

The ingenious Author propofes, in the Sequel of this Work, to give an Account of new Plants only, or at leaft fuch as have not been well figured by others : If he proceeds with the fame Exactnefs, as I don't doubt he will, the Work very well deferves Encouragement ; for of Plants thus figured and defcribed, there can be no future Doubts.

Happy had it been for us, had the Antients left fuch Types or Descriptions of thofe they recommended as confiderable for their Ufe in Medicine. This would have faved the Learned World much Labour and Study in an Enquiry, which 'tis to be feared, for want of fuch Helps, will prove unfeceffful.

III. *An Attempt to folve the Phænomenon of the Rife of Vapours, Formation of Clouds and Defcent of Rain. In a Letter from Dr. J. T. Defaguliers, L. L. D. F. R. S. to Dr. Ruty, R. S. Secr.*

S I R,

THE Reason of my writing upon a Subject which has been fo often treated of, is, that none of the Accounts hitherto given of this *Phænomenon* (at leaft that I have met with) feem to me fufficient to folve all the Circumftances of it.

Dr. *Niewentyt* and fome others fay — That Particles of Fire feperated from the Sun-Beams, by adhering to Particles of Water, make up *Moleculæ*, or fmall Bodies fpecifically lighter than Air, which therefore, by hydroftatical Laws, muft rife and form Clouds that remain fufpended when they are rifen up to fuch an  
Height

Height that the Air about them is of the same specific Gravity with themselves. —

That Rain is produced by the Separation of the Particles of Fire from those of Water, which last being then restored to their former specific Gravity, can no longer be sustained by the Air, but must fall in Drops. See *Niewentyt's Religious Philosopher*. Contemplation 19. From Sect. xiii. to Sect. xxv.

Now this is liable to several Objections, *First*, It is built upon a Supposition that Fire is a particular Substance, or distinct Element, which has never yet been prov'd by convincing Experiments and sufficient Observations; and which the Reverend Mr. *Hales* has in his late excellent Book of *Vegetable Statics* shewn to be an ill grounded Opinion, making it very plain, that in Chymical Operations those Bodies which had been thought to become heavier by Particles of Fire adhering to them, were only so by Adhesion of Particles of Air, &c. which he has shewn to be *absorbed* in great Quantities, by some Bodies, whilst it is *generated* (or reduced from a fixt to an elastick State) by others; nay, that it may be *absorbed* and *generated* successiive by the same Body, under different Circumstances.

*Secondly*, If we should allow the above-mentioned Supposition, the Difficulty will still remain about the Production of Rain by the Separation of the Fire from the Water; For Dr. *Niewentyt* ascribes this Effect to two different Causes. *First*, to Condensation (*Sect.* xxiii.) Saying, “That when contrary Winds blow  
“ against the same Cloud and drive the watery Particles together, the Fire that adhered to them gets  
“ loose, and they (becoming then specifically heavier)  
“ precipitate and fall down in Rain”. Then in the  
very

very next *Self*. he ascribes it to Rarefaction, when he says, “ That when a Wind blowing obliquely upwards  
 “ causes a Cloud to rise into a thinner Air (*i. e.* spe-  
 “ cifically lighter than it self ) the Fire which by  
 “ sticking to the Particles of Water rendered them light-  
 “ er, extricates it self from them, and ascending by its  
 “ Lightness, the Water will become too heavy, not  
 “ only to remain in this thin and light Air, but  
 “ even in a thicker and heavier near the Earth, and  
 “ so will be turned into a descending Dew, Mist, or Rain,  
 “ or Snow, or the like, according as the watery Va-  
 “ pours are either rarefied or compressed”.

The first of these Causes of Rain is contrary to Expe-  
 rience ; for when two contrary Winds blow against  
 each other over any Place of the Earth, the Barometer  
 always rises, and we have fair Weather. For then (as  
 Dr. *Halley* says, in Philosophical Transf. No. 183)  
 the Air being accumulated above, becomes specifically  
 heavier about the Clouds, which (instead of falling in-  
 to Rain, as Dr. *Niewentyt* supposes) ascend up into  
 such a Part of the Atmosphere, as has the Air of the  
 same specifick Gravity with themselves.

If the falling of Rain might be attributed to the se-  
 cond of these Causes, then every time a Cloud is encom-  
 passed with Air specifically lighter than it self (whe-  
 ther it be when by the blowing away some of the supe-  
 rior Air, that which is about the Cloud becomes ra-  
 rer as it is less compressed, or by the Cloud being dri-  
 ven upwards) Rain must necessarily follow ; whereas  
 one may often see the Clouds rise and fall without Rain,  
 even when the Barometer shews the Weight of the Air to  
 be alter'd. For that happens only when by the great  
 Diminution of the specifick Gravity of the Air about  
 the

the Cloud, it has a great Way to fall ; in which Case, the Resistance of the Air, which increases as the Square of the Velocity of the descending Cloud, causes the floating Particles of Water to come within the Power of each others Attraction, and form such big Drops, as being specifically heavier than any Air, must fall in Rain.

No gentle Descent of a Cloud, but only an accelerated Motion downwards, produces Rain.

N. B. *I don't mean that the quick Descent of a Cloud is the only Cause of Rain; because the Shock from a Flash of Lightning, and the sudden return of the Air, after the Vacuum made by the Flash, will condense the floating Vapour into Water; and also the same Cloud which in the free Air, might be carried horizontally without being turned into Rain, meeting with an high Hill in its Way, will be condensed and fall in Drops; especially if, in the Day-time, it be driven by the Wind out of the Sunshine, against the shaded Side of the Mountain.*

Besides all this, if Particles of Fire were joined with those of Water to raise them up, those igneous Particles must be at least 1000 Times greater in Bulk than the watry ones; so that a Person, who at the Top of a Hill, has his Hands and Face in a Cloud, must feel a very sensible Warmth, by touching a much greater Surface of Fire than Water in the Cloud, and afterwards find the Rain produced from that Vapour sensibly colder; whereas the contrary is proved by our Senses; the Tops of Hills, though in the Clouds, being much colder than the Rain at Bottom.

There is another Opinion concerning the Rise of Vapours, namely, that tho' Water be specifically heavier than Air, yet if its Surface be encreased by very much diminishing the Bulk of its Particles, when once raised, it cannot easily fall ; because the Weight of each Particle diminishes as the Cube Root of its Diameter, and the Surface to which the Air resists, only as the Square Root of the said Diameter : That we see this in the Dust in Summer, and in Menstruums that sustain Metals dissolved, which are specifically heavier than the Menstruums.

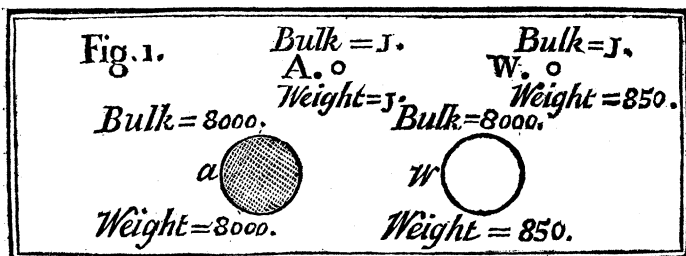
But this will not explain the *Phænomenon* ; because though the Encrease of Surface (the Weight remaining the same) will in a great Measure hinder (or rather retard) the Descent of small Bodies moving in the Air, by reason of its great Resistance to so large a Surface ; it will for the same Reason also hinder the Ascent. For the Rise of Dust is owing to the Motion of Animals Feet in it, or to the Wind : Whereas Vapours rise in calm Weather, as well as windy ; neither do they, like the Dust, always fall to the Ground when the Wind ceases to blow.

The third Opinion, and which is most commonly received, is, that by the Action of the Sun on the Water, small Particles of Water are formed into hollow Spherules filled with an *Aura*, or finer Air highly rarefied, so as to become specifically lighter than common Air, and consequently that they must rise in it by hydrostatical Laws. As for Example, If a Particle of Water, as it becomes a hollow Sphere, be only encreased ten Times in Diameter, its Bulk will be encreased a thousand Times ; therefore

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fore it will then be specifically lighter than common Water, whose specifick Gravity is to that of Air, as 850 to 1; then if the Density of the *Aura*, or Spirit within the little Shell, be supposed 9 Times less than that of Air, or as 50 to 850, that specifick Gravity of the Shell, and its Contents will be to that of Air, as 900 to 1000; therefore such an aqueous Bubble must rise till it comes to an *Æquilibrium* in Air, whose Density is to the Density of that in which it began to rise, as 850 to 945 nearly. But it appears by Experiments, that Air rarefied by an Heat which makes a Retort red hot, is only encreased in Bulk, or dilated 3 Times; by the Heat of boiling Water only  $\frac{1}{4}$  or near two Thirds; and by the Heat of the Humane Body (such as will raise Vapours plentifully) only  $\frac{1}{9}$  or about  $\frac{1}{5}$ . I own my Objection may be answered, by supposing the Spherule of Water to be more encreased in Diameter, as for Example 20 Times; because then if it be filled with Air only  $\frac{1}{7}$  rarer than common Air, it will be specifically lighter, and capable of rising to a considerable Height.

To give this Solution all its Force, let us express it in Numbers. Let A and W (*Fig. 1.*) represent



a Particle of Air, and one of Water of equal Bulk, then will the Weight of A be to the Weight of W as 1 to 850, their Bulks being equal. If the Particle of Water be blown up into a Bubble ( $w$ ) of 20 Times its Diameter, then will its Bulk be to its Weight, as 8000 to 850, whilst a Sphere of Air ( $a$ ) of the same Bigness, has its Weight as well as Bulk equal to 8000: Now if an Air or *Aura*  $\frac{1}{4}$  rarer than common Air be supposed within the watry Bubble to keep it blown, it will be the same as if  $\frac{1}{4}$  of the Air of ( $a$ ) was carried into ( $w$ ) and then the Weight of ( $w$ ) would be encreased by the Number 6000; so that the Shell of Water being in Bulk 8000, would be in Weight  $850 + 6000 = 6850$ , whilst an equal Bulk of Air weighed 8000, and consequently the watry Bubble would rise till it came to an Air, whose Density is to the Density of the Air next to the Surface of the exhaling Water as 6850 to 8000.

This is the strongest Way of stating the Hypothesis. But to support it, the following Queries must be answered.

*Query* 1st, How comes the *Aura*, or Air in the Bubbles, to be specifically lighter than the Air without them, since the Sun's Rays, which act upon the Water, are equally dense all over its Surface?

*Query* 2d, If it could be possible for a rarer Air to be separated from the denser ambient Air, to blow up the Bubbles (as Bubbles of soaped Water are blown up by warm Air from the Lungs, whilst the ambient Air is colder and denser) what would hinder that cold Air by its greater Pressure, from reducing the  
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the Bubbles to a less Bulk, and greater specifick Gravity than the Air, especially since Cold can be communicated through such thin Shells, and the Tenacity of common Water is very small when compared to that of soaped Water (whose Bubbles, notwithstanding that Tenacity) are soon destroyed by the Pressure of the outward Air, as the Air within them cools?

*Query* 3d, If we should grant all the rest of the Supposition, yet this Difficulty will remain. If Clouds are made up of hollow Shells of Water filled with Air, why do not those Clouds always expand when the ambient Air is rarefied, and presses less than it did before, and also suffer a Condensation, as the ambient Air is condensed by the Accumulation of the superiour Air?

If this Condensation and Rarefaction should happen to the Clouds, they would always continue at the same Height, contrary to Observation; and we shou'd never have any Rain.

*From all this it follows, that the Condensation and Rarefaction of the Vapours, which make Clouds, must depend upon another Principle than the Condensation and Rarefaction of the Air: And that there is such a Principle, I shall endeavour to shew.*



## L E M M A.

*The Particles of all Fluids have a repellent Force.*

**F**LUIDS are elastick or unelastick: The elastick Fluids have their Density proportionable to their Compression, and Sir *Isaac Newton* has demonstrated (*Princip. Lib. ii. Sect. v.*) that they consist of Parts that repel each other from their respective Centers. Unelastick Fluids, like Mercury, Water and other Liquors, are by Experiments found to be incompressible; for Water in the *Florentine Experiment* could not by any Force be compressed into less Room, but ooz'd like Dew through the Pores of the hollow golden Ball in which it was confined, when a Force was apply'd to press the Ball out of its spherical, into a less capacious Figure. Now this Property of Water and other Liquors must be intirely owing to the centrifugal Force of its Parts, and not its want of Vacuity; since Salts may be imbib'd by Water without encreasing its Bulk, as appears by the Encrease of its specifick Gravity. So Metals, which (singly) have a certain specifick Gravity beyond which they cannot be condens'd, will yet receive each other in their Interstices so as to make a Compound specifically heavier than the heaviest of them; as is experienced in the Mixture of Copper and Tin.

## S C H O L I U M.

By encreasing the repellent Force of the Particles, an unelastick or incompressible Fluid may become elastick, or a Solid (at least a great Part of it) may be changed into an elastick Fluid; and, *vice versâ*, by diminishing the repellent Force, an elastick Fluid may be reduc'd to an unelastick Fluid, or to a Solid. That the Particles of Quicksilver, Water and other Liquors are likewise endued with an attractive Force, is evident from those Substances running into Drops in an exhausted Receiver, as well as in the Air, and likewise their adhering to other Bodies. The Attraction and Repulsion exert their Forces differently: The Attraction only acts upon the Particles, which are in Contact, or very near it; in which Case it overcomes the Repulsion so far, as to render that Fluid unelastick, which otherwise would be so; but it does not wholly destroy the Repulsion of the Parts of the Fluid, because it is on Account of that Repulsion that the Fluid is then incompressible. When by Heat or Fermentation (or any other Cause, if there be any) the Particles are separated from their Contact, the Repulsion grows stronger, and the Particles exert that Force at great Distances, so that the same Body shall be expanded into a very large Space by becoming fluid, and may sometimes take up more than a Million of Times more Room than it did in a solid or incompressible Fluid. (See the *Queries* at the End of Sir *Isaac Newton's* Opticks.) Thus is Water  
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by boiling, and less Degrees of Heat, changed into an elastick Vapour rare enough to rise in Air, Oils and Quicksilver in Distillation made to rise in a very rare Medium, such as remains in the red-hot Retort, and sulphureous Steams will rise even in an exhausted Receiver, as the Matter of the *Aurora Borealis* does in the thinner Part of our Atmosphere. If Aqua-fortis be poured on Quicksilver, a reddish Fume will rise much lighter than common Air; so also will Fumes rise from Filings of Metals, from Vegetables when they ferment by Putrefaction; and (as the Reverend Mr. *Hales* has shewn) several solid Substances by distilling, as well as Fermentation, will *generate* permanent Air.

That Heat will add Elasticity to Fluids is evident from numberless Experiments, especially from Distilling and Chymistry: But what is needful to consider here is only, that it acts more powerfully on Water than common Air; for the same Heat which rarefies Air only  $\frac{2}{3}$  will rarefy Water very near 14000 times, changing it into Steam or Vapour as it boils it: And in Winter, that small Degree of Heat, which in Respect to our Bodies appears cold, will raise a Steam or Vapour from Water at the same Time that it condenses Air.

By a great many Observations made by Mr. *Henry Beighton*, F. R. S. and my self, upon the Engine to raise Water by Fire, according to Mr. *Newcomen's* Improvement of it; we found that the Water in boiling is expanded 14000 times to generate a Steam as strong (*i. e.* as elastick) as common Air, which therefore must be near  $16\frac{2}{3}$  times specifically

cifically lighter. And that this Steam is not made of the Air extricated out of the Water is plain, because it is condens'd again into Water by a Jet of cold Water spouting in it ; and the little Quantity of Air that comes out of the injected Water must be discharged at every Stroke, otherwise the Engine will not work well. There is also another Experiment to confirm this.

#### E X P E R I M E N T.

ABCD is a pretty large Vessel of Water, which must be set upon the Fire to boil. In this Vessel must be suspended the glass Bell E, made heavy enough to sink in Water ; but put in, in such a Manner that it be filled with Water when upright, without any Bubbles of Air at its Crown within, the Crown being all under Water. As the Water boils, the Bell will by Degrees be emptied of its Water, being press'd down by the Steam which rises above the Water in the Bell ; but as that Steam has the Appearance of Air, in order to know whether it be Air or not, take the Vessel off the Fire, and draw up the Bell by a String fasten'd to its Knob at Top, till only the Mouth remains under Water ; then, as the Steam condenses by the cold Air on the outside of the Bell, the Water will rise up into the Bell at F quite to the Top, without any Bubble above it, which shews that the Steam which kept out the Water was not Air.

*N. B. This Experiment succeeds best when the Water has been first purg'd of Air by boiling, and the Air-Pump.*

We know by several Experiments made on the Fire-Engine (in Captain Savery's Way, where the

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Steam

Steam is made to prefs immediately on the Water) that Steam will drive away Air, and that in Proportion to its Heat; though in the open Air it floats and riles in it like Smoak.

Now if the Particles of Water turn'd into Steam or Vapour repel each other strongly, and repel Air more than they repel each other; Aggregates of fuch Particles made up of Vapour and Vacuity may rife in Air of different Densities, according to their own Density dependant on their Degree of Heat, without having Recourfe to imaginary Bubbles form'd in a Manner only fuppofed, and not proved, as we have already fhewn. *I own indeed, that if the watry Particles had no repellent Force, they must precipitate in the same Manner that Dust will do after it has been raised up; but we have too many Observations and Experiments to leave any Doubt of the Existence of the repellent Force above-mentioned. Neither can I shew by any Experiment, how big the Moleculæ of Vapour must be which exclude Air from their Interstices, and whether those Moleculæ do vary in Proportion to the Degree of Heat by an Increase of repellent Force in each watry Particle, or by a farther Division of the Particles into other Particles still less; but in general we may reasonably affirm, that the Rarity of the Vapour is proportionable to the Degree of its Heat, as it happens in other Fluids (See Phil. Transact. Numb. 270.) and that, though the different Degrees of the Air's Rarefaction are also proportionable to the Heat; the same Degree of Heat rarefies Vapour much more than Air.*

Now to shew, that what has been said will account for the Rife of Vapours and Formation of Clouds,

Clouds, we must only consider ; — whether that Degree of Heat, which is known to rarefy Water 14000 \* Times, being compared with several of those Degrees of Heat in Summer, Autumn and Winter, which are capable of raising Exhalations from Water or Ice ; the Rarity of the Vapours (estimated by the Degree of Heat) will appear to be such, that the Vapour will rise high enough in Winter, and not too high in Summer, to agree with the known *Phænomena*.

*That the Effects are adequate to the Causes in this Case, I think I can make out in the following Manner, viz.*

The Heat of boiling Water, according to Sir *Isaac Newton's* Table (*Phil. Transact.* Num. 270) is 34, the mean Heat of Summer 5, the mean Heat of Spring or Autumn 3, and the least Degree of Heat, at which Vapours rise in Winter (*alias* the mean Heat of Winter) is 2. The Rarity of Vapour proportionable to these four Degrees of Heat, is 14000, 2058, 1235, and 823. The Rarity of Air is, in Summer 900, in Spring or Autumn 850, and in Winter 800, the Density of Water compared with the above-mentioned Densities, being inversely as *One* to the said fore-mentioned four Numbers. The Heights above the Earth to which the Vapours will rise, and at which they will be in *æquilibrio*, in an Air of the same Density with themselves, will vary according to the Rarity of the Vapour depending on the Heat of the Sea-

\* *As the Digression wou'd be too long to mention here those Observations on the Fire-Engine, which shew that the Vapour from boiling Water is expanded 14000 Times more than cold Water ; I refer the Reader to the 6th Section of 25th Contemplation of Niewentyt's Religious Philosopher, where he proves by an Experiment made with an Æolipile, that one Inch of Water produces 13365 Inches of Vapour ; which, considering the great Allowances made against the Assertion, may well be call'd 14000.*

son. For the Vapour which is raised by the Winter's Heat, expressed by the Number 2, when the Air's Rarity is 800, will rise to (and settle at) an Height of about the Sixth of a Mile, when the Barometer is above 30 Inches high. But if the Heat be greater then, the Vapours will rise higher, and pretty much higher if the Sun shines, though in frosty Weather, the Barometer being then very high. If the Barometer falls, and thereby brings the Place of *Æquilibrium* (for Vapours raised by the Heat 2) nearer the Earth, then also will the Heat be encreased, the Vapour more rarefied, and consequently the new Place of *Æquilibrium* sufficiently high. It is to be observed, that in Winter, when the Heat is only equal to 2, the Air is densest close to the Earth, which has not any Heat sufficient to rarefy it near the Ground, as happens in warm Weather; therefore the Vapour will rise gradually in an Air whose Density decreases continually from the Earth upwards; neither will the Vapour be hindered of its full Rise, by any Condensation from a greater Cold of the ambient Air, the Air being then as cold next to the Ground where the Vapour begins to rise, as it is at any Height from the Earth.

The Vapour which is raised by the Heat of Spring or Autumn expressed by Number 3, will rise to the Height of  $3\frac{1}{2}$  Miles, when the Barometer is at 30, and the Air's Rarity is 850. But then, as the Air is hotter nearer the Ground than at the Height of half a Mile or a Mile, the Vapour will condense as it rises; and as the Air, when the Earth is heated, is rarer near the Ground than at some Height from it, the Place of *Æquilibrium* for Vapour will, upon these

these two Accounts, be brought much lower than otherwise it would be ; as for Example, to the Height of about a Mile, which will agree with *Phænomena*.

In Summer, the two Causes above-mentioned encreasing, the Vapour raised by the Heat 5 ( whose Place of Æquilibrium would be  $5\frac{1}{2}$  Miles high, if the Vapour after it began to rise was not condensed by cooling, and the Air was densest close to the Earth ) will settle at the Height of about  $1\frac{1}{2}$  or 2 Miles, which is also agreeable to *Phænomena*.

*Lastly*, As the Density and Rarity of the Vapour is chiefly owing to its Degree of Heat, and in a small Measure to the encreased or diminished Pressure of the circumambient Air, when it is not confined ; and the Density and Rarity of the Air is chiefly owing to the increased or diminished Pressure, by the Accumulation or Exhaustion of superior Air, whilst Heat and Cold alter its Density in a much less Proportion ; the Clouds made of the Vapours above-mentioned, instead of conforming themselves to the altered Density of the ambient Air, will rise when it is condensed, and sink when it is rarefied ; and also rise or sink ( when the Pressure of the Air is not altered, and its Density very little changed ) by their own Dilatation, owing to Heat or Cold ; as may be observed often, by seeing them change their Height considerably, whilst the Barometer continues exactly at the same Degree, and the Thermometer's Liquor rises or falls very little, and sometimes not at all.

As for the Manner how Clouds are changed into Rain, I have hinted it in the Beginning of this Paper ; but for farther Satisfaction, I refer the Reader



to Dr. *Halley's* Account of it, in the *Philosophical Transactions* ( Numb. 183. ) in which I entirely acquiesce, having always found it agreeable to the *Phænomena*.

If by publishing these Thoughts, I have explained the Rise of Vapours, in a more satisfactory Way than has been done before; or if I have only given useful Hints to others more capable of doing it, I have my End.

P. S. Since I have, for Brevity sake, only mentioned at what Heights from the Surface of the Earth, Vapours of different Densities will come to an *Æquilibrium*, without giving a Reason for settling the Place of *Æquilibrium*, at those Heights; I think proper to give the Method here by which they are to be found, *viz.* As the Vapours will settle and rise where the Air is of the same Density with themselves; it is only required to find the Density of the Air at any Distance from the Earth, at several Heights of the Barometer, which may be deduced from Dr. *Halley's* two Tables, *Philosoph. Transact.* Num. 386. ( the First shewing the Altitude to given Heights of the Mercury, and the Second the Heights of the Mercury at given Altitudes ) and knowing the Degree of Heat by the Thermometer, because the Density of the Vapour depends upon the Degree of Heat of the Season; provided that proper Allowances be made for the great Rarefaction of the Air near the Earth in hot and dry Weather, and the Condensation of the Vapours in their Rise, by reason of the Air being colder at a little Height above the Earth than just at the Surface of it.

#### IV. *An Account of some Observations relating to Natural History, made in a Journey to the Peak in Derbyshire, by Mr. J. Martyn, F. R. S.*

THE *Peak* in *Derbyshire*, having hitherto been described in scarce any other Light, than as a Place composed of Wonders; I was not a little desirous to make some Enquiry into the Nature of a Place generally esteemed one of the most Surprising of our own Country.

In my Way thither, I took Notice of the following Plants, which I have not observed to be common