) proceed to V, where they are fhorteft ; from whence they return towards P, where again they are longeft, and, from P they proceed towards W, where they are again fhorteft. In like manner, the filaments at T, take their direction towards Q, and from thence towards X, and from X again towards Q : fo that, in this figure (allowing it to be confidered as an hemifphere) may be feen the one half of the courfe or circuit of the filaments. In a word, the filaments L I, in *fig*. 2, are the fame as in this, are fhewn at P S ; and the filaments between L and M in *fig*. 2, are here feen between P and X, and thofe between L and O, in *fig*. 2, are here, between P and T ; fo that the filaments which in *fig*. 2, are feen between F O L I K E, and in *fig*. 3, in R T P S do reprefent the felf fame filaments.

I muft here farther obferve, that the filaments, of which the cryftalline humour, or rather fubftance, confifts, are thickeft about R and S, and, where they approach nearer, at P or Q, they become thinner or flenderer. Finally, upon an attentive examination of the cryftalline humour, we fhall be convinced, that its tranfparency is not to be exceeded by any glafs, although it confifts of fo many thoufand filaments, which is moft wonderful; and the more, if we confider, how clofely the filaments muft be united, that they may admit the rays of light to pafs through them in ftrait lines; for otherwife, the cryftalline humour would not be pellucid, but would exhibit a white appearance.

In order to explain this formation of the cryftalline humour ftill more plainly to fome curious gentlemen, I took a fmall tennis ball, and wound it clofe round about, with fome very fmall twine, confining the twine by pins ftuck in the ball, in the pofition or courfe which the filaments take; I then fpread over the whole fome ftrong glue, and when it was dry, I took out the pins, and then the twine thus wound round the ball, gave a true reprefentation of the courfe of the filaments as before defcribed.

I have mentioned in the beginning of this Effay, that the parts which I now plainly perceive are filaments, I then thought were compofed of globules, and this, in fome filaments, did then feem to me very apparent; but, not having feen the fame appearance uniformly in all, I now conclude, that the filaments being (as before mentioned) moft clofely united, it might happen, that in the feparating them, fome fragments or particles of one, might ftick to another of them, and thefe I might miftake for globules.

After this, I took the eyes of fheep, hogs, dogs, cats, and other animals, and examined their cryftalline humours, in the fame manner as I had treated the eyes of oxen; but, neither in the fcales or coats conftituting the cryftalline humours, nor in the difpofition of the filaments, of which each coat or fcale was compofed, did I perceive the leaft difference. Moreover, I extracted the cryftalline humour, from the eyes of hares and rabbits; thefe alfo, I found to confift of fcales or coats, inclofed one in another, and each fcale or coat compofed of filaments; but, whereas the filaments compofing the cryftalline humour in the eyes of the feveral animals I have firft enumerated, do arife from three centers, and thence are difperfed three different ways round the circumference, the filaments in thefe two laft mentioned animals, take only a twofold courfe or direction. This is fhewn in *fig*. 4, A B C D, which reprefents the hemifphere, or one half of the cryftalline humour, in the eye of an hare or a rabbit. E, is the center near the pupil or fight of the eye; thefe filaments, compofing the coats or fcales, paffing through, or near the central point E, take their courfe, fome towards F, and others towards G, fo that F and G, on the contrary fide, conftitute another central point.

I alfo made a drawing, which is copied at *fig*. 5, of the fame object, as it appeared when viewed fideways, in order more clearly to fhew the nature of thefe laft mentioned filaments, which, with a kind of fibrous fubftance, compofe each fcale or coat. I will fuppofe then, that the filaments, which in *fig*. 4, are reprefented between E F, are the fame which in *fig*. 5, are pictured at the letters I O; fo that, the filaments proceeding from the point I, that is, in the former figure at E, here end their courfe at N and L, where they are the fhorteft, and thofe at O, take their courfe through or befide the point or center N, where they are the longeft, and then terminate, or rather, with a kind of flexure or bending, return as here reprefented. In a word, thofe filaments, which, on this fide, appear neareft the center, would, on the farther fide be feen remoteft from it.

In thefe experiments, I always endeavoured, to difcover the formation of that part of the Eye which anatomifts call the vitreous or glaffy humour, and, which in great part, furrounds the cryftalline humour, becaufe I was well affured, that this vitreous humour, was not a watery fubftance, but rather a kind of pellucid mufcle; but, notwithftanding all my endeavours, I could not form any determinate or certain judgment on this head, becaufe the fubftance of this vitreous humour, always changed into a kind of watery matter.

Moreover, I examined the eyes of fifhes; thefe are perfectly fpherical, and I found, that they confifted of the fame kind of thin coats or fcales, laid one on another, as I have defcribed the eyes of animals to be formed; each coat or fcale, was alfo compofed of filaments, but, thefe filaments have not that kind of bending courfe, as in animals; and, with all my endeavours, I could not difcover in what direction they were placed; for, where the filaments draw towards a point or center, they are fo exceedingly flender, and cohere fo clofely, that they efcape the fight, and caufe fuch a confufion of objects, that I cannot be certain, whether they terminate in that center, or return back again from it. *Fig.* 6, ABC D, reprefents the cryftalline humour or fubftance in the eye of a cod-fifh; and, though I drew the lines, here made to reprefent the filaments, from the center or point A, to the center or point C, with only a pair of compaffes, wider apart than in the other figures, yet the filaments which compofe thefe fcales or coats, are not in fact thicker, except in the middle at B and D, and the nearer they approach the point A or C the thinner they are. *Fig.* 7, fhews the natural fize of the cryftalline humour in this eye.

I alfo examined the cryftalline humour in the eyes of birds, only to fee how the filaments compofing their coats or fcales, took their courfe; and, at length, after many obfervations, I found the filaments, in the eye of a turkey, to take the fame direction, as thofe in fifhes: but whereas the cryftalline humour in the eyes of fifhes is perfectly round, that in the eyes of birds, is flattened, as at *fig.* 8, lying with its flat fide D, next the tunica cornea or horny coat of the eye. And, upon my cutting with a fharp knife many pieces of the fcales or coats compofing it, in order to reduce the fize fmaller, it altered its figure to an oblong and flat fhape, as fhewn at *fig.* 9, where E is the fame part which, in *fig.* 8, was fhewn at D; being the point where the filaments are united, or, in other words, where they fo clofely approach, and are fo exceedingly flender, as to become invifible: hence we may conclude, that the filaments which lie neareft to the central point, being very thin, do thereby produce the oblong round fhape, and, where the cryftalline humour is larger, the filaments in the middle are thicker, and thus caufe the fhape to be flattened, which I myfelf have feen; for the filaments in the eye of a turkey, where they were thickeft, were, fingly, larger than thofe in the eye of an ox, hog, or fheep.

I have often, while looking in a mirror, taken notice of that liquid fubftance or moifture, with which the exterior membrane or coat of the eye is covered, and, in which liquid, there are always fome few very minute globules intermixed; which moifture, and the globules in it, as often as we fhut our eye-lids are thereby made to change their places: feeing this, I gathered the reafon, why it is neceffary for terreftrial animals to be furnifhed with eye-lids (for fifhes, and other inhabitants of the waters do not need them) and, that if it were not for the eye-lids, we fhould become blind; becaufe if the eye-lids did not continually, when we clofe them, moiften the external membrane or coat of the eye, its furface would grow dry, and contract in wrinkles, efpecially in ftrong funfhine, or when we approach a large fire. And I think it very probable, that there is continually, fome kind of humour or moifture, protruded from the inner part of the eye through the tunica cornea, which, by the eye-lids, is fpread over the eye: for, in feveral eyes of hogs, whofe bodies had been immerfed in hot water, to facilitate the fcraping off the hair, I almoft always faw a thin membrane, lying on the outer furface of the tunica cornea, which was fomewhat fcalded by the water, and therefore might eafily be taken off; and, upon compreffing the ball of the eye between my fingers, I faw in many places, a thin watery matter, iffue from the tunica cornea, and appearing on its furface, like vapour or fteam, adhering to a glafs, and, when the preffure was continued, the watery particles, which ftood on the furface, in the form of minute drops, were fo much enlarged, as to run into one another. And we need not wonder at this appearance, when we confider, that the tunica cornea is compofed of nothing but particles, like ftreaks or fibrous parts with their ramifications, and all of them very thin and flender.

I at one time cut the tunica cornea of an ox's eye into fuch thin flices, that the thicknefs of it was feven times divided, and, in each of thofe feven parts, I faw with great admiration (and more diftinctly than I had before done) the great multitudes of pellucid ftreaks or fibres intermixed together, many of which I judged were a kind of blood veffels, though fo fmall and flender, that they would not admit the globules of blood, which caufe its red colour, to pafs through them ; and I conclude that, when we rub our eyes, thofe veffels may, by the preffure, be fo extended, as to admit the red globules of blood, which, for a time, ftagnating there, caufe the eyes to appear red, or, what is commonly called blood-fhot.

But, to return to the eye-lids, it is my opinion, that they never can be confidered as in a ftate of reft, except when they are fhut; and hence it is, that we cannot keep them fteadily open, for any length of time, without applying fome external force : and, as it were, to give them reft, we frequently (and involuntarily) clofe them; which involuntary motion in the eye-lids, does, I doubt not, by preffing on the orifice of fome minute lymphatic veffels, caufe them continually to emit fmall portions of the lymph, whereby the tunica cornea is continually kept moift, as has been before obferved. And I have feen perfons, in a public audience, when very attentive, clofe their eyes, though fome did this more frequently than others.

Myfelf, and thofe of my family, have often, when contemplating objects by the microfcope, feen an appearance of fmall globules before the fight,* which, I have no doubt, were particles iffuing from the veffels in the eye, and lying on its furface: thefe, with the leaft motion of the eye, feemed to be in great agitation, and many would affirm, that they faw living creatures before their fight; but whoever gives this fubject an attentive confideration, will find, that thefe globules or ftreaks, though they feem, while the eye is kept ftill, to be in motion, fometimes upwards and fometimes downwards, yet they do not alter their pofition in refpect of each other; and perhaps at another time we fhall fee none, or if any, of a very different kind. I believe, however, that this appearance is what has led fome people to fancy, that they beheld animalcules moving in water, even after it has been boiled, and to affirm, that thefe are the fame kind of animalcules which I profefs to have plainly feen: but we muft forgive fuch perfons their error, confidering they know no better.

* The Tranflator can give a ftrong fimilar inftance, from his own painful experience; for, having met with an accident by which the furface of his eye was injured, the confequence was, for fome hours after the hurt, an appearance of minute, wonderfully bright globules, feeming to whirl round the ball of the eye with a rapidity like lightning; and, for feveral following days, many dark fpecks, in motion before the fight; but all, as Mr. Leeuwenhoek fays, preferving the fame diftance in refpect of each other: one of thefe in particular, appeared in fize, colour, and fhape, much like a common fly, which feemed to be running along the wainfcot of the room, or upon the table.

ADDITION, BY THE TRANSLATOR.

THE preceding Eſſay is one of the moſt curious, and the Tranſlator conceives, that his Readers will deem it the moſt intereſting, of any in this Work; foraſmuch as it reſpects the choiceſt corporeal gift of God to his creatures, the Bleſſing of Sight: and, for the information of thoſe, who are not acquainted with the particular ſtructure of that wonderful Organ, the Eye; the following deſcription of it is ſubjoined, taken from Mr. Adams's Eſſay on Viſion, a ſmall Treatiſe, well worthy the peruſal of every one.

"OF THE GLOBE OF THE EYE.

" If the conſtruction of the Univerſe were not ſo evident a proof of " the exiſtence of a ſupremely wiſe and benevolent Creator, as to " render particular arguments unneceſſary, the ſtructure of the eye " might be offered as one, by no means the leaſt; this inſtance, " among numberleſs others, demonſtrating, that the beſt perform- " ances of art are infinitely ſhort of thoſe which are continually pro- " duced by the DIVINE MECHANIC.

" The globe of the eye, or the organ of ſight, may be defined in " general as a kind of caſe, conſiſting of ſeveral coats, containing " three pellucid humours, which are ſo adjuſted, that the rays pro- " ceeding from luminous objects, and admitted at a hole in the fore " part of the eye, are brought to a focus upon the back part of it, " where they fall upon a ſoft pulpy ſubſtance, from whence the mind " receives it's intelligence of viſible objects.

" It is not to be expected, that any account given of the eye can be " altogether accurate; for as it is impoſſible to examine all the " parts of the eye whilſt in a natural and living ſtate, ſo it is alſo " nearly impoſſible, when it is taken out of its ſocket, to preſerve

" the figure of the parts entire; a circumſtance which accounts for " the diſagreement we find among anatomiſts.

" *Of the Coats of the Eye.*

" The eye is compoſed externally of three coats, or teguments, " one covering the other, and forming a ball perfectly globular, ex- " cept at the fore part, which is a little more protuberant than the " reſt; within this ball are three different ſubſtances called humours.

" The firſt, or outer coat, is called the *ſclerotica;* the ſecond, or " middle one, is called the *choroides;* the interior one is named the " *retina.*

" *Sclerotica. Cornea.*

" The exterior membrane, which incloſes and covers the whole eye, " is called the ſclerotica and cornea; it is, however, ſtrictly ſpeak- " ing, but one and the ſame membrane, with different names appro- " priated to different parts: the hinder and opake part being more " generally denominated the ſclerotica, the fore and tranſparent part " the cornea.

" The ſclerotica is hard, elaſtic, of a white colour, reſembling a kind " of parchment; the hinder part is very thick and opake, but " it grows gradually thinner as it advances towards the part where " the white of the eye terminates. The fore part is thinner, and " tranſparent; it is alſo more protuberant and convex than the reſt " of the eye, appearing like a ſegment of a ſmall ſphere applied to " a larger, and is called *cornea,* from its tranſparency. The cornea " is thick, ſtrong, and inſenſible; its tranſparency is neceſſary for " the free admiſſion of the light. This membrane is compoſed of ſe- " veral plates, laid one over the other, repleniſhed with a clear " water, and pellucid veſſels; theſe plates are more evidently diſ- " tinct in the fore than the hinder part. The ſclerotica is embraced

" on its outfide by fix muscles, by which the eye may be moved in
" any direction.

" *Choroides. Uvea. Iris.*

" Under the fclerotica is a membrane, known by the name of the " choroides ; it is a foft and tender coat, compofed of innumerable vef- " fels ; it is concentric to the fclerotica, and adheres clofely to it by a " cellular fubftance, and many veffels. This membrane is outwardly " of a brown colour, but inwardly of a more ruffet brown, almoft " black. Like the fclerotica, it is diftinguifhed by two different names, " the fore part being called the *uvea*, while the hinder part retains " the name of the choroides.

" The fore part commences at the place where the cornea begins ; " it here attaches itfelf more ftrongly to the fclerotica by a cellular " fubftance forming a kind of white narrow circular rim : the cho- " roides feparates at this place from the fclerotica, changes its " direction, turning, or rather folding, directly inwards, towards the " axis of the eye, cutting the eye as it were tranfverfely : in the mid- " dle of this part is a round hole, called the pupil, or fight of the eye : " the pupil is not exactly in the middle of the iris, that is to fay, the " centers of the pupil and iris do not coincide, the former being a lit- " tle nearer the nofe than the latter.

" This part, when it has changed its direction, is no longer called " the choroides; but the anterior furface, which is of different co- " lours, in different fubjects, is called the *iris* ; the pofterior furface " is called the *uvea*, from the black colour with which it is painted. " The iris has a fmooth velvet-like appearance, and feems to confift of " fmall filaments regularly difpofed, and directed towards the center " of the pupil.

" The eye is denominated blue, black, &c. according to the colour " of the iris. The more general colours are the hazel and the blue,

" and very often both these colours are found in the same eye. It has " been observed, that in general, those, whose hair and complexion " are light coloured, have the iris blue or grey ; and on the contrary, " those whose hair and complexion are dark, have the iris of a deep " brown: whether this occasions any difference in the sense of vision, " is not discoverable. Those eyes which are called black, when nar- " rowly inspected, are only of a dark hazel colour, appearing black, " because they are contrasted with the white of the eye. The black " and the blue are the most beautiful colours, and give most fire and " vivacity of expression to the eye. In black eyes there is more " force and impetuosity ; but the blue excel in sweetness and delicacy.

" The pupil of the eye has no determinate size, being greater or " smaller, according to the quantity of light that falls upon the eye. " When the light is strong, or the visual object too luminous, we con- " tract the pupil, in order to intercept a part of the light, which " would otherwise hurt or dazzle our eyes ; but when the light is weak, " we enlarge the pupil, that a greater quantity may enter the eye, " and thus make a stronger impression upon it. This aperture dilates " also for viewing distant objects, and becomes narrower for such as " are near. The contraction of the pupil is a state of violence, " effected by an exertion of the will : the dilatation is a remission of " power, or rather an intermission of volition. The latitude of con- " traction and dilatation of the pupil is very considerable ; and it is " very admirable, that while the pupil changes its magnitude, it pre- " serves its figure.

" Anatomists are not agreed, whether the iris be composed of two " sets of fibres, the orbicular and radial, or of either. Haller says, " he could never discover the orbicular fibres, even with a microscope ; " the radial seem visible to the naked eye, and are sufficient to an- " swer all the purposes required in the motion of the iris : when the " pupil is contracted the radial fibres are strait, when it is dilated, " they are drawn into serpentine folds.

" In children this aperture is more dilated than in grown perſons ; " in elderly people it is ſtill ſmaller than in adults, and has but little " motion ; hence it is, that thoſe who begin to want ſpectacles, are " obliged to hold the candle between the eye and the paper they " read, that the ſtrong light of the candle may force their rigid " pupils into ſuch a ſtate of contraction, as will enable them to ſee " diſtinctly. Thoſe who are ſhort-ſighted, have the pupils of their " eyes, in general, very large; whereas in thoſe whoſe eyes are " perfect, or long-ſighted, they are much ſmaller.

" The whole of the choroides is opake, by which means no light " is allowed to enter into the eye, but what paſſes through the pupil. " To render this opacity more perfect, and the chamber of the eye " ſtill darker, the poſterior ſurface of this membrane is covered all " over with a black mucus, called the pigmentum nigrum. This pig- " ment is thinneſt upon the concave ſide of the choroides, near the " retina, and on the fore ſide of the iris; but is thickeſt on the ex- " terior ſide of the choroides, and the inner ſide of the uvea.

" The circular edge of the choroides, at that part where it folds in- " wards to form the uvea, ſeems to be of a different ſubſtance from " the reſt of the membrane, being much harder, more denſe, and " of a white colour ; it has been called by ſome writers the ciliary " circle, becauſe the ligamentum ciliare (of which we ſhall ſoon " ſpeak) ariſes from it.

" *Retina.*

" The third and laſt membrane of the eye is called the retina, be- " cauſe it is ſpread like a net over the bottom of the eye ; others de- " rive the name from the reſemblance of the net which the gladia- " tors called *retiarii*, employed to entangle their antagoniſts. It is " the thinneſt and leaſt ſolid of the three coats, a fine expanſion of

" the medullary part of the optic nerve. The convex ſide of it " lines the choroides, the concave ſide covers the ſurface of the vi- " treous humour, terminating where the choroides folds inwards. " It is an eſſential organ of viſion; on it the images of objects are " repreſented, and their picture formed. This membrane appears to " be black in infants, not ſo black at the age of twenty, of a greyiſh " colour about the thirtieth year, and in very old age almoſt white. " The retina, however, is always tranſparent and colourleſs : any ap- " parent changes therefore, of its colour, muſt depend upon altera- " tions of the pigmentum which is ſeen through it.

" *Optic Nerve.*

" Behind all the coats is ſituated the optic nerve, which paſſes out of " the ſcull, through a ſmall hole in the bottom of the orbit which " contains the eye. It enters the orbit a little inflected, of a figure " ſomewhat round, but compreſſed, and is inſerted into the globe " of the eye, not in the middle, but a little higher, and nearer to " the noſe; an artery runs through the optic nerve, goes ſtrait " through the vitreous humour, and ſpreads itſelf on the membrane " that covers the back ſide of the cryſtalline.

" Monſ. Mariotte has demonſtrated, that our eyes are inſenſible " at the place where the optic nerve enters : if, therefore, this nerve " had been ſituated in the axis of the eye itſelf, then the mid- " dle part of every object would have been inviſible, and where all " things contribute to make us ſee beſt, we ſhould not have ſeen at " all; but it is wiſely placed by the divine artiſt for this and " other advantageous purpoſes, not in the middle, but, as we have " already obſerved, a little higher and nearer to the noſe.

" *Of the Humours of the Eye.*

" The coats of the eye, which inveſt and ſupport each other, after

" the manner of an onion, or other bulbous root, include its humours,
" by which name are underſtood three ſubſtances, the one a ſolid, the
" other a ſoft body, and the third truly a liquor. Theſe ſubſtances
" are of ſuch forms and tranſparency, as not only to tranſmit rea-
" dily the rays of light, but alſo to give them the poſition beſt
" adapted for the purpoſes of viſion. They are clear like water, and
" do not tinge the object with any particular colour.

" *Aqueous Humour.*

" The moſt fluid of the three humours is called the aqueous one;
" filling the great interſtice between the cornea and the pupil, and
" alſo the ſmall ſpace extending from the uvea to the cryſtalline lens;
" it is thin and clear like water, though ſomewhat more ſpiritous and
" viſcuous; its quantity is ſo conſiderable, that it ſwells out the fore
" part of the eye into a protuberance very favourable to viſion. The
" uvea ſwims in this fluid. It covers the fore part of the cryſtalline;
" that part of this humour which lies before the uvea, communicates
" with that which is behind, by the hole which forms the pupil of
" the eye. It is included in a membrane, ſo tender, that it cannot
" be made viſible, nor preſerved, without the moſt concentrated lixi-
" vial fluid.

" It has not been clearly aſcertained whence this humour is derived;
" but its ſource muſt be plentiful: for if the coat containing it be ſo
" wounded, that all the humour runs out, and the eye be kept cloſed
" for a ſeaſon, the wound will heal, and the fluid be recruited.

" The colour and conſiſtence of this humour alters with age; it
" becomes thicker, cloudy, and leſs tranſparent, as we advance in
" years, which is one reaſon, among others, why many elderly peo-
" ple do not reap all that benefit from ſpectacles which they migh
" naturally expe ct

" *Cryſtalline.*

" The ſecond humour of the eye is the cryſtalline, which is as " tranſparent as the pureſt cryſtal; and though leſs in quantity than " the aqueous humour, yet it is of equal weight, being of a more " denſe and ſolid nature; in conſiſtency it is ſomewhat like a hard " jelly, growing ſofter from the middle outwards. Its form is that " of a double convex lens, of unequal convexities, the moſt convex " part being received into an equal concavity in the vitreous humour.

" The cryſtalline is contained in a kind of caſe, or capſule, the " fore part of which is very thick and elaſtic, the hinder part is thin- " ner and ſofter. This capſule is ſuſpended in its place by a muſ- " cle called ligamentum ciliare, which, together with the cryſtalline, " divides the globe of the eye into two unequal portions; the firſt " and ſmaller one contains the aqueous humour, the hinder and " larger part the vitreous humour. The cryſtalline has no viſible " communication with its capſule, for as ſoon as this is opened the " humour within ſlips clean out.

" The cryſtalline is placed ſo, that its axis correſponds with that of " the pupil, and conſequently it is not exactly in a vertical plane di- " viding the eye into two equal parts; but ſomewhat nearer the noſe. " It is formed of concentric plates or ſcales, ſucceeding each other, and " theſe ſcales are formed of fibres elegantly figured, and wound up " in a ſtupendous manner; theſe are connected by cellular fibres, " ſo as to form a tender cellular texture. Between theſe ſcales is a " pellucid liquor, which in old age becomes of a yellow colour. The " innermoſt ſcales lie cloſer together, and form at laſt a ſort of nu- " cleus, harder than the reſt of the lens. The cryſtalline has no vi- " ſible communication with its capſule, ſo that when this is opened, " it readily ſlips out: ſome ſay, that a ſmall quantity of water is " effuſed round it. Leeuwenhoek has computed that there are " two thouſand laminæ, or ſcales, in one cryſtalline, and that each

" of thefe is made up of a fingle fibre, or fine thread, running this " way and that, in feveral courfes, and meeting in as many centers, " and yet not interfering with, or croffing, each other.

" The yellow colour wherewith the cryftalline is more and more " tinged as we advance in years, muft make all objects appear more " and more tinged with that colour: nor does our being infenfible of " any change in the colour of objects, prove to us that their colour " continues the fame; for in order that we fhould be fenfible of this " change, the tincture muft not only be confiderable, but it muft hap- " pen on a fudden. In the cataract it is opake; the feat of this dif- " order is in the cryftalline lens.

" *Vitreous Humour.*

" The vitreous is the third humour of the eye; it receives its name " from its appearance, which is like that of melted glafs. It is nei- " ther fo hard as the cryftalline, nor fo liquid as the aqueous humour; " it fills the greateft part of the eye, extending from the infertion of " the optic nerve to the cryftalline humour. It fupports the retina, " and keeps it at a proper diftance for receiving and forming dif- " tinct images of objects.

" The vitreous humour is contained in a very thin pellucid membrane, " and concave at its fore part, to receive the cryftalline; at this " place its membrane divides into two, the one covering the cavity " in which the cryftalline lies, the other paffing above, and covering " the fore part of the cryftalline, thus forming a kind of fheath for " the cryftalline. The fabric of the vitreous humour is cellular, " the fubftance of it being divided by a very fine tranfparent mem- " brane into cellules, or little membraneous compartments, con- " taining a very tranfparent liquor.

" *Ligamentum Ciliare.*

" There is ftill one part to be defcribed, which, though very

" delicate and ſmall, is of great importance; it is called the liga-
" mentum ciliare, becauſe it is compoſed of ſmall filaments, or fibres,
" not unlike the cilia, or eyelaſhes; theſe fibres ariſe from the
" inſide of the choroides, all round the circular edge, where it joins
" the uvea; from whence they run upon the fore part of the vitreous
" humour, at that place where it divides to cover the cryſtalline;
" thoſe fibres are at ſome diſtance from one another, but the inter-
" ſtices are filled up with a dark-coloured mucus, giving it the ap-
" pearance of a black membrane.

" *Of the Figure repreſenting the Eye.*

" Figure 10, repreſents a ſection of the eye through the middle,
" by an horizontal plane paſſing through both eyes; the diameter of
" the figure is about twice the diameter of the human eye.

" The outermoſt coat, which is called *ſclerotica*, is repreſented by
" the ſpace between the two exterior circles B F B; the more glo-
" bular part, adjoining to the ſclerotica at the points B B repreſented
" by the ſpace between the two circles at B A B, is the *cornea*.

" The next coat under the ſclerotica is a membrane of leſs firm-
" neſs, repreſented by the two innermoſt circles of B F B, and called
" the *choroides*.

" Adjoining to the choroides, at B B, is a flat membrane, called
" the uvea: a a is the pupil, being a ſmall hole in the uvea, a little
" nearer the noſe than the middle.

" V the *optic nerve*; the fibres of this nerve, after their entrance
" into the eye, ſpread themſelves over the choroides, forming a thin
" membrane, called the retina, and is repreſented in the figure by
" the thick ſhade contiguous to the circle B F B.

" E E is the *cryſtalline* humour; it is ſuſpended by a muſcle B b b B,
" called the *ligamentum ciliare*. This muſcle ariſes behind the uvea
" at B B, where the ſclerotica and cornea join together at b b. it

" enters the capſula, and thence ſpreads over a great part of its " anterior ſurface.

" The *aqueous* humour occupies the ſpace B A B b C b.

" The larger ſpace B b D b B F contains the *vitreous* humour.

" The foregoing deſcription, we preſume, will be found ſufficient " to give the reader a general idea of the conſtruction of this won- " derful organ : for a fuller account we muſt refer him to the writers " on anatomy. Enough has been exhibited to ſhew with what art " and wiſdom the eye has been conſtructed."

The following is a quotation by Mr. Adams, from Reid's Inquiry into the Human Mind :

" If we ſhould ſuppoſe an order of beings endued with every hu- " man faculty but that of ſight, how incredible would it appear to " ſuch beings, accuſtomed only to the ſlow information of touch, that " by the addition of an organ, conſiſting of a ball and ſocket of an " inch diameter, they might be enabled, in an inſtant of time, without " changing their place, to perceive the diſpoſition of a whole army, " the order of a battle, the figure of a magnificent palace, or all " the variety of a beautiful landſcape ? If a man were, by feeling, to " find out the figure of the Peak of Teneriffe, or even of St. Peter's " church at Rome, it would be the work of a life-time.

" It would appear ſtill more incredible to ſuch beings as we have " ſuppoſed, if they were informed of the diſcoveries which may be " made by this little organ, in things far beyond the reach of any " other ſenſe. That, by means of it, we can find our way on the " pathleſs ocean, traverſe the globe of the earth, determine its ſize " and figure, meaſure the planetary orbs, and make diſcoveries in " the ſphere of the fixed ſtars.

" Would it not appear ſtill more aſtoniſhing to theſe beings, if " they ſhould be further informed, that by means of this organ we " can perceive the tempers and diſpoſitions, the affections and paſ-

" fions, of our fellow-creatures, even when they want moft to " conceal them? that by this organ we can often perceive what is " ftrait and crooked, in the mind as well as the body: that it par- " ticipates of every mental emotion, the fofteft and moft tender, as " well as the moft violent and tumultuous: that it exhibits thefe " emotions with force, and infufes into the foul of the fpectator the " fire and the agitation of that mind in which they originate? To " many myfterious things muft a blind man give credit, if he will " believe the relations of thofe that fee! his faith muft exceed that " which the poor fceptic derides as impoffible, or condemns as " abfurd.

" It is not, therefore, without reafon, that the faculty of feeing is " looked upon as more noble than the other fenfes, as having fome- " thing in it fuperior to fenfation, as the fenfe of the underftanding, " the language of intelligence. The evidence of reafon is called " *feeing*, not feeling, fmelling, tafting,; nay, we exprefs the man- " ner of the divine knowledge by *feeing*, as that kind of knowledge " which is moft perfect in ourfelves."

It is too true, that we do not, in general, know the real value of any bleffing, until we are deprived of it; therefore, let us hear, how the lofs of fight is pathetically defcribed by Milton, from his own feeling: In his addrefs to the Light he fays,

> " I feel thy fovran vital lamp; but thou
> " Revifit'ft not thefe eyes, that roll in vain
> " To find thy piercing ray, and find no dawn;
> " So thick a *drop ferene hath quench'd their orbs
> " Or dim fuffufion veil'd.——

* This is a literal tranflation of the Latin words *gutta ferena*, a difeafe, by which the patient is deprived of fight, though to a fpectator, the eye does not appear to be injured; becaufe the feat of the diforder is in the optic nerve, and not in the ball of the eye. This was Milton's cafe.

———————" Thus with the year
" Seafons return, but not to me returns
" Day, or the fweet approach of ev'n or morn,
" Or fight of vernal bloom, or fummer's rofe,
" Or flocks, or herds, or human face divine ;
" But cloud inftead, and ever-during dark
" Surrounds me, from the cheerful ways of men
" Cut off, and for the book of knowledge fair
" Prefented with a univerfal blank
" Of Nature's works to me expung'd and ras'd,
" And wifdom at one entrance quite fhut out.

The Tranflator concludes this fubject in the words of the fame great Poet, as conveying a fentiment, which a wife man muft deem the moft effectual, if not the only real confolation under fuch an affliction.

" So much the rather thou, celeftial Light,
" Shine inward, and the mind through all her powers
" Irradiate, there plant eyes, all mift from thence
" Purge and difperfe, that I may fee and tell
" Of things invifible to mortal fight."

Milton's Paradife Loft, Book III.

On the internal formation of an Ox's Tongue; and on that of the Heart, in Animals, Fowls, and Fiſh.

A CERTAIN profeſſional gentleman of my acquaintance, was urgent with me to examine the formation of a cat's tongue, but this I deferred from time to time, wiſhing rather, to inveſtigate the nature of the human tongue, which I thought would be much more worthy of examination; by reaſon, that it muſt neceſſarily be provided with more muſcles than the tongues of animals: for, this will appear manifeſt, if we conſider how many various motions our tongues muſt exert in ſpeaking, ſinging, or whiſtling.

Not finding an opportunity to procure an human tongue, or that of a cat, I began by examining the tongues of oxen, cutting from them ſmall pieces, both longitudinally and tranſverſely: and, though I thought that a complete deſcription of the whole tongue would take up too much time and labour, I determined to give a drawing of the ſmall muſcles, and point out how they are diſpoſed longitudinally and tranſverſely; for, in an ox's tongue, the number of them is incredible, and in this deſcription will be ſeen, not only the wonderful formation and multitude of theſe minute muſcles, but alſo, we ſhall be fully ſatisfied with regard to the manner in which the tongue is ſometimes extended and ſometimes contracted, both in breadth and thickneſs.

In Plate VIII. *fig.* 11, A B C D E F G H I K L M, repreſents a ſmall piece of an ox's tongue, cut off from the ſide, in that part where the tongue was thickeſt. In this ſmall piece are to be ſeen various minute muſcles, cut tranſverſely, which are repreſented between BCKL, and DEHI; and among theſe, again, there appear many exceedingly minute particles, alſo cut tranſverſely, which, by reaſon of their ſmallneſs, could by no means be repreſented in the drawing, but each of them may, in fact, be conſidered as a muſcle, for if, by the microſcope, we were to diſſect the before mentioned minute muſcles, we ſhould find them compoſed of ſmaller parts, like a large muſcle, when diſſected and viewed by the naked eye.

Theſe fleſhy muſcles, thus cut tranſverſely, conſtitute the ſubſtance or thickneſs of the tongue; and the muſcles pictured at the three places in this figure, A B L M, C D I K, and E F G H, which are ſhewn lengthwiſe, extend along the tongue from end to end. And, as between the letters B C K L and D E H I, is ſhewn how the fleſhy muſcles appear, when cut tranſverſely, ſo at A B L M, C D I K and E F G H may be ſeen their figure when cut longitudinally.

All theſe fleſhy muſcles, taken together, are not larger, when viewed by the naked eye, than the ſmall piece or particle ſhewn at *fig.* 12.

I alſo judged it right, to take off one of theſe fleſhy muſcles, lengthwiſe, and to cauſe a drawing to be made of it, to exhibit to the eye its true formation, and alſo, as nearly as poſſible, to ſhew thereby, how, in the motion of the tongue, theſe muſcles are exerted, and how they change their figure.

Fig. 3, N O P Q, repreſents this fleſhy muſcle, which I took off lengthwiſe, preſerving the whole of its thickneſs, ſo that none of its conſtituent parts were broken off, except at the extremities N O and P Q: in which muſcle ſeveral bendings are to be ſeen.

Now, ſuppoſing this muſcle, placed lengthwiſe in the tongue, to be contracted in bendings, we muſt conclude, that the tongue then becomes ſhorter and thicker, and the muſcles which lie acroſs it, are then perfectly ſtraight; and, that when the animal extends its tongue, this fleſhy muſcle, *fig.* 13, NOPQ, and all the others which lie lengthwiſe in the tongue, are extended and become ſtraight, and thoſe muſcles which lie acroſs the tongue are then inflected or bent in like manner as repreſented in the former muſcle at *fig.* 13, NOPQ.

When this muſcle had ſtood three months before the microſcope, it became covered with a ſort of mouldineſs,* which, bearing a reſemblance to ſmall flowers, I directed the limner to imitate them as nearly as poſſible in his drawing, and they are to be ſeen at RRRRRRR.

The fleſhy muſcles, which in *fig.* 11, appear cut tranſverſely, are, in the part lying between BCKL, four diſtinct and ſeparate muſcles, and, in the ſpace between DEHI, ſix of the ſame kind, all of them diſtinct from each other. The parts, or ſpaces between them in the figure, are no other than membranes, and particles of fat, lying within thoſe membranes. For, I never ſaw in ſuch a muſcle as is exhibited in *fig.* 13, NOPQ, any vein, nor any detached particle of fat, but every one of theſe kind of muſcles, as far as I have hitherto obſerved, is always enveloped in a membrane, and, if the ox is a very fat one, particles of fat will be ſeen in the membrane.

It ſhould be remembered, that every one of theſe muſcles muſt have its tendon, or terminate in a membrane which conſtitutes a tendon, and not only ſo, but every oblong fleſhy particle, of which each ſuch muſcle conſiſts, and which appear in *fig.* 13, NOPQ, muſt alſo be provided with a tendon, or terminate in a membrane as before mentioned, and all theſe tendons and membranes (in my judgment) do, together, conſtitute that part which many take only for an inner ſkin, which inner ſkin, or rather muſcular part, covering the tongue all over, is defended, as it were, by a thick external ſkin:

* The ſame appearance is noted by the author, when treating of the young plant in the Coffee-bean.

this latter ſkin is eaſily taken off when a tongue has been boiled, or has lain ſome time in hot water.

This diſpoſition of the muſcles in the tongue is wonderful, and the manner of their acting inconceivable by us, and ſtill more, with regard to the human tongue, when we conſider the variety of ways in which the muſcles muſt move and turn, to produce the effect of ſpeaking, ſinging, and whiſtling, as before obſerved.

The exertions of the fleſhy muſcles in the tongue, are chiefly produced by their aſſuming a ſtraight figure, or by being inflected or bent, contrary to the manner of the fleſhy muſcles in other parts of the body, (as far as has come to my knowledge) for their contraction and extenſion, is produced by means of the multitudes of exceſſively minute wrinkles or crimped up particles, of which each muſcle conſiſts.

After this, I curſorily examined the tongue of an hog, to ſee, whether in it, the fleſhy muſcles were intermixed or laid one acroſs another, in the ſame manner as I have deſcribed in the tongue of an ox: this I firſt inſpected in the thickeſt part of the tongue, on the upper ſide, where it riſes in a ridge like a back; and, I ſaw not only, that the muſcles were diſpoſed in the ſame manner as the ox's, but that ſome few of thoſe which lay the lengthway of the tongue, in ſome places croſſed each other; the tranſverſe muſcles were the ſame as in the ox's. Searching farther inward into the thickeſt part, I there ſaw many fleſhy muſcles lying parallel to each other, lengthways in the tongue; but no others lying athwart or croſſing them. I alſo beſtowed ſome inveſtigation on the thinner parts of this tongue, without finding any thing worthy of note.

I have often employed my thoughts, on the formation of the fleſhy part in the hearts of animals; not particularly to inveſtigate the courſe of the fleſhy muſcles, which I doubt not, has been ſufficiently examined and explained by others. And, though I determined, if I ſhould obſerve any thing particular in that part of the ſubject, to commit my remarks to writing, yet, my principal object was, to inveſtigate the formation of the very ſmalleſt fleſhy muſcles, and to examine whether any thing might be found therein worthy of note.

For this purpoſe, I took the heart of a ſheep, but, with all my pains, I could not ſucceed in ſeparating or taking off any fleſhy muſcle like that deſcribed at *fig.* 13, NOPQ, for, in the operation, it was ſo torn, and, ſo many of the adjoining parts adhered to it, that I could not then ſatisfy myſelf as to the true formation of ſuch muſcle; nor with regard to the union or connection between it and the adjoining parts.

After this, I tried the heart of an ox, cutting off many pieces, and contriving every poſſible means I could deviſe, to ſeparate a ſmall ſtrip or oblong particle from the adjoining parts, but all to no purpoſe; and, at length, I found, that theſe fleſhy particles were ſo linked together, that it would be impoſſible to ſever them without breaking.

This concatenation, or linking together of the fleſhy parts, (which parts, in treating of the tongue, I have called minute fleſhy muſcles) in the ſubſtance of the heart, is of ſuch a nature, that, at firſt, I deſpaired of being able to repreſent it to the eye by any figure or drawing; but at length, I ſo far ſucceeded, as to exhibit a repreſentation thereof to the reader.

In theſe experiments, I tried the heart of a duck, in order to ſee whether its formation, and particularly this union of the parts, agreed with that of an ox; and I found, that the fleſhy parts in the duck's heart, were linked together in the ſame manner as in that of the ox; and not only ſo, but that I could better give a repreſentation of ſuch concatenation or linking, from the heart of the duck, than from any of the other ſubjects I had examined: and thereupon, I delivered to the Limner a microfcope, before which was placed an exceeding fmall piece of the flefhy part of a duck's heart, directing him to make as accurate a drawing as poffible, of the object which prefented itfelf to him.

Fig. 14, ABC DEFGHIKLM, reprefents this minute particle magnified, in which may plainly be feen, not only how every fingle flefhy particle is united or linked to the adjoining one, but alfo, how all the flefhy particles, fhewn in this figure, are connected, chained or linked together.

As to the vacant fpaces appearing in this figure, two of which may be feen at BCD, and HNI, we muft not fuppofe, that the flefhy parts are fo far afunder as the drawing reprefents, for I am fully perfuaded, that, when the heart is in its natural ftate, all the flefhy particles of which it confifts, are fo clofe to each other, that nothing but an exceeding thin membrane intervenes, within which membrane the blood-veffels take their courfe; and there alfo, may fometimes be feen particles of fat, efpecially where the blood veffels are larger than ordinary.

Farther, I always obferved, not only in the hearts of an ox and fheep, but alfo in that of a duck, all the flefhy particles, which, when defcribing them in *fig.* 13, I have called mufcles, but which I cannot here call by that name, becaufe they are not enveloped by membranes peculiar to themfelves; thefe particles, I fay, which in *fig.* 4, are exhibited at LM or AB, I found, again to confift of great numbers of flender oblong particles, which often feparated from each other, and at little diftances united with other particles: but thefe fmaller particles are not reprefented in the figure, becaufe they had become fo dried, as not to be vifible to the Engraver.

We may now figure to ourfelves, that the particle of flefh, which *fig.* 4, exhibits at A B, again confifts of an hundred and more oblong particles, and, that a little above A B, they are divided into four parts, and thefe parts, again united with other flefhy particles. But how often this feparation and reunion of parts take place, and what courfe the particles themfelves take, I have not yet been able to difcover.

Each of thefe feveral flefhy parts, of which only two are exhibited in *fig.* 4, at B C D, and H N I, were covered with broken and torn fragments of other parts, but thefe I directed the Limner not to delineate, that the concatenation, or the manner in which the particles are linked together, might be better diftinguifhed.

After I had caufed the before mentioned drawing, *fig.* 14, to be made, I again examined various flefhy particles in the heart of a duck, and, while I was thus employed, I met with one fmall piece, in which I was convinced, that the concatenation or linking together of the parts, would be ftill more diftinctly feen. This, being placed before a microfcope of fomewhat lefs magnifying power, I delivered to the Limner to make a drawing of.

Fig. 15, A B C D E F G H, is this piece of a duck's heart, in which, more plainly than before, can be feen the nature of its formation, which will appear ftill more wonderful, if we confider, as the truth is, that the connection or linking together of the parts, in the particle which this *fig.* 15, reprefents, was, in the fubject itfelf, thrice as much as here expreffed; for, I could not feparate a piece of this fize from the heart, without tearing afunder twice as many parts or points of union as are here exhibited. This particle was taken from almoft the outfide of the heart, and, that part which in the figure is marked A B C D, was fituated pointing towards the fmall end or tip of it.

In order to fhew the true dimenfions of the particle reprefented, in this laft figure, I meafured it, and found, that the whole length fhewn in the figure, between the letters E F G H, was, in its natural fize, not more than two third parts of the breadth or thicknefs of that part which, in the figure, appears between the letters G and H, or, the fize pictured at X.

Seeing now, that this flefhy particle, though not in fact, larger than the fpace between G and H, or at X, does yet confift of more than an hundred diftinct oblong particles, as I can affirm from the moft exact computation of my own view, and, that this is not only the cafe, in the heart of a duck, but alfo in that of an ox ; and moreover, that each of thofe flender, oblong, component particles, again confifts of a great number of exceffively minute particles, we fhall more and more be ftruck with wonder, at this formation of the heart. And who can tell, into how many fmall particles, entirely undifcoverable by us, thefe laft named particles may be again divided ?

We find, that in the common mufcles of the body, thofe fmall mufcular parts, which conftitute a large mufcle, may be feparated from the larger one, often without tearing the oblong flefhy parts which compofe it, nothing being broken, except the thin membrane with which the fmall mufcular parts are, as it were, enveloped: for, all thofe flender, oblong, flefhy parts, lie difpofed in regular parallel order, befide each other ; and, at their extremities, are united to a membrane which furrounds the mufcle, or, rather, forms the tendon of that mufcle, which in fact the membrane does : hence we may eafily comprehend, that, when any part of a common mufcle is wounded, the part which remains uninjured, may ftill, in fome degree, perform its functions ; becaufe, as I have before faid, the fmall mufcles which compofe a larger one, are only connected by a kind of membrane : but, on the contrary, when any one particle in the flefhy fubftance of the heart, fuch as is reprefented in *fig.* 15 at A B C D, or any other particle though much more minute, is wounded, the whole flefh or fubftance of the heart, (by reafon of the intimate union of its parts) not only fuffers, but, through the violent and continual agitation of the heart, in the protrufion or expelling the blood in circulation, it becomes weaker, and, from fo fmall a wound, death muft enfue. Moreover, when I confider, how often we find a fmall exulceration or fore, in the hand, finger, or other part of the body, of which we cannot perhaps trace the caufe, I can eafily conceive, that a fmall exulceration may, by fome accident, happen in the heart, whereby fome of the flefhy particles may be injured, or rendered incapable of performing their functions; whence the heart not only languifhes, and becomes feeble, but, at length, may ceafe to move, whence fudden death enfues: and the Phyfician, not knowing the real caufe, is led to pronounce, according to the common opinion, that the perfon died of an apoplexy. Thefe are, however, no more than my own conjectures.

From what I have advanced, it may naturally be concluded, that I fhall farther lay it down as a certain pofition, that the heart cannot fuffer any wound, without certain and immediate death being the confequence: this, however, is not my opinion, in all cafes whatfoever. For, we know, that there are many veins between the flefhy parts in the infide of the heart, which take their courfe from thence, and unite with the blood veffels furrounding it on the outfide; which blood veffels, are, throughout, and efpecially on the outfide of the heart, covered with fatty particles; fo that there may be inftances, where the very extremity or point of a fword, may penetrate into the heart itfelf, but, being in a part where thofe veins and particles of fat lie, none of the flefhy particles of the heart may be injured, and the vein and fatty particles alone receive the wound, together with the external membrane furrounding the heart: hence it will follow, that fudden death may not in fuch a cafe enfue.

After this, I examined the heart of a hen, in which alfo, not without pleafure, I faw the concatenation or linking of the flefhy parts, to be exactly the fame as in the other hearts I have mentioned.

This, however, I obferved in the hen's heart, that, when cutting it longitudinally, there appeared fome difference in the formation, for, whereas the cavity in the hearts of oxen and fheep, is provided with a tendon; on the contrary, here, inftead of the tendon, I found various flefhy parts, with their ramifications, fpread over the cavity of it. Whereupon, I began to reflect on the great exertion, which birds are obliged to ufe in flying, and how little they are fatigued, even after taking a long flight. But, to fay any thing fatisfactorily on this head, many previous obfervations ought to made.

Afterwards, I examined the heart of a cod fifh, and found its component parts linked together in the fame manner as I have defcribed thofe of the other animals, and of the duck, to be: but when I reflected on the circulation of the blood through this heart, (which appeared more of a flefhy than a fifhy nature) and confidered, how the blood is propelled from it, into a white body, in folidity or denfity nearly equal to the heart, whofe particles are linked together in the manner I have defcribed, and to how great a degree thefe particles upon the infufion of the blood muft be extended, and how contracted in its propulfion, I was more and more loft in admiration.

On the eye of a Whale, with the Author's obſervations on the preſſure of the ſea-water at great depths.

THE maſter of one of our Greenland ſhips, by name *Iſaac van Krimpen,* upon a certain time, made me a preſent of the eye of a Whale, preſerved in ſpirits of wine. This eye was not of a perfectly ſpherical figure, for its axis, in the thickeſt part, was two inches and ſeven-tenths of an inch in length, and the axis in the thinneſt part was not longer than two inches and an half.

That part of the tunica cornea in front of the eye, which riſes in a globular protuberance, was two inches and an half in diameter.

The cryſtalline humour was not quite of a circular figure, as we generally find it to be in fiſhes ; but on one ſide, its ſhape was ſomewhat depreſſed, and the axis thereof meaſured ſeventeen thirtieth parts of an inch, but the axis of that part which was extended towards the object of viſion, was about half an inch in length.

The cavity, wherein the cryſtalline humour is included, was almoſt two inches diameter. The ſubſtance conſtituting the ſurface of, and ſurrounding that cavity, was ſo compact and ſtrong, that I was ſcarcely able to cut it with a very ſharp knife.

Obſerving this, I began to conſider, whether the nature of this fiſh did not require, that the ſubſtance incloſing the cryſtalline humour, ſhould be ſo hard and ſolid ; becauſe a Whale ſometimes dives to great depths in the ocean, and, as the fiſh under conſideration, had run out the length of fourteen whale lines, each of which is an hundred fathoms long; and, in this depth of fea, the preffure of water on the bottom, is much greater than is commonly imagined.

For, fuppofing the ocean, in any given place, to be 1400 fathoms deep, and each fathom to contain fix feet, which is the common meafure, it follows, that the ocean is, in fuch a place, 8400 feet deep.

It is well known, that a cubic foot of water, fuch as is found in our canals, weighs 65 pounds, but that the fame quantity of fea water, being in its nature heavier, does not weigh lefs than 66½ pounds; but taking it only at 66 pounds, the refult will be, that every cubic foot of fea water, where the ocean is 8400 feet deep, does prefs on the bottom with the weight of 554,400 pounds. And, with regard to the whale lines, which I have faid are 100 fathoms long, I am told that they are more commonly 120 fathoms, which gives a depth of 16,080 feet.

The fame Captain Krimpen, in a fubfequent converfation informed me, that this Whale, having run out the length of fourteen lines, lay on the fandy bottom of the fea at that depth, from whence it was weighed up or raifed by means of the windlafs, and he added, that he fhould not have fucceeded in getting up this fifh, unlefs the line, which by the harpoon iron was fixed in it, had alfo got a turn or two round the tail, by which means, the Whale was brought up to the furface, the tail foremoft.

The weighing up this Whale, was at firft fo difficult and laborious, that fix men at leaft, were neceffarily employed in heaving at the windlafs, and no lefs than fix hours were fpent in the operation. But, when all the lines fave one, were hove in, the labour became as nothing; for which latter circumftance, I affigned to Krimpen, this twofold reafon, that the preffure of the water on the Whale was then greatly diminifhed; and, that the fifh abounding with oily or fatty parts, which are lighter than water, would have a tendency to be buoyant.

Let us now fuppofe, the eye of this Whale, in that part of it which was expofed to the fea water, to contain fix fquare inches in its fuperficies, we may juftly fay, that when the fifh defcended to the depth of fea we have mentioned, the preffure on its eye muft be equal to 23100 pounds weight. For, fix fquare inches are the twenty-fourth part of a fquare foot, and, if the preffure on a fquare foot, at the before mentioned depth, is 554,400 pounds, it follows, that the twenty-fourth part, will fuftain a preffure of 23100 pounds, which is one ton, fix hundred, and a quarter of a hundred weight.

Seeing then, that fix fquare inches of fpace, at the bottom of the fea, where it is 8400 feet deep, do endure a preffure of water equal to 23100 pounds weight, it is no wonder that the fea in the Bay of Bifcay is not to be fathomed by the lead. For, if the fea water, at the depth we have mentioned, preffes on the bottom with the weight we have computed, it follows, that in fome parts of the ocean, which are at leaft eight times that depth, the preffure muft be eight times as much.

Hence we may fairly infer, that a weight, although of lead, fuch as that which feamen call the deep-fea lead, cannot, where the depth is fo very great, touch the bottom, or at leaft, not in a manner to be perceptible, not only on account of the very great preffure on the lead, but alfo, on account of the much greater preffure on the lead-line, by reafon of its great length, which line itfelf is not much heavier than the fea water; fo that the preffure may very naturally be fuppofed to prevent the lead reaching the bottom. Again, it muft be confidered, that the ocean, though no current may be vifible on its furface, yet is never at reft; fo that though the lead, when caft, feems to fink ftraight downwards, yet it may be carried away by fome fubmarine current, far from the man who heaves it, and the line may be bent and twifted many ways, by all which means, in fuch great depths, the lead may be prevented from reaching the bottom. But to return, The cryſtalline humour in this eye, was ſo cloſely joined to the tunica cornea, as to force it out into a kind of globular extuberance or riſing, which appearance ſeemed very ſtrange to me, having never obſerved the like, in any fiſh or animal.

I took off a piece of the tunica cornea, rather more than an inch in diameter, and, after leaving it a while to dry, I cut it by an oblique inciſion into ſlices, in order to count, with greater facility, the number of thin membranes of which it was compoſed, and I found, that it conſiſted of, at leaſt ſixteen or eighteen of thoſe thin membranes, laid one on another.

This tunica cornea, was lined on its inſide, with a black membrane, every where entirely impervious to the light, excepting an oval aperture immediately in front of the cryſtalline humour, through which the light was tranſmitted; this alſo was to me an unuſual appearance. This oval aperture was in length half an inch, and in breadth ſomewhat leſs than a quarter of an inch.

From this laſt obſervation, a thought occurred to me, whether the whale has not a power of enlarging and contracting this aperture at pleaſure, ſo as to alter the manner of its viſion, as occaſion may require. The ſame power of dilating and contracting the pupil, I remember to have obſerved in the eyes of a cat.

I then employed myſelf, to extract the membrane which covers the back part of the eye, and to examine the optic nerve; this I found to be no larger than the optic nerve in the eye of an ox, but I noted this ſingular circumſtance attending it, that in many places, and I eaſily counted as far as twenty five of them, I ſaw adhering to the membrane, arteries and nerves, which iſſued from the part through which the optic nerve paſſes. Some of theſe, were about the ſize of a common pin, others much larger.

Theſe are the matters, which appeared to me worthy of note on this occaſion, though, if it were poſſible to obtain the eye of a Whale when newly taken out of the head, I doubt not, that our enquiries might be profecuted much farther, and that, confequently, greater fatisfaction might be procured in the inveftigation.

If we confider the propagation of the Whale, by comparifon with that of the fmaller fifh, we fhall be led to admire the wife difpofition of Nature in this refpect. To inftance in the common fhrimp; every one of them may be denominated a female, for they all, without exception, propagate their fpecies by eggs; and that, in fuch numbers, that once, when I began to count the eggs on one fhrimp, I had not got half way through the mafs of them, before I was tired, and gave up the attempt. Such a vaft number of eggs, produced by one fmall fifh is wonderful, efpecially if we confider, that every one of thefe minute eggs is nourifhed by a blood veffel. Now the larger fifh, which devour the fmaller, fuch as the Whale, the porpoife, and the fword fifh, are not propagated by eggs, but bring forth their young perfectly formed; for if thefe kind of fifh increafed fo abundantly as the others, the fmaller fifh would every one be devoured by them. The Whale in particular, brings forth only a fingle young one at a time, and is provided with two breafts filled with milk, and fuckles the young, after the manner of terreftrial animals.

I have fometimes, when reflecting on the enormous bulk of thofe Whales which were taken at the beginning of the Whale fifhery, and on thofe huge bones of Whales, which are in many places fixed up for public view; I have, I fay, on thefe occafions, conjectured, that probably thofe Whales might be of the age of a thoufand years and upwards. For I am perfuaded, that fifhes never die of old age, forafmuch as their bones, being always of a foft texture, which never grows hard, may always be extended, fo that the fifh themfelves are always growing larger. But, terreftrial animals are expofed to the changes of the atmofphere, whereby their bones grow hard, and when the bones are hardened, the body of the creature cannot be extended to a larger fize.

Having once, with the affiftance of an able geometrician, and by the eye with the help of quadrants, meafured the height of the tower of our new church in Delft, we found it to be 299 feet.* So that the depth of the fea, to which the Whale I have mentioned defcended, was twenty-fix times as much as the height of that tower.

* The London reader will be better able to judge of thefe altitudes, (the word *altitude* taken in the fenfe of the Latin, *altitudo*, from which it is derived, fignifies both height and depth) by comparing them with the Church of St. Paul's or the Monument: the former of thefe is about 500 feet in height, and the latter 200; fo that if we call the height of the fteeple at Delft 300 feet, the Church of St. Paul's is two thirds higher, and the Monument one third lower than that fteeple. And the depth of fea from whence the Whale was raifed, was equal to forty-two times the height of the Monument, and more than fixteen times the height of St. Paul's.

Of the Quills ufed in writing, and their feathers: on human hair, and the hair and wool of animals.

MY reflections on the nature of thofe Quills with which we write, as alfo on the general make of the feathers of birds, led me to an inquiry into the manner of their formation; which at length I difcovered, and found, that Quills are compofed of ftreaks, or more properly fpeaking, veffels. Thefe veffels, in every Quill, are threefold. The firft, or external ones, which conftitute but a fmall part of the Quill, are parallel to its length: the fecond, which are in a much larger quantity, take their courfe round about the Quill, within the former ones: thefe fecond fort of veffels are not fo clofely united as to form what may be likened to a folid body, but lie one on another like fcales or coats, in fuch manner, that the different layers of them may be plainly perceived: the third fort of veffels, which compofe the thickeft or greateft part of the Quill, lie lengthwife, in like manner as the firft mentioned ones: this third fort of veffels, are alfo difpofed in the manner of fcaly parts laid one on another; and, confidering the thinnefs of a Quill, and the large cavity it contains, its formation is, in my judgment, the moft perfect that could be contrived; for, hereby it is made tough and ftrong, both in its circumference, and in its length. To exhibit the nature of it to the eye, I caufed a drawing to be made of one.

In Plate IX. *fig*. 1, ABCDEFG, reprefents a common goofe

Quill, drawn fmaller than the natural fize. At A B G, are reprefented thofe veffels which compofe the external part of the Quill, and lie in it longitudinally ; B C F G, are thofe which take their courfe round about it ; C D E F, are the veffels, which, like the firft mentioned ones, are placed the length way of the Quill.

From thefe obfervations, I difcovered the reafon, why fome Quills when they are fplit lengthwife, in that part where they are hardeft, form a kind of indented or jagged part in the fiffure ;* namely, becaufe thofe veffels, whofe courfe is round the Quill, are not all broken in an even ftraight line ; efpecially, as I faid before, where the Quill is hardeft : and where thefe veffels are heaped together in greater quantities than in other parts. Therefore, to prevent this accident, when the Quill is fo very hard, it is neceffary to fcrape it a little with the pen knife, by which means, in the fplitting, it will be ftraight and even.

I have frequently, by the microfcope, contemplated that part of thefe Quills which is called the feather, and alfo the feathers of fmall birds; and always viewed them with admiration ; not only on account of the multitude of parts to be feen in them, but alfo, by reafon of the great numbers, and extreme minutenefs of the veffels, of which, not only the whole feather, but every little part of it is compofed.

To exhibit to the view, the great numbers of veffels of which the feather confifts, I placed a fmall piece of one before a microfcope, and a drawing of it is given at *fig*. 2, LMNOPQ.

In the preceding *fig*. 1, DHIKE exhibits part of the feather of the common writing Quill, fmaller, as before obferved, than the natural fize. At K, is reprefented a fmall part of the feather, a piece of which, feen by the microfcope, is fhewn at *fig*. 2, for, if the whole

* This moft commonly happens in thofe Quills which have not been, what is called clarified, or when the Quill is fplit near the feather; this jagged fhape of the fplit is well known to fchool boys, and is denominated by them, cats teeth.

of this piece were to be drawn when magnified, it would appear larger than the whole feather, feen by the naked eye. When this fmall part of the feather is viewed by the microfcope, it will appear, how every one of its parts confifts of a great number of fmaller feather fhaped parts, all which parts are fo connected or knit together, as to give ftrength to the whole feather.

The reader, here, muft underftand, that the particle or piece which is fhewn magnified at *fig.* 2, LMNOPQ, is not, in fact, fo big as a large grain of fand: and further, that this particle received nourifhment in its growth, no otherwife than by fmall veffels: the reader alfo will advert to *fig.* 3, RS, which is drawn from a microfcope of greater magnifying power, and is ftripped off from the fide of *fig.* 2, at MNO, and alfo to *fig.* 4, TV, which is taken from the fide of *fig.* 2, at QPO.

At LMQ, is reprefented a part, bearing the appearance of globules, of which the interior fubftance of this fmall particle of a feather is compofed, which agrees with the formation of the correfponding part in the entire feather of the Quill, pictured at *fig.* 1.

In the figures 3 and 4, by R and T, are reprefented fome fmall veffels broken or torn afunder.

All thefe fmall particles, each of which may be called a minute feather, not only ferve to give ftrength to the whole feather, but are fo contrived, that in the bird's flight, thefe particles remain fo clofely joined together, as to enable it to make a ftrong impreffion on the particles of air, by the exact and regular order of the component parts of the feathers. For otherwife, birds would not be able to fupport themfelves in the air. All thefe particles, as I faid before, lie in moft exact order befide each other, which has induced me frequently to contemplate them, as alfo on account of the innumerable multitudes of veffels of which the Quill confifts.

From this inftance, in the formation of the feathers of birds, we may obſerve, that provident Nature, if not in all, at leaſt in many things which come under our inveſtigation, performs her operations with the greateſt uniformity; for, in like manner, the cryſtalline humour of the eyes, not only of men, but of the larger terreſtrial animals, and alſo of fiſhes, as far as I have examined into them, conſiſts of a kind of ſcaly parts, laid one on another: ſo likewiſe the tunica cornea or horny coat of the eye, which coat, I at firſt conceived to be compoſed of only three diſtinct membranes, but afterwards, on a more accurate inveſtigation, I found to conſiſt of an hundred membranes, laid one on another like ſcales. And I conclude that this formation is deſigned, not only to give the coats of the eye a great degree of ſtrength and firmneſs, but alſo, that if one of the membranes ſhould be hurt, the others may eſcape uninjured.

It is the opinion of many, that the hairs on the bodies of men and animals, are hollow, and ſome think, that they contain in them a marrow like the bones; but theſe opinions are erroneous. Hairs are formed with a kind of coat, which is analogous to the bark of trees, and their internal ſubſtance conſiſts of ſtreaks or fibres. Their growth, is not like that of plants, but is produced by a kind of propulſion, that is to ſay, that the part which one day is within the ſkin, and is as it were, the root, in a day or two, is thruſt out beyond the ſkin: and as, when the hair firſt comes forth, it is, in all its parts, very moiſt, as ſoon as the moiſture begins to evaporate, the coat or bark of the hair, and the fibres adjacent to it, acquire a degree of firmneſs which prevents the hair from contracting inwards, whence it comes to paſs, that, as the internal fibres continue to dry, and thereby become thinner, they are divided aſunder, and recede from each other, ſometimes forming one, and ſometimes more chinks, exhibiting a kind of darkiſh furrow or furrows, which, doubtlefs, is what has been taken for the marrow of the hair. All this will be better underftood from the following figures.

Fig. 5, ABCD, is a piece of an hog's briftle, which I cut by a tranfverfe fection; EEEE, are the chinks or cracks, arifing from the drying of the hair as above mentioned, and this hair is burft or cracked, in the infide, more than ordinary. *Fig.* 6, FGHI, is a piece of the fame hair, fomewhat nearer the fkin, alfo cut tranfverfely, in which, there are not many cracks, or chinks, but only one, which is, however, fo large, as to exhibit the appearance of a hole or cavity in the hair, as appears at KLM, and any one, upon feeing fuch an hair as this, would certainly conclude, that the cavity here feen, was not accidental, but the natural form and make, and confequently, that all hairs are hollow. *Fig.* 7, NOPQ, is another piece of an hog's briftle cut tranfverfely, from which I fuppofe the moifture had evaporated fo flowly, as not to leave the leaft appearance of a chink or crack: *fig.* 8, is a perfectly black hog's briftle cut tranfverfely, and, as it exhibited a pretty appearance, I have given a drawing of it. And, though the roughnefs, which is on the edge of the fharpeft razor, frequently leaves fcratches on the face of the hairs thus cut tranfverfely, I almoft wholly avoided that appearance, for which reafon, I was better able to point out the ftreaks or fibres of which the hairs confift.

From the preceding figures, it will appear, how much thofe are miftaken, who will have it, that all hairs are round, whereas we ought rather to fay, that every hair has a figure peculiar to itfelf.

It is my opinion, that the hairs on man's body, do, at certain feafons, fall off, and are again renewed, like the feathers on birds; at leaft, I have experienced this to be the cafe with myfelf every fpring, (excepting the hairs on my head and beard) and I have obferved, that thofe hairs which feemed ready to fall off, could be pulled out with a fmall pair of pincers, and not caufe that pain which attends the plucking out a hair that is firmly fixed ; and I have farther obſerved, that thoſe hairs which are pulled out by force, have large thick roots, whereas, the roots of thoſe which are near falling off, are very ſmall and pointed.

Fig. 9, ABCDEFG, and HLMNPQ, are two very ſmall human hairs with their roots ; in theſe will be ſeen, that the points or ſmall ends of them, at G and Q, are ſomewhat bent, which I attribute to this, that the points, when thin and tender at their firſt expulſion from the ſkin, had met with ſome obſtacle in their growth, which not being able to penetrate, they were bent obliquely : It is not uſual to ſee hairs bent at the ſmall end, in the manner ſhewn at G, but they moſt commonly appear as at Q.

AB, and HL, are the roots of theſe hairs, which do not appear ſo large, if the hair falls off of itſelf, but, when a hair is pulled out by force, the root appears much larger than the hair itſelf, as is ſhewn in this figure.

The bending of the hairs I have noted above, may very eaſily be occaſioned by their meeting with ſome obſtruction in their growth, and having obſerved a hair on my arm, which was very much bent, I pulled it out, and placed it before a microſcope, in order to ſhew its figure in a drawing.

Fig. 10, ABCDEFGHI, exhibits this hair, in which, ABC is the root, and at AC may be ſeen a ſmall portion of the cuticle or outer ſkin, which adhered to the hair. DEF, indicate a conſiderable bending in the hair, and at GEH is ſhewn a much greater bending, or rather, an entire circular curve.

I have ſaid, that hairs are covered with a coat or bark, in like manner as trees, and that, however ſmall, they are compoſed on the inſide of oblong parts or fibres, and I am perſuaded, that there is no difference between ſheep's wool, which is the ſmalleſt kind of hair, and the hairs of men and animals, except, that ſheep's wool conſiſts of a lefs number of internal fibres. In order to fatisfy myfelf in this refpect, I often broke pieces of wool, and endeavoured to fplit them into fmaller parts, wherein at firft I was unfuccefsful, but at length I found means, not only, diftinctly to fee this formation myfelf, but alfo to exhibit the fame to the view of others.

I therefore delivered to the Limner three microfcopes, directing him, to make drawings of the objects he faw.

Fig. 11, KLMN, reprefents a fmall piece of white fheep's wool, in which, at L and M may be feen, that it confifts of a great number of fmaller hairs, (if we may call the interior parts of the wool by that name;) and who can tell, whether each of the particles, fhewn at LM, may not again confift of a great number of ftill fmaller particles?

This piece of white fheep's wool, was very tranfparent before it was broken, or cracked; but, at L and M, where many of its oblong component particles are broken or fevered afunder, it appeared quite opake, and more of a black colour than tranfparent.

Fig. 12, OPQ, reprefents a piece of white wool, placed before another microfcope; this piece is broken or burft open only in one place, where alone the internal parts appear, and at Q only two of thofe internal parts can be feen, whereas, in the piece pictured at *fig.* 11, all the internal fibres are divided afunder.

Obferving one of the hairs on my arm, to be not only much broken or worn away, by the friction of my fhirt, but alfo the internal parts to be feparated from each other, I pulled out the hair, and placed it before a microfcope: this piece of broken hair, magnified, is reprefented at *fig.* 13, RS, wherein at S, which is the part worn or fretted away, fome fmaller particles appear, being the fmall fibres of which the hair confifts.

The preceding experiments and obfervations, will, I truft, refute the erroneous opinion I have mentioned, that the hairs on our bodies are hollow within, and, if hair and wool, (which is the hair of ſheep) were not compoſed of many minute hairs or fibres, they would not have that ſtrength and toughneſs which we obſerve in them.

Sometimes, in human hairs, and eſpecially in the very middle of them, I have obſerved a dark line: particularly in ſeveral of the hairs taken from my own beard: and when I attentively examined this dark line, I found it to conſiſt of ſuch minute and ſlender particles, as to be almoſt undiſcoverable even by the microſcope. Examining ſome very ſmall hairs, of three, four or five days growth, and finding ſome to be throughout quite tranſparent, others darkened only in a very ſmall degree, and finally, others with no more than a ſmall dark ſpot on them, I began to conſider, whether this dark ſhade in the hairs, might not proceed from ſome particles of blood in the ſubſtance of the hair, and there dried.

To give the reader an idea of this dark line, I cauſed a drawing to be made of a piece of a ſingle hair, which I concluded to be of three days growth; this is to be ſeen at *fig.* 14, O P Q R S T V W, in which at Q R S and V W O, are the two ends where the piece of hair was cut with a knife: from W to P, or as far as T, the dark line I have mentioned extends, which I have mentioned to be viſible in ſome hairs, and in others not ſo conſpicuous. Laſtly, between R and T P are repreſented thoſe dark ſpots, which are to be obſerved in other hairs.

The TRANSLATOR, to the READER.

IF this tranflation is a faithful one, I doubt not that the Reader will be led to admire the extenfive range of the Author's refearches, and the pains he takes to make his difcoveries intelligible to all ; and thofe who compare his defcriptions with the productions of Nature at this day, will be equally pleafed to obferve their exact coincidence.

But, though I think it may fairly be faid, that the works of Mr. Leeuwenhoek are, upon the whole, fuperior to any that have appeared upon Microfcopical fubjects, I do not mean to fay, that there are no inftances, in which others have not been equally fuccefsful. A countryman of our own, Dr. Robert Hooke, who was a cotemporary of the Author, and Secretary to the Royal Society foon after its firft inftitution, publifhed feveral Effays, containing his difcoveries by the Microfcope, with many very judicious and ufeful remarks. In fome of thefe, Dr. Hooke has handled the fame fubjects as our Author, and I fhall take occafion, here to introduce a paffage from that Book, wherein fome of the particulars refpecting Feathers, mentioned in the preceding Effay, are more minutely defcribed than by Mr. Leeuwenhoek. *

" Examining feveral forts of Feathers, I took notice of thefe par-
" ticulars in all forts of wing-Feathers, efpecially in thofe which
" ferved for the beating of the air in the action of flying.

" That the outward furface of the Quill and ftem was of a very
" hard, ftiff, and horny fubftance, which is obvious enough, and
" that the part above the quill was filled with a very white and light
" pith, and, with the microfcope, I found this pith to be nothing
" elfe but a kind of natural *congeries* of fmall bubbles, the films of

* Hooke's Micrographia, p. 165, Edit. 1667.

" which feem to be of the fame fubftance with that of the quill, that " is, a ftiff tranfparent horny fubftance.

" As for the make and contexture of the down itfelf, it is indeed " very rare and admirable, and fuch as I can hardly believe, that " the like is to be difcovered in any other body in the world; for " there is hardly a large Feather in the wing of a bird, but contains " near a million of diftinct parts, and every one of them fhaped in " a moft regular and admirable form, adapted to a particular defign: " for, examining a middle fized goofe quill, I eafily enough found " with my naked eye, that the main ftem of it contained about 300 " longer and more downy branchings upon one fide, and as many on " the other of more ftiff but fomewhat fhorter branchings. Many " of thefe long and downy branchings, examined with an or- " dinary microfcope, I found divers of them to contain near 1200 " fmall leaves, (as I may call them) fuch as EF in the figure* " and as many ftalks: on the other fide, fuch as IK in the fame " figure, each of the leaves or branchings, EF, feemed to be di- " vided into about fixteen or eighteen fmall joints, as may be feen " plainly enough in the figure, out of moft of which there feemed " to grow fmall long fibres, fuch as are expreffed in the figure, each " of them very proportionably fhaped according to its pofition, or " placed on the ftalk E F; thofe on the under fide of it, namely, " 1, 2, 3, 4, 5, 6, 7, 8, 9, &c. being much longer than thofe directly op- " pofite to them on the upper; and divers of them, fuch as 2, 3, 4, 5, " 6, 7, 8, 9, &c. were terminated with fmall crooks, much refem- " bling thofe fmall crooks, which are vifible enough to the naked " eye, in the feed-buttons of burdocks. The ftalks likewife, I K, on " the other fide, feemed divided into near as many fmall knotted " joints, but without any appearance of ftrings or crooks, each of " them about the middle K, feemed divided into two parts by a kind

* Plate IX. *fig.* 15.

" of fork, one fide of which, namely, K L, was extended near the " length of K I, the other, M, was very fhort.

" The tranfverfe fections of the ftems of thefe branchings, mani- " fefted the fhape or figure of it to be much like I N O E, which con- " fifted of a horny fkin or covering, and a white feemingly frothy " pith, much like the make of the main ftem of a Feather.

" The ftems of the downy branches I N O E, being ranged in the " order vifible enough to the naked eye, at the diftance of I F, or " fomewhat more, the collateral ftalks and leaves (if I may fo call " thofe bodies I newly defcribed) are fo ranged, that the leaves or " hairy ftalks of the one fide lie at top, or are incumbent on the " ftalks of the other, and crofs each other, much after the " manner expreffed in the figure,* by which means every one of " thofe little hooked fibres of the leaved ftalk gets between the " naked ftalks, and the ftalks being full of knots, and a pretty " way disjoined, fo that the fibres can eafily get between them, " the two parts are fo clofely and admirably woven together, " that it is able to impede, for the greateft part, the tranfcurfion of " the air; and though they are fo exceedingly fmall, as that the " thicknefs of one of thefe ftalks amounts not to a 500th part of an " inch, yet do they compofe fo ftrong a texture, as, notwithftanding " the exceeding quick and violent beating of them againft the air, by " the ftrength of the bird's wing, they firmly hold together. And it " argues an admirable providence of Nature in the contrivance and " fabrick of them; for their texture is fuch, that though by any ex- " ternal injury the parts of them are violently disjoined, fo as that " the leaves and ftalks touch not one another, and confequently fe- " veral of thefe rents would impede the bird's flying; yet, for the " moft part, of themfelves they readily re-join and re-contex them-

* Plate IX. *fig.* 16.

" felves, and are eafily by the birds ftroking the Feather, or draw-
" ing it through its bill, all of them fettled and woven into their for-
" mer and natural pofture ; for there are fuch an infinite company of
" thefe fmall fibres in the under fide of the leaves, and moft of them
" have fuch little crooks at their ends, that they readily catch and hold
" the ftalks they touch."

Here we fee a perfect agreement between thefe two valuable writers, in defcribing the fame fubject, with this difference only, that the Englifh author has more minutely defcribed that curious part in Feathers, which Mr. Leeuwenhoek only mentioned flightly; I mean the contrivance of Nature, whereby the feveral minute Feathers compofing the larger, are knit together fo firmly as to bear the ftrong exertion of the bird in flying, without yielding a paffage to the air.

The fame Author, in treating of hair, has thefe words, " The
" root of the hair was pretty fmooth, tapering inwards, almoft like
" a parfnip, nor could I find that it had any filaments, or any other
" veffels, fuch as the fibres of plants.

" The top when fplit (which is common in long hair) appeared
" like the end of a ftick, beaten till it be all flittered, there being
" not only two fplinters, but fometimes half a fcore and more.

" For the briftles of a hog, I found them to be, firft, a hard
" tranfparent horny fubftance, without the leaft appearance of pores
" or holes in it, and this I tried with the greateft care I was able,
" cutting many of them with a very fharp razor, fo that they ap-
" peared, even in the glafs, to have a pretty fmooth furface, but
" fomewhat waved by the fawing to and fro of the razor, as is vifi-
" ble in the end of the prifmatical body A in the figure.* The fhape
" of the briftles was very various, neither perfectly round, nor fharp
" edged, but prifmatical, with divers fides, and round angles as
" appears in the fame figure. †

* Micrographia, p. 157. † Plate IX. *fig.* 17.

An extraordinary quantity of Fiſh on the ſea coaſt near Delft, noted by the Author, with the reaſons aſſigned by him for the ſame.

IN the months of April and May 1716, there were brought to our town of Delft, from the ſea coaſts at Schevling, Catwick, and Terheid, a great quantity of the fiſh called haddocks, which, though very freſh and good, were ſold at a low price. The glut of this fiſh was ſo great, that though in general they are caught with hooks, they were on this occaſion, taken in nets.

Seeing this, I conſidered, that there muſt be ſome particular reaſon, why theſe fiſh ſhould at that time reſort to our coaſts in ſuch multitudes, and I was afterwards confirmed in that opinion, for in a month or two afterwards, not one of thoſe fiſh was to be taken : and the reaſon which I aſſigned to myſelf for the abundance I have mentioned was, that at that time, there was a greater quantity of food for them on the coaſt than uſual, whereby they had been tempted thither.

In order to inveſtigate this matter, I opened the ſtomachs of many haddocks, and found them to be filled with a certain ſmall ſpecies of ſhrimps, called by our fiſhermen meutjens, which are taken among the common ſhrimps, and are uſed for food by people living along the ſhore.

About a fortnight afterwards, on examining the ſtomachs of the haddocks, I found ſome of them quite empty, and others not more than half filled with the before mentioned fmall fifh ; and fo much was the glut then diminifhed, that few or no haddocks were taken. Upon enquiring the reafon of this diminution from a fifherman, he anfwered only, that every fort of fifh had its feafon, though I fhould rather have faid, in the words of fcripture, "that where the food is, there will the eagles be gathered together."

At the time there was this glut of haddocks, there was a great quantity of cod fifh caught on our coaft, the reafon of which I took to be, that thefe cod flocked to our fhores in purfuit of the haddocks which are their food.

About the beginning of October, in the fame year, there were taken on our coafts, great quantities of the common fhrimps, and thofe in better condition than they are generally found in the fummer time. Hence I concluded, that the haddocks would again refort to our coafts, and that the fhrimps, to avoid them, would crowd in greater quantities to the fhores and fhallows.

To fatisfy myfelf in this refpect, and that I might learn what particular kind of food is ufed by the haddock, I caufed the entrails of a very large one to be brought to my houfe; but, to my great furprize, I found not only the ftomach, but the inteftines adjoining it, to be entirely empty of food.

I enquired of a fifhwoman what might be the reafon of this, who gave me the following anfwer: Our fifhermen (for fhe lived at Delftshaven) have a pond or ciftern, lined at the bottom and on the fides with timber full of holes, fo that the water freely paffes in and out with the tide ; and the fifh being kept in this ciftern, can at all times be brought to market alive and vigorous. But the fifhermen fay, that when the haddocks are thrown into this ciftern, they immediately empty their ftomachs of all the food they have fwallowed.

Hereupon, I examined a little of the matter or fubftance contained in the inteftines at a confiderable diftance from the ftomach, and I found the fame to confift of fragments of fhrimps mixed with many particles of fand, rather larger than the fand found on the fea fhore, and which particles of fand I concluded the haddock had picked up with the fhrimps from the bottom of the fea, and had fwallowed down both together. Among thefe grains of fand, I faw many fhining particles, fome thoufands of which, laid together in an heap, would not equal a large grain of fand: thefe were all of different fhapes, but, in every one of them, the fides, angles and points, were fo fmooth and glittering, as to be very little inferior in beauty to the moft polifhed diamonds. At firft, I fuppofed them to be no other than common falt, but I found them to be much more hard and folid than our falt. After I had fteeped them a fhort time in rain water, I could ftill diftinguifh fome of them, though much diminifhed in brightnefs; others of them, feemed to be partly diffolved, and to be furrounded with fmaller particles: thefe latter, I concluded to be, ftill more minute falts, which, in diffolving, had feparated from the larger ones, and afterwards concreted in clufters.

In the month of November in the fame year, there was another great draught of haddocks on our coaft, whereupon I went to the fifh market to examine the inteftines, when newly taken out of the fifh: I found moft of the ftomachs to be empty of food, but fome remains thereof in the inteftines; and, as at the fame time, great plenty of cod fifh were caught, I judged that the haddocks, avoiding the purfuit of the cod, and thefe purfuing the haddocks, was the reafon, that both were taken in fuch abundance.

Thofe perfons, who are very nice in their tafte, prefer the haddocks brought to us from Maeflandfluys, to thofe that are brought ftraight from the fea fhore, though both are taken near the fame tract in the ocean. Upon confidering with myfelf, what might be the reafon of this difference, I could not affign any more probable one than this, that thofe haddocks which are brought ftraight from the fea fide, are, as foon as taken, thrown into bafkets, to the number of eight or ten in each bafket, and die, thus heaped together, before they are expofed to fale: whereas, the fifhermen at Maeflandfluys, keep their fifh for a time in thofe cifterns I have defcribed; and the fifhermen of Delftfhaven, have alfo a kind of fifh trunk or well in their boats for the like purpofe. Therefore, the fifh which are thus kept alive without food for two or three days after they are caught, are of a much better tafte.

The fame is experienced in river fifh, efpecially trout, which, when caught in the fummer time, are unpleafant to the palate, tafting of the herbs on which they feed, but, if kept a few days in ftew ponds, cifterns, or other fit receptacles, are much improved in flavour.

But to return to the fubject of the fifh market, I obferved a large cod fifh, very much diftended with a quantity of food, namely, haddocks, which it had devoured, when fome of the fmaller cod lying near it, appeared empty. Hereupon, I enquired of an old fifherman, whether thofe cod fifh, which were fo diftended, did not differ in tafte from thofe, whofe ftomachs were empty; to which he anfwered, that thofe cod were to be preferred, whofe bellies were compact or clofe. This is a phrafe among fifhermen, applied to thofe fifh whofe roes are not very large, and whofe ftomachs are very little, or not at all diftended with food.

Of the Nutmeg; the young plant in it discovered; the root of the Nutmeg-tree examined and described; with some hints from the Author respecting the best method of preserving Nutmegs from being injured by insects.

HAVING, at many different times, employed myself in the examination of Nutmegs, in order, if possible, to discover the young plant of the future tree (which, I was well assured they contained) but always without success, I at length received, from one of the Directors of the East India Company, residing in our town, a few Nutmegs, and also a parcel of powder or dusty matter, which had been found adhering to some of the nuts *, to the intent, that I might examine them, and see whether this powder had not been gnawed or bitten off the nuts by mites.

With the greatest accuracy I was able, I examined this dusty matter, and, with all my attention, I could not discover in it any mite either alive or dead, but in some of the Nutmegs which had been in part eaten away, I found several small maggots of different kinds, and also a few flying insects which I concluded had been bred from maggots of the same species; but the bodies of all these creatures were so much shrivelled, that I concluded they had been long dead, and that, not being natives of these regions, they could not endure the cold of our climate.

* This valuable fruit or spice, which, in English, is called by the single word Nutmeg, is in Dutch denominated Noot Muscaat, herein agreeing with the botanical Latin name Nux moschata, the Musk-nut; it is also denominated Nux myristica, the odoriferous or sweet-smelling nut.

I next went to our Eaſt India Company's warehouſe, at the time the officers employed to ſort the ſpices were buſy in allotting the Nutmegs according to their qualities, and I brought home with me, two or three handfuls of the refuſe thrown away: any one upon viewing this with the naked eye, would eaſily be led to conclude, that it contained mites, but with my utmoſt attention, I could not diſcover any mites, much leſs their eggs, and only a few of the dead inſects I have before mentioned. I alſo brought home ten or twelve of the moſt damaged Nutmegs, which felt very light in the hand, and were much ſhrivelled: upon examining theſe carefully, I found that moſt part of the duſt or powder, which upon a curſory view might be taken for mites, was nothing elſe than the duſt of the Nutmegs, and the excrements of maggots which had almoſt entirely ſcooped out the inſides of thoſe nuts.

In the examination of theſe and other Nutmegs, it appeared to me, that thoſe which had been gathered unripe, were the moſt liable to be devoured by maggots, becauſe the oily matter in this nut, which pervades its ſubſtance in ſtreaks like the veins of marble, and covers the outward bark in like manner, is contrary to the nature of theſe maggots; for when I cut open the nuts wherein they were, I found the oily part every where uninjured, and on the contrary, all the whitiſh part of the nut conſumed, ſo that thoſe oily parts lay within the nut, exhibiting to me, as it were, a labyrinth of turnings and windings, whereas, the unripe nuts, where the oily ſubſtance was not completely formed, were in the inſides, quite conſumed; I alſo perceived the external coat of the ripe nuts in ſome places bored or eaten through, but in my opinion, when the maggots reached the parts were the oil was fully ripened, they deſiſted from farther biting, and only devoured that part where the young plant is ſituated, and which is the thickeſt part of the nut.

I was much ſurpriſed, that I could not diſcover any mites among the Nutmegs, becaufe there is rarely any fubftance that can be ufed for food, where they are not to be found.

I determined therefore, to examine whether mites fed upon the Nutmeg, and therefore I placed about a quarter of a nut, among a parcel of mites, when I perceived that they fled from it.

Moreover, I took a glafs tube, fomewhat larger than a fwan's quill, one end of which I ftopped with a cork, and, after putting into the glafs fome hundreds of mites, I cut a fmall piece of Nutmeg of a fize that I could put it into the tube; and I perceived that the mites next the Nutmeg foon died. I then put another piece at the other extremity of the tube where there were many live mites, which alfo in a very fhort time died.

To fatisfy myfelf ftill farther, I took a glafs tube, thirteen inches long, and half an inch diameter; one end of this I clofed by melting it, and put as many mites into it as I computed in bulk altogether to be equal to half a cubic inch, and, according to the exacteft computation I could make, they were in number 150,000.

After thefe mites had been about a quarter of an hour in the tube, they fpread themfelves from the mafs in which they were, when firft put in, and difperfed all over the glafs; I then fplit a very found and good Nutmeg into four parts, one of which parts I placed in the open end of the glafs, fo that I might obferve by the microfcope, what effect it would have on the mites when they approached it.

Moft of them I faw creeping towards the open end of the tube, and when they came to within about a ftraw's breadth of that part where the piece of nut touched the glafs by two of its points, many of them returned back, though they might have paffed by the nut without approaching nearer than the eighth part of an inch to the main fubftance of it.

The retreat (fo to exprefs myfelf) of thefe multitudes of mites, afforded me a very pleafant fpectacle, for here it appeared, that the exhalation or vapour proceeding from the piece of Nutmeg, was fo noxious and offenſive to them, that they drew back from it faſter than they had advanced towards it, in order to make their eſcape out of the glaſs.

Some others of the mites having advanced ſo far as to have got ſome hairs breadth diſtance beyond the Nutmeg, were preſently arreſted in their courſe, and, loſing all motion, they expired.

Moreover, I obſerved numbers of the mites creeping along the glaſs, near that part of the Nutmeg which was covered with the rind, and they would have eſcaped, if I had not intercepted them by placing another piece in the way, ſo that they could not get out without paſſing the broken part of the nut, and hence it appeared to me, that the vapour of the nut exhaled much more feebly next the rind, than from the internal newly broken part. Hereby, not only the eſcape of theſe mites was prevented, but all that were near the nut died there, and in the ſpace of eight and forty hours, out of ſo great a number of mites very few were left alive.

To explain this experiment better, I cauſed a drawing to be made of the glaſs tube I uſed on the occaſion, which is to be ſeen in Plate X, *fig.* 1, ABCDEFGHI. Here, AI is the open end of the tube; F, the end which was cloſed, and in which the mites, when firſt put into the tube, lay in the greateſt numbers. Between CD and FG, was placed the firſt quarter of the Nutmeg with the internal broken part next the eye, where ſome of the mites had crept on the other ſide of the glaſs next the rind, and paſſed by the nut, when as I mentioned before, I placed the other piece of nut, with its broken ſide the contrary way to the other, ſo that the rind appears between AB and HI next the eye, by which the mites were prevented from eſcaping, and all died within the glaſs.

In reflecting on the circumſtance of theſe mites being thus killed, I judged that it was not by the vapour of the Nutmeg being hurtful to their bodies in general, fuch as the fkin, bones, &c. but that it acted fo powerfully on the lungs of thofe creatures, as to prevent their refpiration. For, in like manner as noxious vapours do not, fo far as I know, in any manner injure our fkins, becaufe the moifture of our bodies is continually expelled from the inward parts outwards, through the fkin to the furface ; and as no particles, either of foul air or common water can be received into the body through the fkin, for which reafon it is, that the flefhy parts of fifh or other animals, living in water, however falt it be, do not partake of that faltnefs ; fo mites, the fame as larger animals, who are kept alive by refpiration, die when that refpiration is obftructed or prevented. And if fo, we have here another inftance of the furprifing order and regularity with which all things are created, fhewn in the wonderful formation of the mite, which, though unknown to many perfons, and, by reafon of its minutenefs, held of no account, does yet appear to me, endowed with greater perfection, and more curioufly formed than many larger animals.

After the preceding obfervations, our Eaft India Fleet arrived, whereupon, I became defirous to procure fome of the Nutmegs newly imported, and thofe of the beft and ripeft ; in order, that if poffible, I might fo far caufe them to vegetate, that I might be convinced I faw the young plant in the nut, and might alfo be able to take it out from thence. And one of our Eaft India Directors very kindly gave me fome of the largeft Nutmegs ; among thefe I perceived a few, which, though thoroughly ripe, were infefted with maggots.

Two of thefe nuts I opened, and out of each I took a thick fhort white maggot, about the fifteenth part of an inch in length, furnifhed with fix feet in the fore part of its body, and covered with a great number of long and very flender hairs : from the fame nuts I alfo took two or three pellicles or thin fkins of different fizes, which apparently had belonged to maggots of the fame fpecies, whence I concluded, that during their growth, thefe maggots change their fkins in like manner as filk worms are obferved to do.

I alfo found in thefe nuts, two flying infects of different kinds, but they, as well as the maggots, notwithftanding all the care I could take, foon died, whence I was more convinced that the maggots which feed on the Nutmeg are not natives of thefe regions, and I do not doubt, that if the warehoufes in India, where Nutmegs are kept, were to be well fumigated with fulphur, once a month, (for if this is done only once, thofe infects which are at that time alive may be killed, but the minute maggots inclofed in the eggs will efcape unhurt, and therefore the fumigation muft be repeated) by this operation the Nutmegs would, in a great meafure, be preferved from damage. And I alfo think, that it would be very proper to fumigate the holds of the fhips with fulphur, by which means thefe maggots, and thofe whofe nature it is to perforate and feed on timber; alfo, the infects called cock roaches, the millepedes, or thoufand legs, and even mice, which hide themfelves in the holds of fhips, muft be all deftroyed.

I endeavoured, three feveral times, to caufe the Nutmeg to vegetate, but I had not the good fortune to fucceed; which, I think, was partly owing to the lime with which the nuts had been fprinkled, and partly to their being fo much dried, that in many places they were cracked in the infide. In this my fearch, however, after diffecting many nuts, I at length, with great pleafure, not only difcovered the plant, but fucceeded in taking it out of the nut. The outer part of the leaves of this plant was formed with many indentings and points in the manner of vine leaves, and the leaves themfelves were as large as I ever found in the feed of any tree whatever. Upon viewing thefe leaves by the microfcope, I could fee the veins or veffels, lying in as regular order, as are to be feen by the naked eye in the full grown leaf of any tree.

Fig. 2, KLMN, reprefents this fmall plant taken out of the Nutmeg, as nearly as the limner was able to draw it from the naked eye; and though it feems to be compofed of many leaves, yet, in my judgment, there are but two; but I could not examine that matter very accurately, becaufe in the attempt, the plant was often broken. The part in this figure marked N is that, from whence the ftem and root would grow.

Moreover, I placed a fmall piece of the outward part of this leaf before a microfcope, and directed the limner to make a drawing of it with all the veffels in it, as they appeared to him.

Fig. 3, OPQRS, reprefents this piece of leaf; OP, is the part which was broken off from the reft of the leaf, and QR is the external edge of it.

In this fmall piece of leaf we not only fee, how the veffels or veins are branched out into fmaller ramifications, but in many places may plainly be feen, the oily matter or fubftance, which is the fame in nature and colour, as is to be feen in the nut itfelf. And fince we fee fo many branchings of the veins in fo fmall a piece of a leaf, who can tell how many more ramifications there may be in it, entirely efcaping our fight?

During the time that I was employed in fearching for the plant in the Nutmeg, I fell into converfation with a friend refpecting the tree that bears this fruit, which tree, I was perfuaded, had fome cavity in the middle of it; this coming to the ears of a certain Profeffor, he fent me two pieces of the root of the Nutmeg tree.

Upon examining thofe pieces of root, both at the larger and fmaller ends, I was greatly furprized to find, that this wood is of a remarkably fpongy nature and very porous, though it has not any cavity in it, different from the wood of other trees; for, from the root, we muft conclude, that the tree itfelf is of the like formation.

And in this root, I perceived fome wonderfully minute veffels, furrounding, as it in were, many places, the larger tubes of the wood, and through which, as I fuppofe, the tree receives nourifhment in its growth.

In order, as exactly as poffible, to exhibit to view the wood, or rather the root of the Nutmeg-tree, which bears fuch a precious and highly valued fruit, I have given the figure of a circle, which we muft fuppofe to be a branch of the tree, or of its root, fawed off tranfverfely, as is to be feen at *fig.* 4, ABCDEF. From the center of this figure are drawn many very fmall lines, as appears between CDFA, and thefe we are to fuppofe are thofe veffels which ferve for the increafe of the tree or root, and, by means of which, there is every year a new fubftance formed about the tree, as I have often heretofore mentioned.

Now, in order to inveftigate accurately, the true formation of this wood, we muft not examine merely the extremity of it, which would prefent an obfcure object to the eye, but we muft cut off a fmall piece or particle of the wood, as from E to the circumference, after we have, with a very thin and fharp knife, cut or pared the extremity as fmooth as poffible. In this manner I cut off a piece or particle of the wood, not fo large as is fhewn at *fig.* 5. This piece of wood, placed before the microfcope, and copied as exactly as the limner was able to reprefent it in his drawing, is fhewn at *fig.* 6, ABCDEFGH, and in it are to be feen, many of the veffels or tubes of which the wood confifts, fome of the larger ones of which, I have exhibited at I, I, I.

Among thefe larger tubes of the wood are to be feen a great number of fmaller ones, and many of thefe fmaller tubes are again furrounded by other exceffively minute veffels, through which latter veffels, for the moft part, the nourifhment is conveyed upwards in the tree, as I fuppofe.

But, as thefe fmaller veffels, which are plainly to be feen by the microfcope, cannot, by reafon of their minutenefs be well expreffed in a drawing, unlefs ftill more enlarged, I ufed a microfcope of greater magnifying power, and caufed a fmall portion of the wood which in *fig.* 6, is fituated between the two larger veffels, K and L, to be drawn fomewhat larger than it appeared through the microfcope before which it was placed, and this is fhewn in *fig.* 7. ABCD.

This piece of wood was fo cut, that all the horizontal veffels were exactly divided, and I could plainly perceive them, whether I viewed the object upwards or downwards ; and I further faw, that where the horizontal veffels lay, there the larger tubes of the wood were fituated, as appears in this figure at AB, and DC, which is where the horizontal veffels were fituated.

In *fig.* 6, are alfo fhewn, the horizontal veffels which take their courfe among the perpendicular veffels or tubes of the wood, but, as all the afcending veffels or tubes are cut tranfverfely, fo that their cavities become confpicuous, on the contrary, the horizontal veffels, by this manner of cutting, preferve their fhape as near as may be. In this figure there appear more of thefe laft veffels about the parts marked A and B, than about G, or between G and F ; the reafon of which is, that in fplitting the wood, the knife did not pafs in fo ftraight a direction along thofe veffels as I wifhed : for the fame reafon thefe horizontal veffels appear in greater numbers at E, or between E and F, than about C.

In thefe horizontal veffels may be feen a red and yellowifh fubftance, fimilar to the oily matter in the Nutmeg, and the young plant it contains, fo that the horizontal veffels are of a reddifh colour.

Farther, I determined to cut thefe horizontal veffels, each of which can be diftinctly feen, and which generally lie three, or at the moft, four together in rows, in an oblique manner, fo as to exhibit their cavities to view. A fmall particle of the wood reprefented at *fig.* 4, ABCDF, ſplit lengthwiſe, at the part marked DF, I placed before a microſcope, and this very thin particle, ſo ſplit off, is ſhewn at *fig*. 8, PQRS, in which appear eight diſtinct places, where the horizontal veſſels are cut in this oblique manner, as may be ſeen by the cavities in many of them, a part of which is ſhewn at Q.

The perpendicular aſcending veſſels, *fig*. 8, P S, or Q R, are thoſe ſmall veſſels, which in *fig*. 6, between K and L are ſhewn cut obliquely.

Moreover, I ſplit this branch of wood in the middle, as the line A B C in *fig*. 4 denotes, and from the piece ſo ſplit, I cut a ſmall particle, dividing the horizontal veſſels longitudinally. This particle of wood is repreſented at *fig*. 9, TVWXYZAB, where T V, and Y Z, are the aſcending veſſels, and the horizontal veſſels which croſs them, are ſhewn at W X and AB: and in, and among theſe horizontal veſſels we ſaw various minute globules, which the limner, as nearly as he was able, imitated in the drawing.

In my obſervations on this wood, I ſaw four ſeveral kinds of woody tubes, beſides other ſmaller ones, which, by reaſon of their minuteneſs, as I judged, could not be diſtinctly ſeen; but thoſe which could be diſtinguiſhed I cauſed to be drawn.

Fig. 10, CD, repreſents a tube of the wood partly compoſed of annular parts, like a wire wound round a pin; and, next this a tube formed in a different manner, ſeeming to conſiſt of a pellucid membrane, covered with many ſmall dots or ſpecks, which in ſeveral places were contiguous to each other; this tube is repreſented in *fig*. 10, at EE.

Fig. 11, G H, repreſents a third tube of the wood, covered with ſmaller ſpecks or dots, but, what is more remarkable, it contains in this ſmall ſpace five joints, very much like thoſe of which ſtraw is compoſed: two of theſe joints are repreſented at G and H.

I endeavoured alſo, if poſſible, to diſcover the formation of the larger tubes, ſhewn in *fig*. 6, at I, I, K, L, and while I was thus employed, it appeared to me, that the tranſparent membrane conſtitutiug the tube, was compoſed of veſſels taking their courſe round about the tube.

To make proof of this, I tore ſome of theſe tubes of the wood aſunder longitudinally, when I perceived, that where torn, they were very much indented or jagged, whence I concluded, that however tranſparent they might appear to me, they were yet compoſed of a great number of veſſels lying in a circular direction.

Fig. 12, I K, repreſents a part of one of thoſe larger tubes ſo torn and jagged, which is very cloſely united to the adjoining ſmall veſſel at L M in the ſame figure, and from which, as I think, this larger tube received nouriſhment in its growth, and the rather becauſe, though the membrane or coat of this tube appeared tranſparent, yet it plainly appeared, that the membrane was compoſed of minute veſſels, which appeared to derive their origin from that ſmall veſſel.

I then proceeded to examine theſe larger tubes of the wood, with all the accuracy I was able, and I was well aſſured, that I ſaw the membrane compoſing them to be made of veſſels like ſtreaks croſſing each other at right angles; a particle of this membrane is ſhewn in *fg*. 12, at L N O I, where the veſſels or ſtreaks from I to N and from L to O mutually croſs each other, by which means this thin ſubſtance is ſtrengthened; and who can tell how many, and what various parts ſuch a tube of the wood may contain?

I think I have formerly ſaid, reſpecting the veins in the leaves of trees, that they are of a ſpiral twiſted form, like that repreſented in *fg*. 10 at C D; and alſo, that the ſtring by which many nuts (as the filberd, almond, &c.) have nouriſhment conveyed to them through the hard ſhells, conſiſts of many veſſels of the like kind, and upon recollecting this I determined, as far as I was able, to diſſect the young plant I had taken out of the Nutmeg, to ſee whether the veſſels repreſented in *fig*. 10, at C D and which are in great numbers in the wood, could alſo be found in the young plant.

For this purpofe, I firft examined the leaf of the young plant, in that part where it was fo thick as to be opake, and immediately I faw in it three diftinct veffels of the like fpiral or twifted form, as I have before mentioned to have feen in the root. This enquiry I profecuted as far as the extremity of the leaf, where I faw a fmall veffel of the like kind, and fo diftinctly, that I could count every fingle fold or fpiral turning in it.

Since it now appears plain to us, that provident Nature forms all the veffels of this tree in fo perfect a manner, that the fmall ones in a young plant in the feed, are as plainly to be feen as thofe in the wood at full growth, which we may juftly conclude is the cafe in all feeds, however minute ; we are not to wonder that the fmalleft of any animal which we view by the microfcope, is as completely provided with all its parts as when it is grown larger. In a word, the farther we endeavour to dive into the hidden works of Nature, the more we ought to be convinced, that we never can arrive at her fartheft receffes, though many perfons, when making ufe of a good microfcope, weakly fuppofe, that nothing is out of the reach of their obfervation.

On damaged Mace, commonly called white Mace; the caufe from whence this defect arifes, fhewn to be an infect which feeds on the internal parts of the Mace, with a particular defcription of that infect; and fome farther account of the Nutmeg.

UPON hearing formerly, mention made of that fort of Mace which is denominated white Mace, I merely thought, that it was not fo good either in flavour or virtue as the reddifh-coloured Mace, and the rather, as I long ago heard that a certain phyfician had the art to give the white Mace the fame colour as the beft; but having been fince informed that this white Mace had fo little virtue, that it was forted from the reft and burnt, and hearing that its inferiority was fuppofed to proceed from fome defect or want of nourifhment in the growth of the plant, I had a great defire to examine the nature of this white Mace.

On converfing upon this fubject with one of the Directors of our Eaft India Company, he informed me of the time when the officers at the Company's warehoufe, were employed to fort out the white Mace, and gave me permiffion to go to the warehoufe and fatisfy my curiofity in this refpect. I accordingly attended at the warehoufe, and perceived, not without furprize, that the white Mace was compofed of nothing but thin membranes or fkins, and I alfo obferved a kind of webs, which I concluded had been fpun by fome infect, which webs were fixed to fome of the Mace, not only the found, but alfo the damaged. I brought home with me eight or ten of thefe webs, and found them to be covered in part with certain oblong black particles, which I concluded to be the excrements of the maggots, by which thofe webs had been fpun: in feveral of thefe webs, I alfo faw certain particles which feemed to be the fragments of aurelias, from which fome fpecies of flying infect had proceeded, and, as in one of thefe webs I perceived feveral minute feathers, very much like thofe found on the wings of moths, I further concluded, that the flying infects which proceeded from thefe webs muft bear fome refemblance to the moths in this country.

In order to fatisfy myfelf further, I went the next day to the Company's warehoufe, and fpent a whole hour with fome of the officers in fearch of thefe webs, and at the fame time, the officers gave me a leaf or piece of Mace very much fhrivelled, in which was the apperance of a web, and on opening the leaf, I found in it a white flying infect, (which was not only dead, but had loft fome of its legs,) in fhape and fize not unlike thofe white moths that are found in granaries, and from whofe eggs proceeds the maggot called the wolf,* though I judged this infect to be of a different fpecies. Upon my return home, I examined all the webs I had found, and in feveral of them, difcovered the fkins or cafes of aurelias, from which flying infects had proceeded, and in two of them, the infects themfelves; I alfo found one perfect cryfalis, and in it the infect dead; and upon attentively examining this cryfalis, I plainly perceived that it was exactly of the fame fhape and nature with all the other fkins of aurelias which I had found. I caufed a drawing to be made of this aurelia or cryfalis of the fame fize it appeared to the naked eye; this is fhewn at figure 13, AB, in which the refemblance is taken as accurately as the limner could imitate it in his drawing.

Fig. 14, CD reprefents the flying infect which proceeded from one of thefe aurelias; the wings of which, would I believe, have appeared longer than here reprefented, had not the animal while

* The defcription of this infect is to be feen at page 25.

ſtruggling to get out from amongſt the Mace where it was encloſed, broken off part of them, in which ſtruggle alſo, I fancy it had been killed.

After this, I applied myſelf to examine the white Mace, as it is called, a parcel of which I had brought home with me; and I immediately perceived that all the matter or ſubſtance which had been encloſed between the membranes compoſing the outward ſurface of the Mace, was conſumed or eaten away. This ſubſtance, which for the moſt part, conſiſts of oily globules, in which the whole virtue of the Mace conſiſts, being ſo ſtripped from thoſe membranes (of which membranes, the leaves of all plants, however ſmall they be, are compoſed, and whereby the internal moiſture of the leaf is kept from evaporation) nothing remains but the thin membranes themſelves, conſiſting of wonderfully minute veſſels, lying lengthwiſe in the leaf, which altogether exhibit a white appearance: hence theſe leaves are called white leaves, or white flowers of Mace, whereas, in fact they are nothing but the very thin membranes of thoſe leaves.

I found, on the inſide of theſe membranes, various oblong particles pointed at the ends, and ſome of them tranſparent; theſe I concluded to be the excrements of the maggots I have mentioned, and to have been voided by them at different periods of their growth, becauſe, though of different ſizes, theſe particles were all of the ſame ſhape. Farther, I obſerved ſome of the broader leaves of Mace to be ſo eaten away, that only one of the membranes remained, and having in vain ſought among them for any animalcule, I threw them all away.

After this, I procured a freſh ſupply of the white leaves of Mace, not doubting that I ſhould find ſome dead animals among them. At length, after a long ſearch, I found a ſmall white particle, not larger than a grain of ſand, which, examining by the microſcope, I found to be an animalcule, the hind part of whoſe body was tranſparent and oblong, but the fore part was covered with fome extraneous matter, which endeavouring to wipe away, I broke it off from the hind part.

I was, however, hereby induced to make a further fearch, not doubting, that I fhould find fome of thefe infects of a large fize, but I could not difcover any of them among the leaves whofe membranes were entirely ftripped of their contents; whence I concluded, that the maggots, when grown large, had either quitted the leaves or undergone a change in their form, whereupon I fat about examining thofe white leaves which lay next the others that were found, as alfo thofe leaves which were in great part, but not wholly, confumed; fix or feven of which I had brought with me; and among thefe, I found a few animalcules of the fame fhape with the one I laft mentioned; thefe were not only larger than the former, but their bodies were of a reddifh colour, and I judged that this colour proceeded from their feeding on the oily matter, of which the Mace, for the greateft part confifts, and that the former tranfparent animal had died before it had fed on that coloured fubftance.

At *fig.* 15, is fhewn one of thefe maggots, of the fame fize as it appeared to the naked eye; this was one of the largeft that I had met with in my fearch.

The difcovery of thefe maggots very much excited my admiration, becaufe I had never feen any thing like them in the Nutmeg, and the more, becaufe thefe maggots feed and fubfift on the oil in the Mace, of which oil the Nutmegs are alfo in part compofed. But the reafon why thofe animalcules, which feek their food in the Nutmeg are not found in the Mace, is, in my opinion this, that thofe which devour the Nutmeg avoid the oily matter it contains and only feed on thofe parts of the nut where there is little or none of that oil.

Having thus difcovered the maggots (defcribed in *fig.* 16,) which feed on that thin matter or fubftance found within the membranes of the Mace, and which afterwards quit the Mace, leaving the membranes themfelves unhurt, except in that part where they firft gained admittance ; I caufed a drawing to be made of fome of thefe Mace leaves, a part of which is of that fort called white Mace.

Fig. 16, A B K C D E, exhibits part of a leaf of Mace, and in this figure, between E F G and H, may be feen the ftripes of the leaf, which are engraved with very light touches, fo as to give the appearance of white ; thefe are the parts called white Mace, and from them the oily fubftance is all confumed, leaving only the bare membranes. Now, if this whitenefs had been caufed by the want of nourifhment in the plant, then the extremities of the leaves at C or D, would have been white alfo, whereas, on the contrary, they were of the proper colour, and of a good flavour, by reafon that the maggots had not eaten away the oil from within the membranes farther than where the leaves appeared white.

Lower down, in the figure, between G and H, may be feen a fmall hole made in the membrane of the leaf, which I conclude, was bitten by the maggot, to open for itfelf a paffage into the leaf, and the rather, becaufe the thin membranes in this part of the leaf were entirely unhurt, nor did there appear any perforation in them, except in the before mentioned place towards A B. And, if we confider the narrownefs of the cavity in thefe white leaves, where the oil is eaten away, we may conclude, that it muft have been an exceeding minute creature which could turn itfelf about in fo fmall a fpace, and then procure its fubfiftence ; and, between the membranes in this part of the leaf, I found nothing, except the excrements of the maggot.

When I was endeavouring, fome time fince, to difcover the young plant in the Nutmeg, I alfo tried to find out, in what manner the nut, while inclofed in its fhell, received nourifhment from the tree ; and for that purpofe, I took a Nutmeg which was preferved in fugar, and diffected it, but, as the fyrup had penetrated into the infide of the nut and was there candied, my fearch was at that time fruitlefs; however, during my prefent inquiry, the forters of fpices prefented me with fix or eight Nutmegs, which they had found among the Mace, which, with their original hufks, and the Mace inclofing them, altogether fomewhat bigger than large hazel nuts; and alfo two of the fame, fomewhat larger.

Upon examining thefe nuts attentively, I perceived, that the fkin which covers the hard bark or fhell of the Nutmeg, was perforated in fome places among the Mace, though the Mace leaves themfelves were unhurt; hence I judged, that this perforation was the work of thofe maggots, or animalcules which I have in another place mentioned, as feeding on thofe parts of the Nutmeg wherein there is none of the oily matter compofing the Mace, on which oil they cannot fubfift.

I viewed the Mace which inclofed thefe Nutmegs by the microfcope, and found it to be covered with many dried bodies of mites, but in all my fearch, I could not difcover any living mite, whence I concluded, that the packages inclofing thefe Nutmegs, had been ftowed in a part of the fhip near the bread-room, and, upon enquiry, I found that this had actually been the cafe; fo that I doubt not, thefe mites, which multiply in vaft numbers among the bread, had been killed, when the packages of Nutmegs and Mace were ftowed there: and this confirms what I have, in another place mentioned, that the vapour of Nutmegs is mortal to thofe creatures.

Farther, upon examining thefe Nutmegs, and the leaves of Mace inclofing them, I obferved in feveral of them, that, at the part where they receive their nourifhment from the tree, they were perforated with a fmall round hole, penetrating into the nut itfelf, the Mace for the moft part appearing untouched; and this was done where the bark of the nut was the fofteft: in one of thefe holes I found a dead flying infect, of the fame fpecies with thofe, many of which I have mentioned to have found in the Nutmeg. Upon breaking open one of thefe nuts, I faw, that all the internal whitifh fubftance of it, where there had been little of the oil, was eaten away, and nothing left in the cavity except the excrements of the maggot, and the web it had fpun while in that place; but, as I did not find any fkin or remnant of an aurelia, I judged that the maggot, not finding a fufficient quantity of fuftenance in this nut, had quitted it before it arrived at its full growth. On this occafion, I could not but admire the inftinct which teaches thefe infects to perforate the hard fhell of the Nutmegs, and for that purpofe, to find out that part in it which is fofter than the reft; for this I found to be the cafe not merely in one or two inftances, but in as many as ten Nutmegs, I obferved the fame.

Fig. 17, L M N, reprefents the Nutmeg inclofed in its fhell, and covered with the leaves of Mace, but which coverings are, in India ftripped off while frefh and green. All thefe receive their growth and increafe through the part between L and M, which is the place where the nut adjoins to the tree; and I at firft thought, that the Nutmeg was nourifhed from its fhell or bark, as I had obferved was the cafe with the walnut; but upon a more careful inveftigation, and after cutting open the fhell with a fine faw, I found, that I had been miftaken herein, for I could not difcover any thing at the part marked L M, which had the appearance of having tranfmitted nourifhment to the fruit. I foon, however, perceived two places adjoining to each other, one, as I concluded, for the nourifhment of the bark, and the other of the nut itfelf; and, on further fearching, I faw, that the veffels deftined for this purpofe, did not immediately enter the nut at that point, as I had obferved in filberts, almonds, and other feeds, but that the veffels in this nut take a courfe from M in *fig.* 17 to the point of the nut at N, and there pafs through the ſhell, and by this means, the nut receives its nouriſhment; for it is not united to its ſhell in any other place.

To exhibit this to the eye, I cauſed a drawing to be made of the bark or ſhell containing the Nutmeg, after the leaves of Mace had been ſtripped off, and having alſo firſt looſened from it the ſtring through the veſſels in which nouriſhment is conveyed, leaving only the ſtring affixed to the part where it enters through the bark, to ſhew more plainly the place where the nut receives its nouriſhment.

Fig. 18, O P Q, repreſents the bark or ſhell wherein the Nutmeg is incloſed; Q R, is the ſtring, conſiſting of multitudes of veſſels which convey nouriſhment to the nut; O and Q exhibit the furrow or creaſe wherein the ſtring lay before it was pulled out. This ſtring I cut into very thin ſlices, ſome of which I placed before the microſcope, that I might the better diſcern the great number of veſſels in them, of which I cauſed a drawing to be made, as nearly as they could be diſtinguiſhed and repreſented. This is ſhewn in *fig.* 19, A B C D E, being one of the ſlices I have mentioned, cut obliquely, and magnified.

Now, if we contemplate the incredible number of veſſels in ſo ſmall a ſtring, (for that which in *fig.* 18 is ſhewn at Q R, is, in reality twice the ſize of the real ſtring, becauſe I did not ſtrip it of the ſkin which covered it, leſt I ſhould injure the veſſels it contained) beſides thoſe which the ſight cannot reach, we muſt conclude, and be aſſured, that there is not a veſſel in a full grown Nutmeg tree, for whatever uſe it may be deſtined, but there is a ſimilar one in this ſtring; otherwiſe it could not communicate to the young plant in the Nutmeg, all the veſſels requiſite for the formation of the future tree and fruit.

In a word, the inconceivable perfections which are contained in theſe ſtrings of plants, and conſequently in every ſeed, are to us incomprehenſible, and, ſtill more, inſcrutable.

Moreover, I have given a drawing of the bark or ſhell of the Nutmeg, when broken in two, having firſt ſtuck a pin into the place through which the ſtring, which I have been deſcribing paſſes, in order more plainly to ſhew the nature of it. This is repreſented at *fig*. 20, S T V, in which figure, W X is the pin, marking the place through which the ſtring paſſed, and at Y is a kind of protuberance on the inſide of the ſhell; in the nut itſelf is a cavity correſponding with it, and above this cavity, is the place where the ſtring is united to the nut; but the ſtrings are almoſt always broken from the Nutmegs before they arrive in Europe, becauſe the nuts in drying, or by the evaporation of their moiſture, become ſmaller, whereas the hard ſhell dries and ſhrinks little or nothing, ſo that the nut getting looſe within, does, by its weight break off the ſtring, and, when ſhaken in the ſhell may be heard to rattle.

At *fig*. 21, F G H, is a drawing of a piece of the ſhell at that end next the tree, and at K is the round hole I have mentioned, in one of which holes, I found a flying inſect: in this figure alſo, that part of the ſtring conveying the nouriſhment to the nut, and which here, is joined to the tree, is ſhewn at I K L: this ſhell being removed, I found that the animal had penetrated into the nut as I have before obſerved.

Fig. 22, M N O, repreſents the nut itſelf, in which the above mentioned ſmall hole, is ſhewn between P and Q: at this place, the young plant is ſituated in the nut, and here alſo, as far as I have ever obſerved, the inſects penetrate the nuts becauſe it is the ſofteſt part of the fruit, and contains the leaſt of the oil.

Since we now ſee, that theſe creatures, not only when maggots, but alſo when changed into flying inſects, feed on thoſe parts of the nut where the oil leaſt abounds, we may readily conclude that, however minute, they are very pernicious to Nutmegs. In the ſtate of flying inſects, however, they are not, in my opinion, ſo hurtful on account of their feeding on the Nutmeg, as by laying their eggs, the maggots proceeding from which, muſt be exceedingly pernicious, becauſe they acquire their whole growth within the nut.

I am perſuaded, that if the timber and wood in warehouſes was painted with the common red paint uſed in this country, the ſpices might be preſerved from many noxious inſects, becauſe the particles of that paint, though ground very fine, are of ſo hard a nature, that no ſmall inſect can penetrate them. And if the wood is obſerved to be perforated with many worm-holes, the painting ſhould be repeated until all thoſe holes are ſtopped up with it.

It may be ſaid indeed, that Nutmegs and Mace are kept but a ſhort time in the warehouſes, and therefore not liable to be much injured; but in that ſhort time, and while expoſed to dry, they may be infected by theſe flying inſects laying their eggs among them; and it is well known, that many of theſe creatures lay many eggs in a very little time. Indeed, if Nutmegs and Mace are kept in large heaps in the warehouſes, I believe that only the ſurface of them might be expoſed to injury, becauſe the inſects cannot penetrate far into the heaps to lay their eggs, and therefore the middle of theſe heaps may be uninjured.

But theſe matters are all conjecture, and, as it were, riddles to us at this diſtance, reſpecting which, thoſe who are employed upon the ſpot, in collecting or drying the ſpices, could give much better information, if they were perſons of intelligence and obſervation.

To return to the inſects which I found among the Mace; I was doubtful how to purſue my enquiry reſpecting the generation of theſe creatures, and the rather, becauſe thoſe which I found, were not only dead, but their bodies very much dried, for, had they been living, I doubt not, that I ſhould eaſily have diſcovered the manner in which their ſpecies is propagated.

At length, upon conſidering the ſhape and make of theſe maggots, and, having feen by the microfcope, that their bodies are formed with creafes or rings, it occurred to me, that they were of that fort which do not bring forth young ones while in that ftate, but, like catterpillars, feveral kinds of maggots, and alfo fleas, change into aurelias, and thefe again into flying or creeping infects, and in that ftate couple and lay eggs.

Now, as I had found thefe maggots among the fkins of the Mace, I concluded, that when their change approaches, it is in their nature to abandon the leaves: and, as in my former fearch I had found a cryfalis, which I concluded had been changed from one of thefe maggots, inclofed in its fhell or covering, I went a third time to the India Company's warehoufe, and caufed a confiderable quantity of the white Mace to be put into a fieve and fifted, in expectation, that among the finer parts, which paffed through the fieve, I fhould find feveral infects that had gone through their change.

By this means, I obtained two handfuls of fmall matter or duft, mixed with many minute particles of Mace, but I perceived, that the greater part confifted of the excrements of infects; I alfo took a handful of duft, fifted from a parcel of Mace, before the officers had forted the damaged from the found: on my return, I carefully examined the whole, and found in it, at leaft one hundred dead animals, which I concluded had been produced from the before mentioned maggots, I alfo found two flying infects of the fame fort with thofe which I had obferved in the Nutmeg; likewife the fkins of two aurelias, and one of thofe creatures called a weevil, but which, as well as the reft, was dead. Such of thefe animals as had been produced by tranfmutation, were all of the like make, and almoft of the fame fize as the full grown maggots, and I judged, that if they had not proceeded from thofe maggots, they would have been of different fizes.

Some of thefe maggots, I placed before different microfcopes, that I might caufe a drawing to be made of fuch one of them as was the moft perfect, becaufe all that I found were not only dead, but fo dried, that the leaft touch would break their bodies, or at leaft their feet.

I have already given at *fig*. 15, a drawing of one of thefe maggots, of the natural fize; *Fig*. 23, E F G H I K L M N O, reprefents the fame maggot as feen through the microfcope: the body of this creature is formed with many joints or rings, alfo with fix fmall feet, furnifhed with curious nails, the extremities of which nails are indented or notched, as fhewn at G and N.

In the lower part of the body of this animal, as well on the belly as on the back, there appears an uncommon number of blood veffels, which, on each fide of the body at H I and M L are the thickeft and largeft, and feem to come from the inner part of the body: thefe blood veffels are divided into various exceedingly minute branches, feveral of which, proceeding from H to M, and from M to H there meet, and are again united, which not only appears in the branches about H and M, but alfo through the whole body, though the limner could not reprefent them all.

In the head of this creature, fo many organs appeared, that they could not all be copied in the drawing.

At O and F are reprefented, two prettily fhaped horns, made with joints, and covered with hairs: at E is the mouth, or rather two teeth, fomething like pincers, with which the maggot, as I judge bites into the leaves of the Nutmeg on which it feeds, and fcrapes off the fubftance they contain; within the fkin at P P are two other organs with which the head of this maggot is furnifhed.

I know very well, that thefe fmall animals are called bloodlefs, a name given to them by thofe, who, I fuppofe could not difcover either the blood or the blood veffels, but this miftake I attribute only to their want of better information.

Now, as all caterpillars, maggots, and other ſmall animals when changed into flying inſects do ſtill preſerve the ſame ſort of creaſes, rings, or diviſions, which they originally had, ſo I perceived in the flying animal, produced from theſe maggots, the ſame kind of rings or diviſions, but theſe did not become conſpicuous till the two ſhells, or caſes which covered the hind part of the body were removed: under theſe caſes lie two exceeding ſmall wings folded together, and by reaſon of their being longer than the body, doubled up: ſo that it ſeems probable to me, that theſe creatures are formed in the ſame manner as inſects of the beetle kind, with regard to their wings, and the caſes that cover them.

If we reflect on the nature of thoſe flying animals, whoſe wings are thus folded up and covered with ſhields or caſes, and who are deſtined to ſeek their food in hard ſubſtances, ſuch as wood, nuts, and the like, or who are hatched in the earth, we ſhall ſee the neceſſity of their wings being formed in that manner, for if the wings were not longer than the hind parts of their bodies, they would be too ſmall for flight, and if not defended by the caſes or ſhields, they would be liable, when the animals are creeping into holes either in the earth or in the hard ſubſtances on which they feed, to be ſo broken or injured, as to be unfit for the purpoſe of bearing them through the air.

Theſe animals, even after they are converted into flying inſects, do, in my opinion, take food, contrary to what is obſerved in the moths or butterflies produced from ſilk-worms and caterpillars, for I obſerved, that ſome of theſe were of a bright and others of a dark red, the former of which, I ſuppoſe, had not been long changed, and therefore had not taken ſo much food as the latter.

I have often thought, that perhaps, theſe kinds of animals may feed upon wood, but, that when they get among Mace, which is of a much fofter nature, they may then multiply much fafter than thofe which breed in wood, and efpecially in the harder forts.

I placed one of thefe creatures, changed from the maggot into a flying infect, before the microfcope, and having removed the fhields or cafes of its wings a little afide, in like manner as if the animal was living and about to take its flight, I beheld fo wonderful a piece of workmanfhip, wrought with fuch curious art, that I determined to have a drawing made of it, though it was impoffible to delineate all the wonders that were difplayed in this minute animal.

Fig. 24, ABCDEFGHIKL, exhibits this flying animal, which appeared longer than the maggot from which it was produced, the reafon of which I take to be, that the bodies of thefe maggots being very foft, they contract when their moifture evaporates, whereas when changed into flying animals their bodies are hard on the outfide, and therefore cannot contract.

LM, and BN, are the two horns made with many joints and covered with hairs.

L, B, are the eyes compofed of various optical organs, though but few in comparifon of thofe which are found in the eyes of flies.

This creature has fix feet, each furnifhed with two curioufly made little claws; the legs are made with various joints at the extremities, and are covered with hairs, or rather with pointed particles like thofe on brambles: two of thefe legs with their claws, are fhewn at CO and DP.

At DI and KI are pictured the two fhields, or cafes, with which the animal, when not in the act of flying, can cover the hind part of its body, fo that I conclude, no particles of the wood, or of the Mace, nor any drops of water which may accidentally fall on its body, can injure the wings.

Upon attentively contemplating thefe fhields or cafes, I was aſtoniſhed at the wonderful and elaborate workmanſhip exhibited in this creature, which appears ſo minute to the naked eye, but does, I think, in perfection, far exceed the larger animals we daily behold.

If we advert to the hind part of the body, formed with joints indented in the ſame manner as in the maggot, from which, by tranſmutation it was produced, and obſerve the multitudes of veins, ſcattered over it, we muſt more and more be confounded at ſuch great perfection in ſo minute a creature.

In like manner in the wings, we ſee many veſſels and ſinews, which ſinews ſerve to expand and ſtrengthen them; likewiſe many pointed particles or hairs, with which the membranes of the wings are covered: it is alſo worthy of obſervation, how the wings are folded and doubled up, both in length and breadth (which is ſhewn between G and H, as nearly as the limner could imitate it) in order that they may be entirely covered by the caſes; beſides which, this animal is provided with another exceedingly minute wing on each ſide. Let us alſo conſider, with what inconceivably minute ſinews or muſcles theſe wings muſt be provided, in order that the animal, when it prepares for flight, may unfold them both in length and breadth; and how the joints and ſinews muſt be contrived, ſo to ſtrengthen the wings when unfolded, that by their ſwift vibrations, the animal may ſhape its courſe through the air.

In order, more clearly, to give an idea of the foldings in theſe wings, I took one of them from under its caſe, and placed it, together with the ſinew or muſcle which adhered to it, before a microſcope, directing the limner to make a drawing of it, and alſo of the ſinew, whereby the wing is unfolded and put in motion.

Fig. 25, QSVWXY, repreſents this wing according to its poſition when covered by the caſe or ſhell; V, is the broadeſt part of the wing, and this part lay either under or above the correſponding wing. QR is the mufcular part, by means of which, not only the wing is put in motion, but doubtlefs many leffer mufcles are derived from this, by means of which, that part of the wing at W X Y is extended in length, and the part at Y Q expanded in breadth: at S T is the minute wing I mentioned above.

When we duly confider this moft perfect workmanfhip of the Divine Artift, we muft confefs, that thofe things which we difcover by our microfcopes and induftry, are but as the fhadow of thofe which hitherto remain concealed from us, not only in fuch fmall animals as this now under confideration, but alfo in larger animals, and in plants.

It is to be hoped then, that the enquirers into Nature's works, by fearching deeper and deeper into her hidden myfteries, will more and more place the difcoveries of thofe truths before the eyes of all, fo as to produce an averfion to the errors of former times, which all thofe who love the truth, ought diligently to aim at. For,

We cannot in any better manner, glorify the Lord and Creator of the Univerfe, than that, in all things, how fmall foever they appear to our naked eyes, but which yet have received the gift of life, and power of increafe, we contemplate the difplay of his Omnifcience and Perfections with the utmoft admiration.

END OF THE FIRST VOLUME.

SIDNEY,—PRINTER, BLACK HORSE COURT, FLEET-STREET.

A

BRIEF DESCRIPTION

OF THE

Subjects contained in the Plates

TO THE

ENGLISH TRANSLATION

OF THE

SELECT WORKS OF ANTONY VAN LEEUWENHOEK.

BY SAMUEL HOOLE.

PLATE I.

Fig. 1. A piece of oak of eighteen years growth, cut tranſverſely, to ſhew the increaſe of growth in each year, as is particularly repreſented at E.

Fig. 2. A ſmall piece of this wood, when magnified from the natural ſize at X, ſhewing the perpendicular veſſels.

Fig. 3. A repreſentation of the internal ſtructure of the large perpendicular veſſels which appear in *fig.* 2, at E E E.

Fig. 4, 5. The ſame wood cut longitudinally, to ſhew the veſſels in another view.

Fig. 6. A piece of German oak, two years growth, magnified from the natural ſize at X.

Fig. 7. A piece of fir, two years growth, cut tranſverſely, drawn from the microſcope.

Fig. 8. A ſmall fragment of fir, ſplit off longitudinally ſhewing the minute globules of turpentine formed in this tree.

Fig. 9, 10, 11, 12, 13, 14. Fragments of this wood, magnified, to ſhew the nature of the different veſſels.

Fig. 15. A piece of fir, cut and ſplit in different directions, to ſhew the manner of the author's preparing it for his obſervations.

PLATE II.

Fig. 1. The egg of the Weevil, or corn-beetle, magnified; its natural ſize being no larger than a grain of ſand.

Fig. 2. The maggot, bred from this egg, when firſt hatched.

Fig. 3. The ſame when grown to its full ſize, magnified.

Fig. 4. The Weevil, of its natural ſize, is ſhewn at X; this figure ſhews part of the head, the proboſcis, or trunk, with its piercers, and the two horns, as viewed through the microſcope.

Fig. 5. A glaſs tube uſed by the author in his experiments and obſervations on the ſubjects deſcribed in the next figure.

Fig. 6. A moth, which infeſts corn kept in granaries.

Fig. 7. The aurelia, from which this moth is produced.

Fig. 8. The maggot, or caterpillar, bred from the egg, laid by this moth, drawn from the microſcope without the feet.

Fig. 9. Part of the body, with the feet, farther magnified.

Fig. 10. In the centre of this circle is ſhewn the natural ſize of the egg laid by the moth.

Fig. 11. The ſhell, after the maggot had quitted it, magnified.

Fig. 12. The natural ſize of the maggot.

Fig. 13, 14, 15, 16. Feathers, of different kinds, with which the body, feet, and wings of this moth are covered, as they appear when viewed ſingly by a deep magnifier.

Fig. 17. A ſmall part of one of the hind feet of the common garden Spider, as ſeen through the microſcope.

Fig. 18. Part of the ſpider's head, magnified, ſhewing its eight eyes.

Fig. 19. The two fangs, or teeth, of the ſpider, magnified, one being extended, the other at reſt.

Fig. 20 The thread of the ſpider greatly magnified, ſhewing it to be compoſed of a number of ſmaller threads.

Fig. 21, 22. Views of the organs in the ſpider's body, from which theſe threads iſſue.

Fig. 23. The garden Spider of its natural ſize.

Fig. 24. A hook, on the under part of the Spider's body, magnified; which the author ſuppoſes to be uſed by the animal in depoſiting its eggs.

Fig. 25. The Silk-worm's egg magnified, in which, at G H, is ſhewn the opening made by the young ſilk-worm to iſſue forth.

Fig. 26. One half of the ſilk-worm's head, magnified.

Fig. 27. One of the ſilk-worm's teeth.

Fig. 28. A particle of the ſilk-worm's thread magnified, ſhewing it to conſiſt of two threads.

Fig. 29. Another reprefentation of the thread, which fhews it to be of a flat fhape.

Fig. 30. The organ from which this thread is fpun, magnified.

Fig. 31. A farther reprefentation of part of the fame.

Fig. 32. One of the blood veffels in a filk-worm, magnified.

Fig. 33. A fmall portion of one of the eyes of the filk-worm's moth, magnified; the eye is fhewn between L and M.

Fig. 34, 35. Feathers on the body, feet, and wings of the filk-worm's moth, as feen through the microfcope.

Fig. 36. The boney part of one of the wings, magnified, with part of the membrane compofing the wing.

Fig. 37. One of the claws of the filk-worm magnified.

Fig. 38. One of the feet of the filk-worm's moth, magnified.

PLATE III.

Fig. 1. A fcale taken from the belly of an Eel, magnified, the natural fize of which is fhewn at X.

Fig. 2. A particle of the flime on the body of an eel, magnified, and appearing to be no other than a number of minute veffels.

Fig. 3. A flice cut obliquely through the fcale of a carp, the divifions on which denote the age of the fifh.

Fig. 4, 5. The fame feen in different pofitions.

Fig. 6. The natural fize of the piece of fcale, as reprefented at *fig.* 4, when magnified.

Fig. 7. The fea-mufcle of its natural fize.

Fig. 8. The ligaments by which this fifh faftens itfelf to the rocks, as they appear when magnified.

Fig. 9. Young mufcles, as they lie in the parent's body, magnified.

Fig. 10, 11, 12, 13. Different views of young mufcles, taken out of the parent's body, and magnified.

Fig. 14. The frefh-water mufcle, its natural fize.

Fig. 15. Six unborn mufcles, magnified.

Fig. 16. A parcel of unborn oyfters, taken out of the parent's fhell, and magnified.

PLATE IV.

Fig. 1. Blood-veffels in the tail of a tadpole, magnified.

Fig. 2. A farther reprefentation of thefe veffels, to fhew which of them are to be denominated veins, and which of them

are arteries, though, in fact, both of them are a continuation of the ſame veſſel.

Fig. 3. Particles of the blood of a frog, as ſeen through the microſcope, to ſhew how the different ſhades in their colour is produced.

Fig. 4. The natural ſize of a minute fiſh, in the tail of which the author obſerved the circulation of the blood.

Fig. 5. Part of the body and the tail of the ſame fiſh, as ſeen through the microſcope.

Fig. 6. A ſmall part of the tail-fin, farther magnified, to ſhew the circulation of the blood in its veſſels.

Fig. 7. Between the figures 1, 2, 3, 4, are repreſented the blood veſſels in the tail of an eel, within a ſpace, the natural ſize of which did not occupy more ſpace than a large grain of ſand; and by this figure the circulation of the blood, through the arteries and veins is particularly explained.

Fig. 8. Some of the blood veſſels in the tail of a tadpole, as ſeen through the microſcope, ſhewing the nature of the circulation of the blood in another view.

Fig. 9. Another veſſel, in which the blood was coagulated.

Fig. 10. An artery in a tadpole which was wounded.

Fig. 11. Blood veſſels in the wing of a butterfly, greatly magnified, with ſome of the feathers on the membrane of the wing.

PLATE V.

Fig. 1. Views of the external and internal formation of the human teeth.

Fig. 2. A ſmall fragment of a tooth, magnified from the ſize ſhewn at X, exhibiting the minute tubes compoſing it.

Fig. 3. Animalcules in the ſubſtance which collects between the teeth, as they appear through the microſcope.

Fig. 4. A coffee bean, in its ſhell or pod.

Fig. 5. The ſhell cut open, ſhewing that it contains two beans.

Fig. 6. One of theſe coffee beans with its flat ſide upwards.

Fig. 7. A ſlice of the bean magnified in a ſmall degree, and in which the young plant appears at O.

Fig. 8. This young plant farther magnified.

Fig. 9. A minute ſlice from the middle of the coffee bean, magnified, the cavities in which contain an oil.

Fig. 10. The ſalts in vinegar, from whence its acid taſte pro-

ceeds, and two of the minute eels, which are found in vinegar, all drawn from the microfcope.

Fig. 11. The Scorpion, of its natural fize.

Fig. 12, 13. The fting of the Scorpion, magnified.

Fig. 14. The tooth of the Scorpion, magnified.

Fig. 15. One of the claws of the Scorpion magnified.

Fig. 16. A drop of the viper's poifon, viewed through the microfcope, fhewing the falts it contains.

Fig. 17. An oak leaf, which produces galls, or gall nuts.

Fig. 18. A gall nut cut in half, wherein, at N N, appears the cavity in which a maggot was bred, different views of which maggot are reprefented at I K L M.

Fig. 19. A fly bred from this maggot, iffuing from the gall nut.

Fig. 20. The cavity in the nut which the fly had quitted.

Fig. 21. The fly, which lays its eggs on the oak leaf, from which the maggot, caufing the gall nut to grow, is hatched.

Fig. 22, 23, 24. Nuts, or excrefcences, formed on the thiftle, in like manner as gall nuts on the oak.

Fig. 25. One of thefe nuts cut open, containing an aurelia.

Fig. 26. The fly produced from this aurelia.

Fig. 27. A thiftle nut cut acrofs, containing many cavities.

PLATE VI.

Fig. 1. The young plant taken out of a grain of Wheat, as feen through the microfcope.

Fig. 2. A flice cut acrofs the fame, and magnified, fhewing it to contain the origins of three young plants.

Fig. 3. A fmall piece of the hufk of the wheat, magnified.

Fig. 4. A fmall particle of the bran magnified, in which, at D and E, are fhewn fome of the globules of the meal.

Fig. 5, 6. The young plant in a grain of wheat, when beginning to vegetate, magnified; wherein may be feen the formation of the future ear of wheat.

Fig. 7. A young plant of wheat taken out of the ground.

Fig. 8. The young ear of wheat, in this plant, magnified.

Fig. 9. A piece of ftraw cut tranfverfely, and magnified.

Fig. 10. The fame viewed in an upright pofition.

Fig. 11. One of the membranes in a grain of wheat, in which the globules of meal or flour are contained.

Fig. 12. A grain of common fcouring fand, magnified, to

give an idea of the ſize of the globules of flour; *fig.* 13 being ſome of thoſe globules lying near the grain of ſand.

Fig. 14. A grain of wheat, ſhewing at P Q, the place from whence the ſlice was cut, which is deſcribed in the next figure.

Fig. 15. A ſlice cut tranſverſely from a grain of wheat, and magnified, to ſhew the nature and uſe of the chink, or crevice, in grains of wheat.

Fig. 16. Globules of meal, viewed by a very deep magnifier.

Fig. 17. Appearance of the globules after being boiled.

Fig. 18. Appearance of the globules in a piece of bread.

PLATE VII.

Fig. 1. A piece of the wood of the cocoa tree, drawn ſmaller than the natural ſize.

Fig. 2. A very ſmall particle of the wood, cut tranſverſely, and magnified.

Fig. 3, 4, 5, 6. Different views, as ſeen through the microſcope, of the internal texture of this wood.

Fig. 7. A cocoa nut, with its external caſe or covering, drawn on a ſcale reduced from the ſize of the original.

Fig. 8, 9. Views, taken from the microſcope, of the fibres or filaments compoſing the external coat of the nut.

Fig. 10. A piece of the hard ſhell, cut tranſverſely and magnified.

Fig. 11. The kernel of the cocoa nut incloſed in the ſhell.

Fig. 12. A tranſverſe ſection, ſeen through the microſcope, of the tube, which conveys nouriſhment to the nut.

Fig. 13. A piece of the kernel in the place where the young plant is ſituated, its natural ſize.

Fig. 14. A piece of the ſkin incloſing the young plant, cut tranſverſely, and magnified.

Fig. 15, 16, 17. Different views of ſlices cut tranſverſely from the young plant and magnified.

PLATE VIII.

Fig. 1. The natural ſize of the cryſtalline humour in an Ox's eye.

Fig. 2, 3. Figures to ſhew the nature of the filaments or fibres compoſing the ſurface of the cryſtalline humour.

Fig. 4, 5. Views of the diſpoſition of the filaments in the cryſtalline humour in the eye of an hare or rabbit.

Fig. 6. Filaments in the cryſtalline humour in the eye of a Cod.

Fig. 7. The natural ſize of the cryſtalline humour in this eye.

Fig. 8, 9. The ſhape of the cryſtalline humour in the eyes of birds, which is oblong, whereas in fiſhes it is round.

Fig. 10. A figure, illuſtrating the deſcription of the human eye, which is introduced into this work by the Tranſlator, from "Adams's Eſſay on Viſion."

Fig. 11. A tranſverſe ſlice from an ox's tongue, magnified.

Fig. 12. The natural ſize of the piece.

Fig. 13. Another piece of the tongue cut or ſtripped longitudinally, and magnified.

Fig. 14. A ſmall fragment of the fleſhy part of a duck's heart, as ſeen through the microſcope.

Fig. 15. A repreſentation of another piece, leſs magnified than the former, the natural ſize of which is ſhewn at X.

PLATE IX.

Fig. 1. A common gooſe quill, ſmaller than the natural ſize.

Fig. 2. A ſmall piece of the feather of this quill, as ſeen through the microſcope.

Fig. 3, 4. Small pieces ſtripped from this feather, and ſtill farther magnified.

Fig. 5, 6, 7, 8. Different views of an hog's briſtle, cut tranſverſely, and magnified.

Fig. 9. Two human hairs taken from the hand, magnified.

Fig. 10. Another hair, taken from the arm.

Fig. 11. A ſingle thread of white ſheep's wool, magnified, and appearing to be compoſed of many ſmaller filaments.

Fig. 12. Another view of the ſame.

Fig. 13. A piece of human hair, broken or fretted at the end.

Fig. 14. A cutting from the author's beard, magnified.

Fig. 15, 16. Different parts of the feather on a common gooſe quill, as deſcribed by Dr. Hook, in his Micrographia.

Fig. 17. The briſtle of an hog, deſcribed by the ſame author, as viewed by his microſcope.

PLATE X.

Fig. 1. A glaſs tube, uſed by the author to prove the effect of the effluvia of the Nutmeg on the bodies of mites.

Fig. 2. The young plant taken out of the nutmeg and magnified.

Fig. 3. Part of the leaf of this young plant, magnified ftill more.

Fig. 4. Part of the root of the nutmeg tree, cut tranfverfely.

Fig. 5. A fmall piece of the wood, cut tranfverfely, and which at *fig.* 6, is feen drawn from the microfcope.

Fig. 7. Another fmall piece of the wood, cut in the fame direction, and ftill farther magnified.

Fig. 8. A piece cut lengthways, and magnified.

Fig. 9. Another piece, viewed in a different pofition.

Fig. 10, 11, 12. Different views of the minute tubes in this wood, magnified.

Fig. 13. An aurelia, or grub, found among mace newly imported from India.

Fig. 14. The flying infect produced from this aurelia.

Fig. 15. The natural fize of a minute maggot, which feeds on the oily fubftance in the leaves of Mace.

Fig. 16. Part of a leaf of mace, fhewing the opening made by this maggot, and the appearance of the leaves when injured by it.

Fig. 17. A Nutmeg inclosed in its fhell, and covered with the leaves of mace.

Fig. 18. The fhell wherein the nutmeg is inclofed, opened on one fide, to fhew the ligament whereby the nut is nourifhed.

Fig. 19. A flice of this ligament, cut tranfverfely, as viewed through the microfcope, fhewing the many veffels it contains.

Fig. 20, 21. The bark, or fhell of the nutmeg, broken in two pieces, and feen on oppofite fides.

Fig. 22. The nut itfelf.

Fig. 23. A drawing from the microfcope, of the maggot, which at *fig* 15. is fhewn of its natural fize.

Fig. 24. A flying infect produced from this maggot, magnified.

Fig. 25. One of its wings, magnified.

PLATE XI.

Fig. 1. A piece of Elm, cut tranfverfely, magnified from the natural fize fhewn at E.

Fig. 2. A piece of the fame wood, cut longitudinally.

Fig. 3. Spots on the membranes, compofing the veffels in this wood, as they appear through the microfcope.

Fig. 4. A piece of Beech, cut tranfverfely, magnified from the natural fize fhewn at F.

Fig. 5. A piece, cut longitudinally, and magnified.

Fig. 6. A piece of willow, cut tranſverſely, and magnified ; the natural ſize of it is ſhewn at F, *fig*. 6.

Fig. 7. A piece of the ſame wood, cut longitudinally.

Fig. 8. A particle of alder, the natural ſize of which was the thickneſs of an hog's briſtle.

Fig. 9. A piece of the ſame wood, cut in a contrary direction.

Fig. 10. A particle of ebony, greatly magnified: this to the naked eye appeared no larger than a grain of ſand.

Fig. 11. Another particle, cut longitudinally to ſhew the different veſſels.

Fig, 12. One of thoſe veſſels, ſtill farther magnified.

Fig. 13. A piece of box wood, drawn from the ſame magnifier.

Fig. 14. Another piece, cut in a different direction.

Fig. 15. A piece of Lime-tree, cut tranſverſely.

Fig. 16. A piece of the ſame, cut longitudinally.

PLATE XII.

Fig. 1. An ant's egg, magnified, the natural ſize of which was not ſo large as a grain of ſand.

Fig. 2. The ſame laid open, ſhewing the young maggot.

Fig. 3. Another, ſhewing the maggot in a more advanced ſtate.

Fig. 4. The maggot, completely formed.

Fig. 5. The maggot viewed by a deeper magnifier.

Fig. 6. The ſting of the ant, magnified.

Fig. 7. The natural ſize of the ants bred from theſe maggots.

Fig. 8. The forceps, or fang of the Millepeda Indica, or thouſand legs, from India, taken out of the body and magnified.

Fig. 9. The Indian Millepeda, of its natural ſize.

Fig. 10. A worm or maggot, bred from the egg laid by the Flea, as ſeen through the microſcope.

Fig. 11. The egg of the Flea, with the worm in it, magnified from its natural ſize, which was no larger than a ſmall grain of ſand.

Fig. 12. The ſhell of the egg, after the worm had quitted it.

Fig. 13. A cryſalis, into which the maggot is changed.

Fig. 14. The ſkin left by the maggot when it changes.

Fig. 15. The cryſalis, in a more advanced ſtate of growth.

Fig. 16. The Flea, completely formed.

Fig. 17. A part of the flea's head, with its two horns, and the ſheath which contains the piercers.

Fig. 18. The ſheath, ſeparated from the two piercers, which are ſeen joined in one, at K.

Fig. 19. The two ſtings, or piercers, ſeparated at O N.

Fig. 20. One of the hind legs of the flea, greatly magnified.

Fig. 21. The head and (*fig.* 22.) the tail of the maggot's body, farther magnified than they appear in *fig.* 10.

Fig. 23. The glaſs wherein the Author incloſed the fleas for obſervation.

PLATE XIII.

Fig. 1. A ſeed of the aſh, its natural ſize.

Fig 2. The ſhell or pod which contains this ſeed, laid open, and the ſeed taken out, to ſhew the ligament or ſtring through which it received its nouriſhment.

Fig. 3. The young plant in this ſeed, magnified.

Fig. 4. A piece of the ſtem, cut tranſverſely, at the place marked B G in the laſt figure, and drawn from a deeper magnifier, to ſhew the veſſels it contains.

Fig. 5, 6. The leaves of the young plant in a walnut, magnified.

Fig. 7. A figure, to illuſtrate the Author's reaſoning upon the manner in which veſſels in plants receive their nouriſhment.

Fig. 8. The young leaves in the ſeed of an almond, magnified.

Fig. 9, 10. The ſame, in the kernels of a cherry and an apple.

Fig. 11. The filberd, taken out of its ſhell, to ſhew the ligament by which it was nouriſhed.

Fig. 12. The internal make of theſe ligaments deſcribed.

Fig. 13. A filberd, drawn ſomewhat larger than the natural ſize, to ſhew more plainly the manner of its growth.

Fig. 14. A ſlice, cut tranſverſely from the ligament of an almond, and magnified.

Fig. 15. The ſeed of the willow, its natural ſize.

Fig. 16, 17. Figures, to ſhew the nature and uſe of the cotton which incloſes this ſeed.

Fig. 18. A ſingle dry ſeed of the willow, magnified.

Fig. 19. The ſame ſeed, after being placed in moiſt ſand thirty-ſix hours, and beginning to vegetate.

Fig. 20. A cheſnut, broken in half, to ſhew the young plant at A.

Fig. 21. A cheſnut, in a ſtate of vegetation.

Fig. 22. A walnut, before it begins to vegetate.

Fig. 23. A walnut, in a ſtate of vegetation.

Fig. 24. The ſeed of the cotton, entirely conſiſting of a young

plant, and leaves clofely folded round it, which are here fhewn, laid open, and magnified.

Fig. 25. A flice, cut tranfverfely from this young plant, and drawn from a deeper magnifier, to fhew its veffels.

PLATE XIV.

Fig. 1. The tunica cornea of a beetle's eye, magnified, fhewing the number of eyes it contains.

Fig. 2. Two optic nerves taken out of the head of a large fly, as they appear through the microfcope.

Fig. 3. Seven of the fame nerves.

Fig. 4. A great number of the fame nerves, heaped together.

Fig. 5. The brain, taken out of the head of a gnat, magnified.

Fig. 6. One of the hairs on the foot of a crab, magnified.

Fig. 7. S T, part of the fame hair, viewed in another pofition.

Fig. 7. A B C D E F, a fmall crab, in the hind feet of which the circulation of the blood was feen by the Author.

Fig. 8. A willow leaf, on which a fmall maggot is bred.

Fig. 9. The fly, which lays the eggs from which thofe maggots are produced, of its natural fize.

Fig. 10, 11, 12, 13. Different parts of the fting with which this fly pierces the willow leaf, to lay its eggs, magnified.

Fig. 14. A minute maggot, which preys on thefe maggots.

Fig. 15. The aurelia of the maggot, on the willow, magnified.

Fig. 16. An animalcule, found in frefh water, as feen through the microfcope.

Fig. 17, 18. Different parts of its limbs, farther magnified.

Fig. 19, 20, 21. 22. Glafs tubes, ufed by the author, in making experiments on the properties of the Loadftone.

Fig. 23. A piece of the fhell of a feed of the fig, magnified.

Fig. 24, 25. The young plant, taken out of this feed.

Fig. 26. The young plant taken out of one of the feeds on a ftrawberry, magnified.

PLATE XV.

Fig. 1. One of the fibres, compofing the flefh of an Ox, the natural fize of which was no more than the fourth part of an hair, but which when viewed by the microfcope, appeared to be compofed of many fmaller fibres, filaments, or threads.

Fig. 2. A fibre expanded, to fhew its component filaments.

Fig. 3. Minute Eels, diſcovered by the microſcope, whoſe bodies are ſmaller than theſe filaments,

Fig. 4. One of the fiſhy fibres in a Cod fiſh, magnified.

Fig. 5. A fleſhy fibre in the hind leg of a dog, magnified.

Fig. 6. A figure, to illuſtrate the Author's reaſoning on the ſubject of theſe fibres.

Fig. 7. Fragment of a fleſhy fibre in the breaſt of a flea.

Fig. 8. Appearance of the ſcales which cover the ſurface of the human body, viewed by an ordinary magnifier.

Fig. 9. One of thoſe ſcales, viewed by a deep magnifier.

Fig. 10, 11. Different views of theſe ſcales, magnified.

Fig. 12, 13. Scales, taken from the lips, magnified.

Fig. 14. A ſmall particle of an ox's thigh-bone, fixed on the point of a needle, E F G, and drawn from the microſcope.

Fig. 15. The natural ſize of this piece of bone.

Fig. 16. A B C, different views, drawn from the microſcope, of the calcareous ſubſtance, called chalk-ſtones, in a gouty perſon.

Fig. 17. The appearance of this ſubſtance when boiled in water, and ſpread upon a glaſs before the microſcope.

Fig. 18, 19, 20. Views, from the microſcope, of the different ſalts found in this ſubſtance, after being expoſed to a ſtrong heat.

Fig. 21, 22, 23, 24, 25. Views, from the microſcope, of the different ſalts found in the ſubſtance, compoſing the ſtones in the bladder, after it had been expoſed to the fire.

Fig. 26. A ſmall particle of one of theſe ſtones, magnified.

Fig. 27. The real ſize of the ſame particle.

Fig. 28, 29, 30. Glaſſes, uſed by the author, in his experiments on the exploſion of Gunpowder.

PLATE XVI.

Fig. 1. The head of a Louſe, magnified.

Fig. 2. The fore-part of the louſe's head, farther magnified, to ſhew the piercer, or organ, with which it ſucks the blood.

Fig. 3. The ſheath of this piercer taken out of the head, with the ſting or piercer, L M.

Fig. 4, 5. Views of the ſting which the male louſe carries in its tail, drawn from the microſcope.

Fig. 6. One of the ſix feet of the louſe, magnified.

Fig. 7, 8. The louſe's egg, (commonly called a nit) fixed to a hair, as ſeen through the microſcope.

Fig. 9. A mite's egg, magnified.

Fig. 10. A mite, as ſeen through the microſcope.

Fig. 11. A maggot, which feeds on the graſs in meadows.

Fig. 12. The maggot, changed into an aurelia, or grub.

Fig. 13. The ſkin, put off by the maggot, on its change.

Fig. 14, 15. The male and female flying inſects, produced from this maggot.

Fig. 16. A flying inſect, that lays its eggs in the bloſſoms of fruit trees.

Fig. 17. Part of the head of this inſect, magnified, ſhewing the organ with which it pierces the buds.

Fig. 18. A ſide view of this organ.

Fig. 19. A ſmall part of one of the legs of this inſect.

Fig. 20. A cryſalis, or grub, found on apple-trees.

Fig. 21. The flying animal produced from this grub.

Fig. 22. A ſmall ſpecies of fly, its natural ſize.

Fig. 23. One of the wings of this fly, magnified.

Fig. 24. The head of the ſame fly, magnified.

Fig. 25. Another ſpecies of ſmall fly, its natural ſize.

Fig. 26. One of the wings of this fly, magnified.

Fig. 27. One of its two horns.

Fig. 28. The natural ſize of an animalcule, which infeſts the young ſhoots of fruit-trees, particularly gooſeberries and currants.

Fig. 29. The ſame animal, as ſeen through the microſcope.

Fig. 30. The ſame animalcule, changed into a fly.

Fig. 31. One of the young of this animalcule taken out of the parent's body, and magnified.

Fig. 32. Eight of the ſame young, magnified.

Fig. 33. A B, one of the eyes of this animalcule, greatly magnified, conſiſting of many eyes, or optical organs.

Fig. 34. An animalcule, found in the ſediment in gutters on the roofs of houſes, as it appears through the microſcope.

Fig. 34. A B C D E F G, another of theſe animalcules, magnified, ſhewing the manner in which they move from place to place.

Fig. 35. A ſtill ſmaller animalcule, obſerved in the water which contained the former ones.

PLATE XVII.

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Fig. 2 to 13. A particular reprefentation of the Author's apparatus for viewing the circulation of the blood in the tail of an eel, and likewife in the tails and fins of other fifhes.

Fig. 14, 15, 16, 17. Various minute blood-veffels in the tails and fins of fifhes, magnified; in which different appearances of the circulation were difcovered by the author.

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Fig. 21. The young animal, fully formed in the egg.

Fig. 22, 23. Views of the fame animal, after it had quitted the egg, magnified.

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Fig. 25. A figure, to illuftrate a particular appearance, noticed by the Author in the circulation of the blood, in an artery.

Fig. 26, 27, 28, 29. Particles in the blood of different fifhes, as feen through the microfcope.

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PLATE XVIII.

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Fig. 7. The fheath and fting of the Gnat, as feen by Mr. Leeuwenhoek through his microfcope.

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Fig. 17. One of the feathers on a Gnat, magnified.

Fig. 18. The natural fize of the wing of a gnat.

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Fig. 21. A maggot, bred from the egg, laid by the common Fly.

Fig. 22. The cryſalis, into which this maggot changes.

Fig. 23. The common Fly, of its natural ſize.

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Fig. 37. A minute ſea-ſnail, found in the ſtomach of a ſhrimp, and magnified.

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Fig. 39. The receptacle of the eggs, its natural ſize.

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PLATE XIX.

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Fig. 3 to 7. The different ſaline particles extracted from pepper, as ſeen through the microſcope.

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Fig. 11 to 15. Saline particles, extracted from Tea, magnified.

Fig. 16 to 22. Saline particles in Cantharides, magnified.

Fig. 23. The young plant in a grain of Rye, magnified.

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Fig. 25. The young plant, taken out of a grain of Buck-wheat, moderately magnified, to ſhew the root and leaves found in it.

Fig. 26. A ſlice of the ſame ſeed, cut tranſverſely, ſhewing the curious manner in which the leaves are diſpoſed.

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Fig. 28, 29. The young plant in this ſeed, magnified.

Fig. 30. The tobacco feed in a ftate of vegetation, after being four days in moift fand, as it appeared through the microfcope.

Fig. 31. A branch of currants in the bud, magnified.

Fig. 32. A piece of bulrufh, the natural fize.

Fig. 33. One of the tubes it contains, with its valves.

Fig. 34. The appearance of thefe tubes and valves, as feen through the microfcope.

Fig. 35. One of the fmall veffels in a rufh, farther magnified.

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Fig. 37. A fmall portion of a nerve, magnified.

Fig. 38. Several nerves, magnified, adjoining each other.

Fig. 39. A fmall portion of the fpinal marrow, magnified.

PLATE XX.

Fig. 1. Reprefentation of a glafs invented by the Author for extracting air out of water and other liquors.

Fig. 2. The plug or pifton ufed with this tube,

Fig. 3. A glafs globe and apparatus invented by the Author, to illuftrate his opinion refpecting the earth's diurnal motion

Fig. 4 to 8. Figures to illuftrate fundry pofitions laid down by the Author, refpecting the circulation of the blood in an human body.

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Fig. 12. A fmall part of the eye of the libella, or dragon fly, as feen through the microfcope.

Fig. a. A fmall particle of phofphorus, fhewing the manner in which its light appeared to be emitted, when viewed through the microfcope.

Fig. b c d e. Glafs tubes ufed by the Author in his examination of phofphorus.

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Plate I

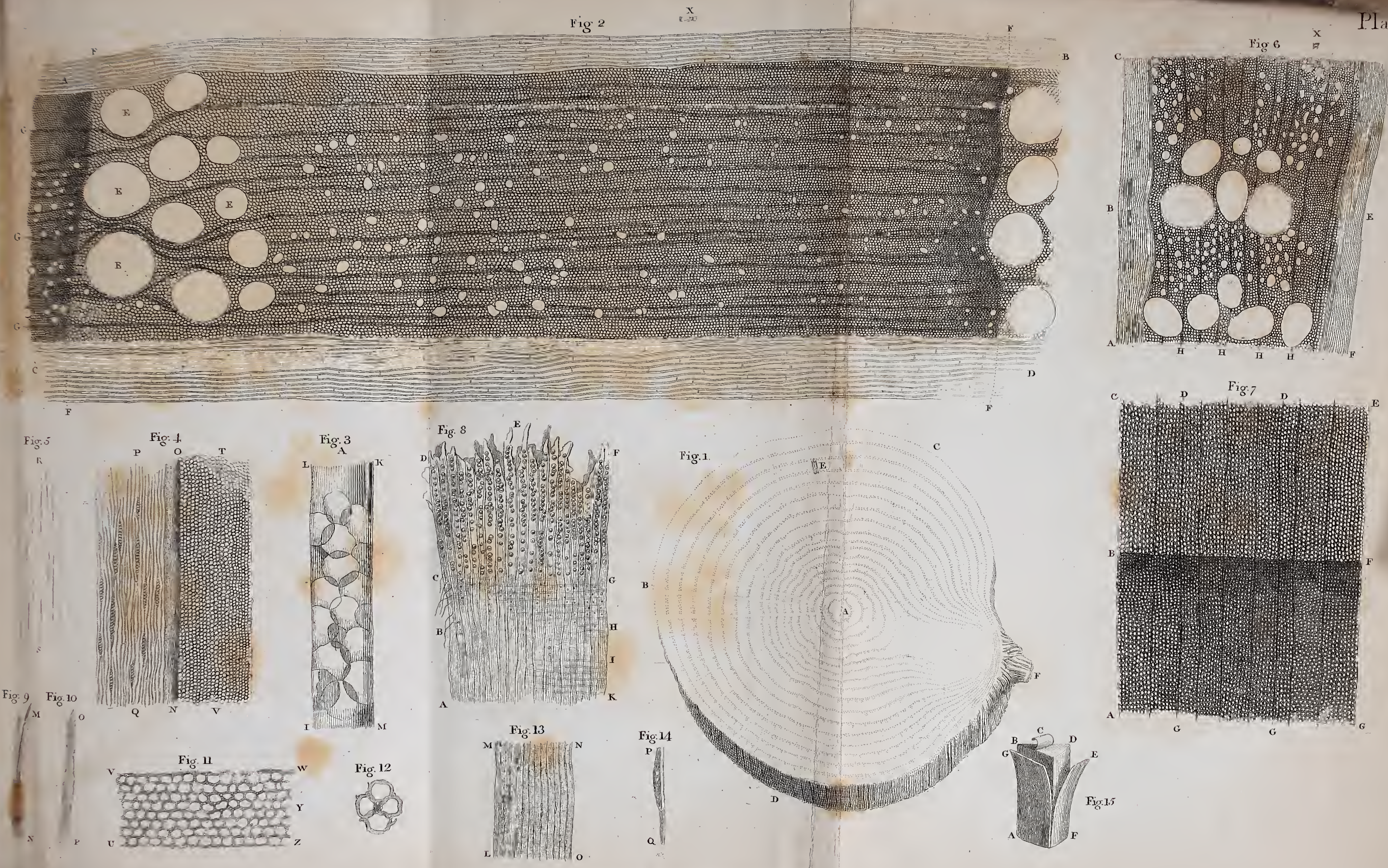
Fig. 1.
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Plate II.


Fig. 1
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Fig. 38

Plate III.


Fig. 1.
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Fig. 16.

Plate IV

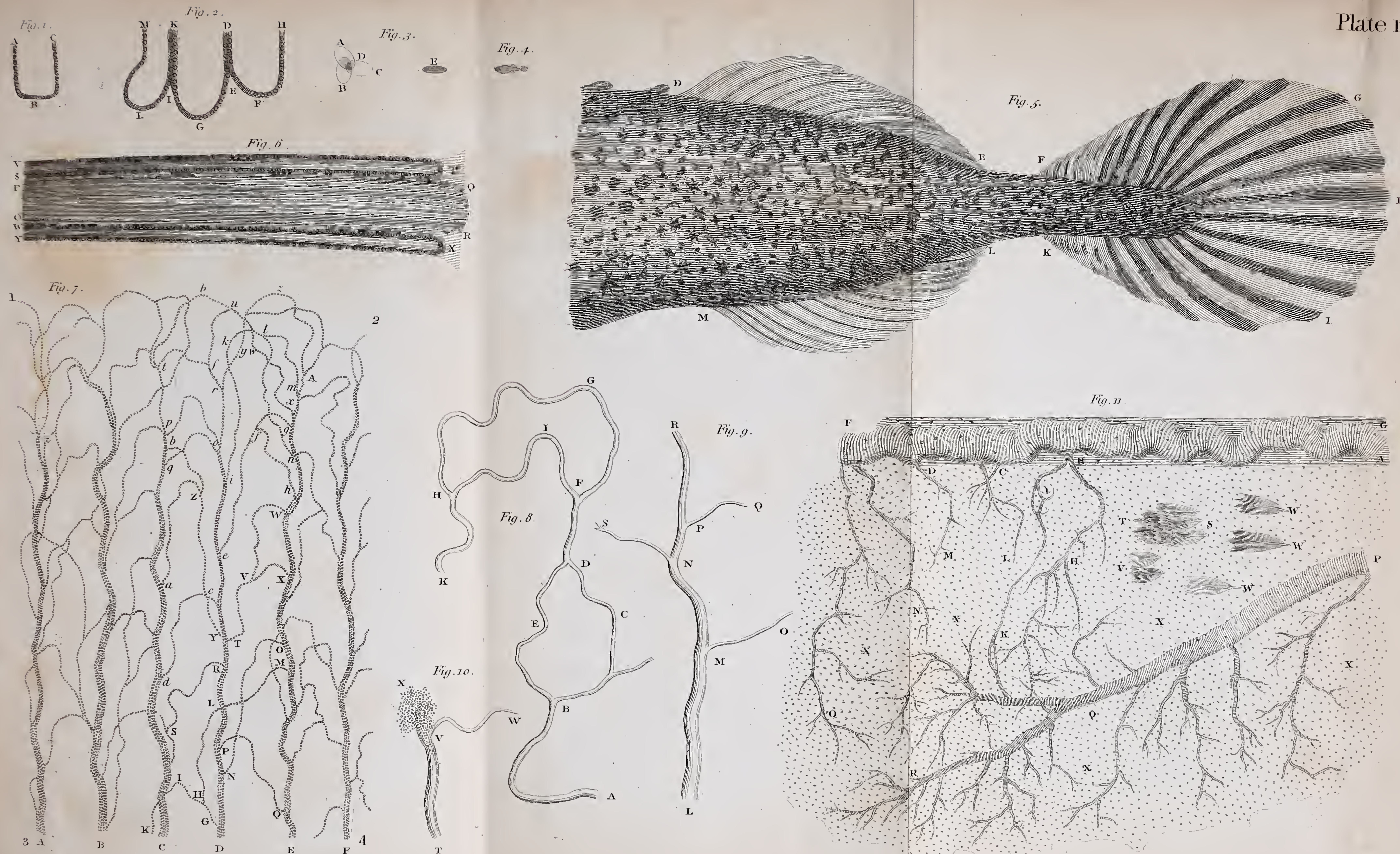

Plate V

Fig: 1
Fig: 2
Fig: 3
Fig: 4
Fig: 5
Fig: 6
Fig: 7
Fig: 8
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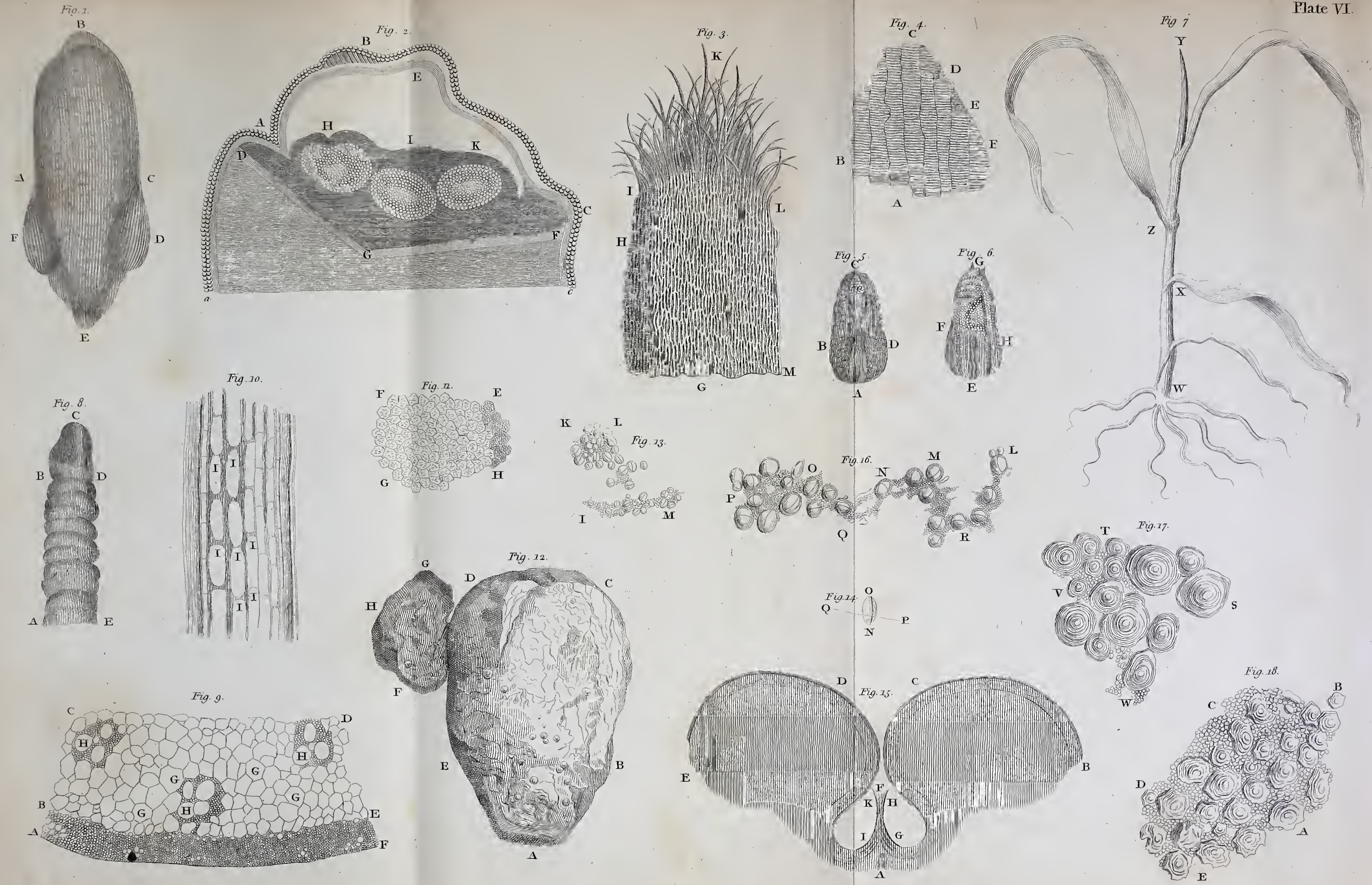
Plate VI.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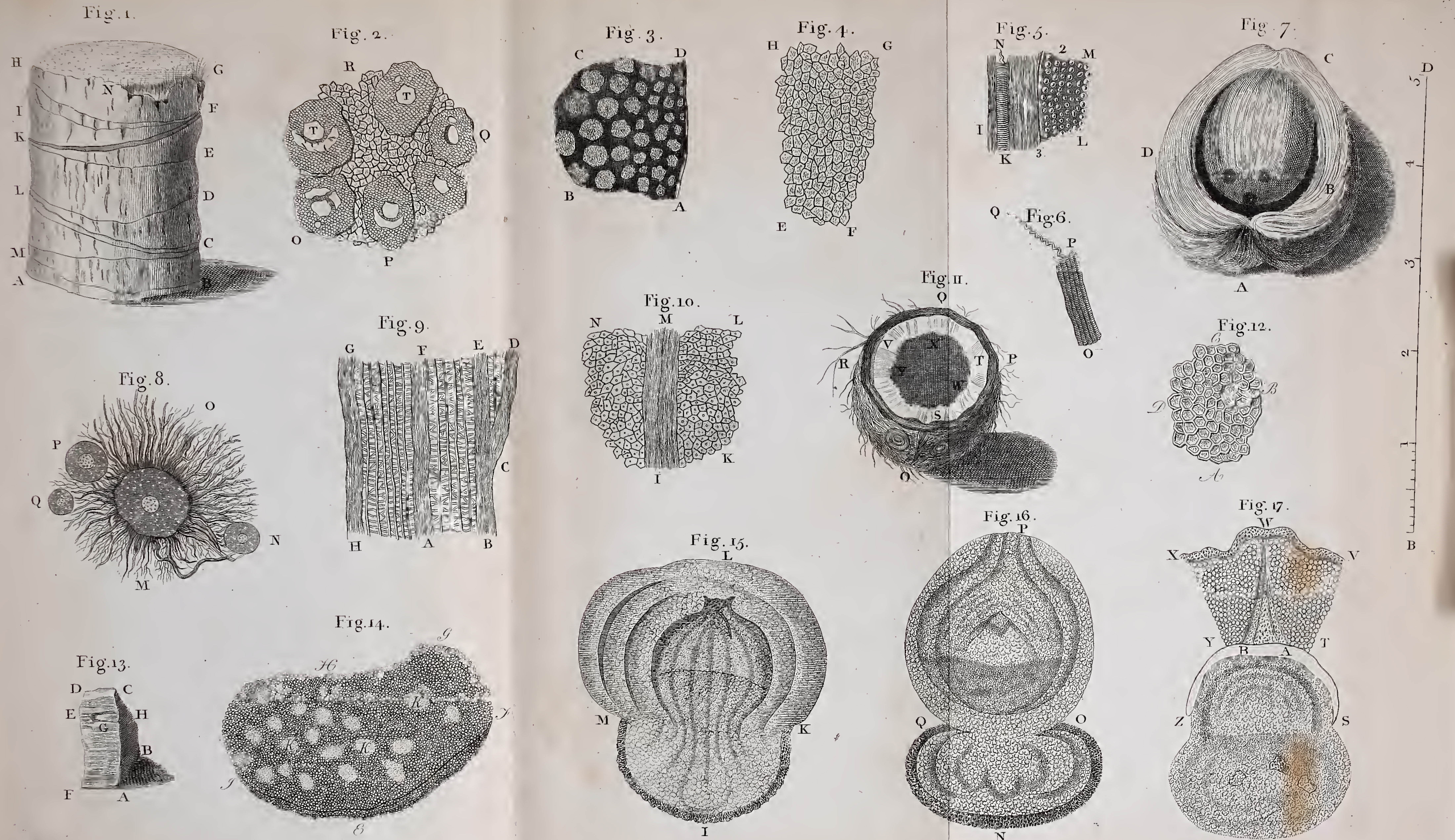
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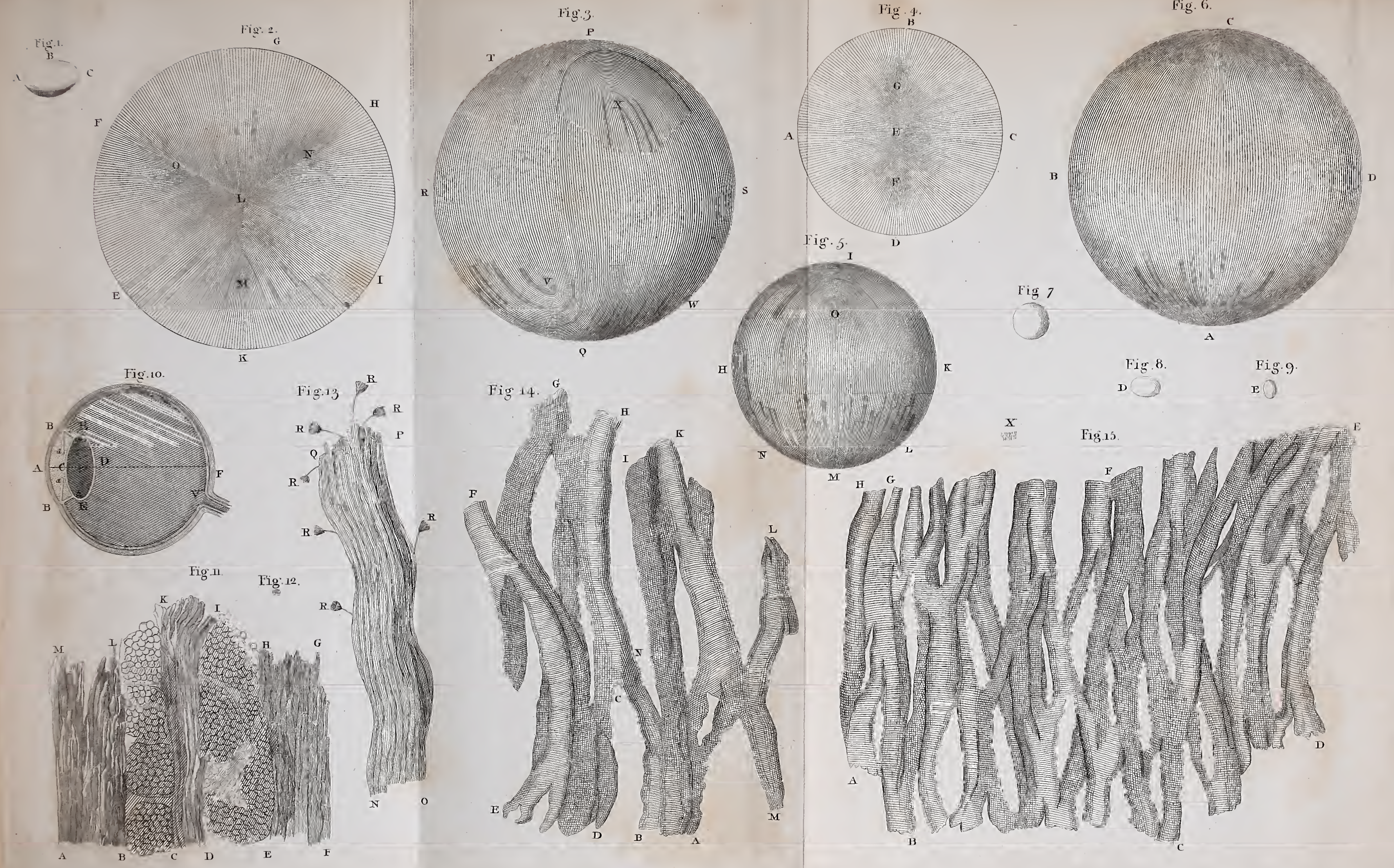
Plate VIII.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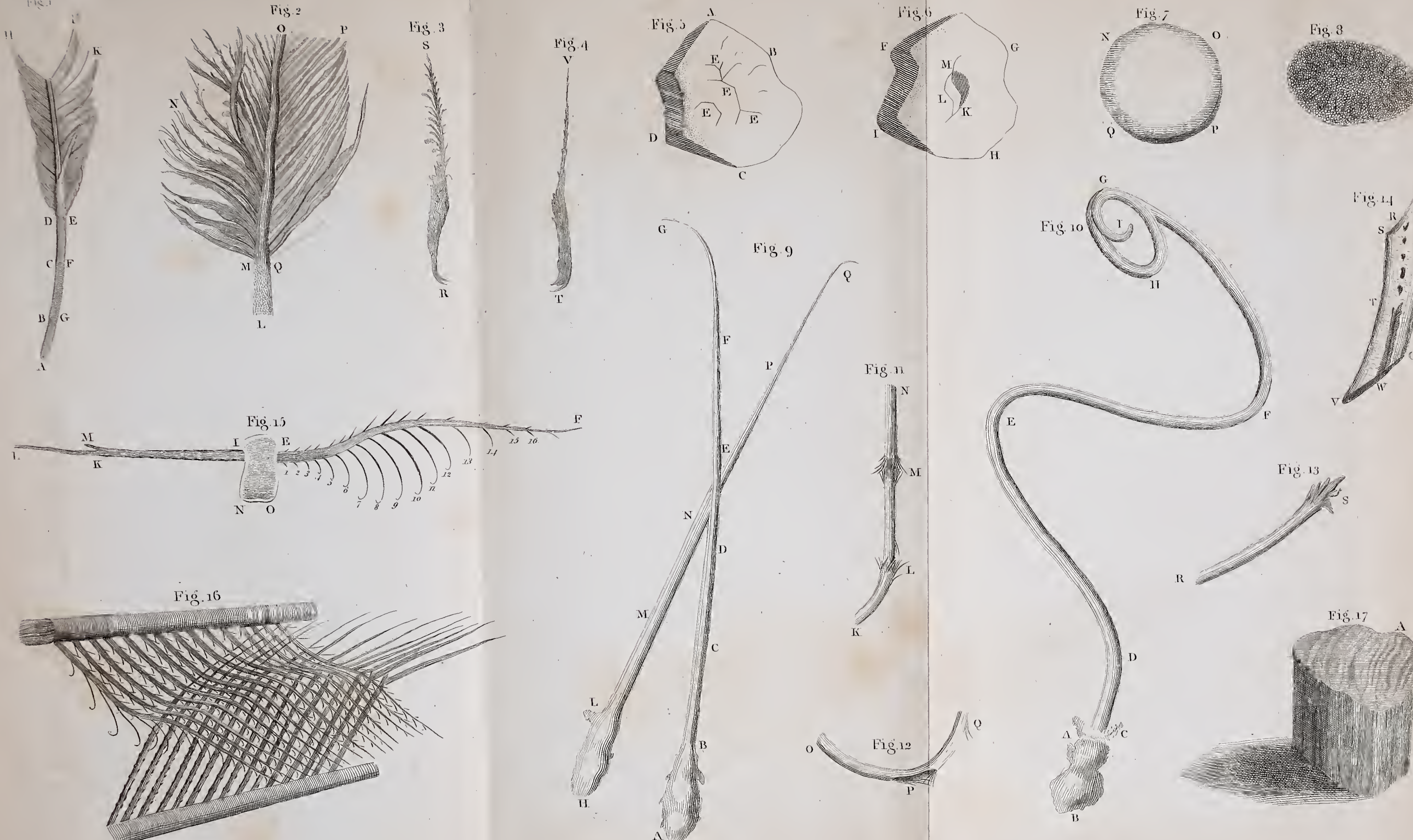
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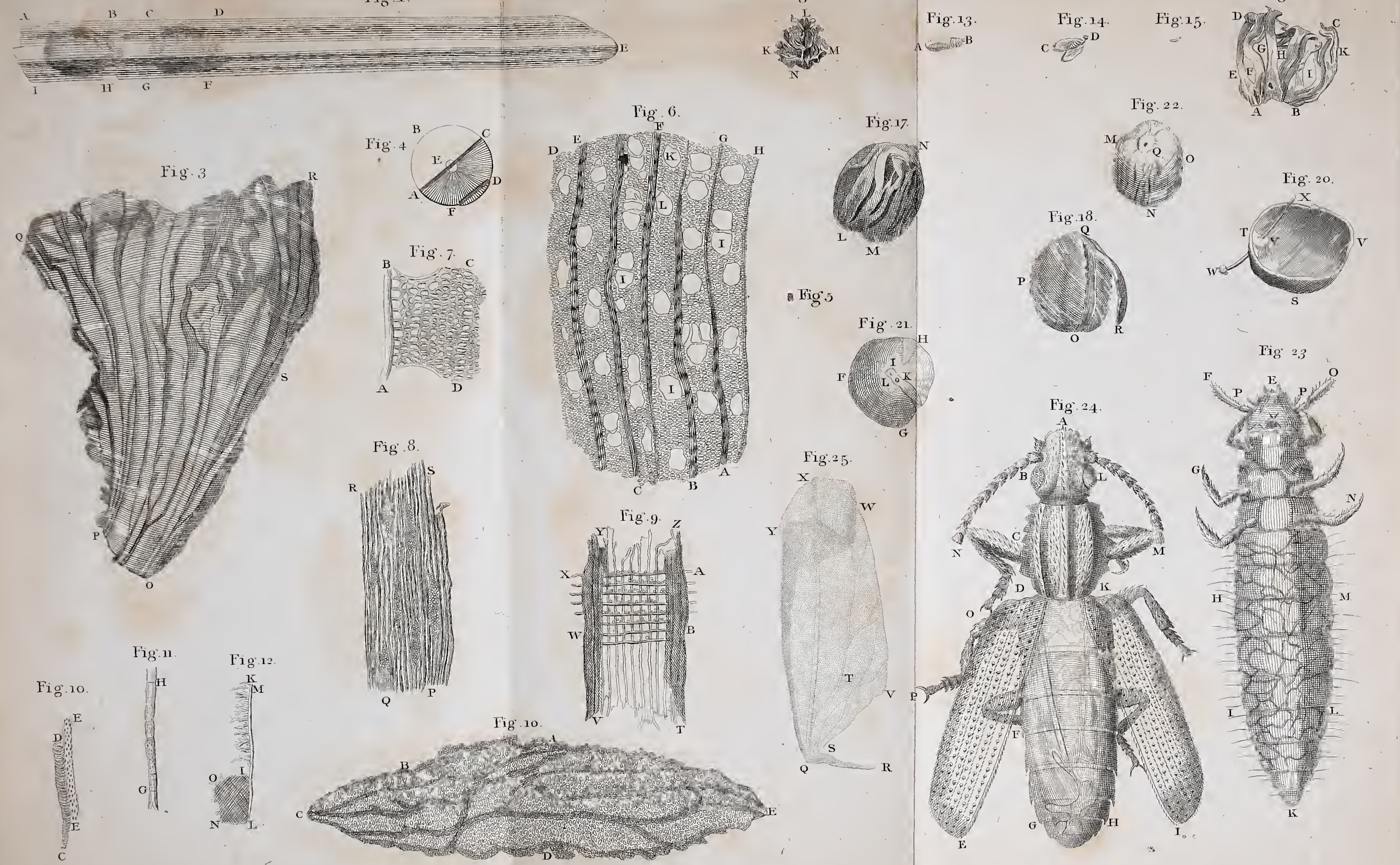
Plate, X.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