in a ſwimming Poſture; but the Members and Legs on the other Side are ſo various, and ſo much more curiouſly form'd than thoſe of Lobſters and Shrimps, that I deſpair'd of giving any tolerable Repreſentation of them in any other Poſition. Theſe are about the ſame Size, the biggeſt being rather leſs than a very ſmall Flea, and the leaſt a little bigger than a Mite; but all are Breeders, and carry their Spawn at their Tail, that of *Fig.* 90. in two Bags (one on each Side) which are faſten'd about the fifth Joint, and the other in a ſingle Bag or Film under the Tail; and I have often ſeen theſe Bags broken, and the Spawn (which is globular and large in the Proportion to the Fiſh) ſcatter'd through the Water. There is alſo among theſe a third ſort of the ſame kind not leſs elegant, tho' far leſs in Bulk, which is ſhap'd more like a Shrimp, and carries its Spawn like that; but I could never make any Figure of it worth preſerving. All theſe three Species (as alſo ſome other Water-Inſects) are certainly monoculous, and have their Eye exactly in the middle of their Head, and I could never, with my utmoſt Application, find ſo much as a dividing Line in it. Some of them, eſpecially in ſome Waters, are dark and cloudy; but they are generally ſo tranſparent, that through the Shell I can ſee the *Periſtaltick Motion* quite through their whole Length, and a conſtant Pulſation of a Part, which I gueſs is the *Heart*; but I could never diſcover any Courſe of Blood in them (nor even in *Shrimps*, which are as large as ſome Thouſands of theſe) tho' I have ſeen it plainly in Creatures a little bigger, *viz.* the ſmalleſt new-hatch'd *Spiders*, and in that Water-Inſect which is deſcrib'd and pictur'd (tho' not accurately) by *Swammerdam*, under the (very improper) Name of *Pulex aquaticus*. But this is of the Teſtaceous kind, of which I have ſeen a greater Variety (and not leſs curious) than of the Cruſtaceous. Fig. 90.

—farther Obſervations. ibid. p. 1498.

3.] I have farther obſerv'd the *Lens Paluſtris*, and am fully ſatisfy'd of the Truth of its firſt ſpringing from the Bottom. I lately took up ſome on the ſhallow Side of a Pond, and found the Ends of the Stalks (moſt of which were at leaſt five Inches long, and as thick as a ſtrong Horſe-hair) manifeſtly radicated in the Bottom, ſo that I could not take them up without raiſing the Mud with them, which alſo adhered very viſibly to them. Theſe Stalks or Roots are of a curious Texture, and almoſt tranſparent; and I have ſeen their Outſide very prettily cover'd with a regular ſort of Net-work. The Draught Mr. *Leuwenhoek* gives is very ſtiff, and ill repreſents them. *Vide* ſupra.

In my Obſervation of theſe Stalks, I often ſaw adhering to them (and ſometimes ſeparate in the Water) many pretty Branches, compos'd of rectangular Oblongs and exact Squares, which were join'd together, as in *Fig.* 91. which I drew as exactly as I could from one of them. There are often twenty or more of theſe Figures in one Branch, which generally adheres at one End to the Stalks of the Fig. 91.

Plant; and I think it remarkable that these Rectangular Parellelograms are all of the same Size; the longest Side exceeds not $\frac{1}{3}$ of an Hair's Breadth, and that the Length is just double the Breadth, the Squares being visibly made up of two Parallelograms join'd longwise. They seem very thin, and the Texture of every one is nearly the same. To a very large Magnifier they appear as in *Fig.* 92. I took these Branches at first for Salts; but finding them always of the same Size, and that there was no sensible Increase of their Bulk while they continued in the Water; that after they had lain a Day or two dry on a Glass Plate, they alter'd not their Figure, and upon the Addition of new Water (warm or cold) they had still the same Appearance and Cohesion; and that their Adherence (tho' touching only in the angular Points) was so firm and rigid, that all moved together, and kept the same Position in respect of one another, however agitated by the Water: These Considerations, I say, persuade me, that they may be rather Plants than Salts; but they being so very minute, that no Judgment can be made of 'em but by the Eye, I shall not determine any thing positively.

Fig. 92.

A Water-Newte.

In some Water which I took out of a Pit, I found a small *Water-Newte*, not an Inch long, which I suppose was of this Year's Hatch; and the Legs being so small as not readily to be discern'd at first View, and the Body very clear, I took it at first Sight for a Fish. This I kept by me (instead of Tadpoles) to shew the Circulation of the Blood in its Tail. But that was not the only Entertainment it gave me; for I found the Course of the Blood in every Part of its Body, and particularly in every Digit of the Feet: It was a curious Sight to observe the Stream come to the Extremity of the Toe in one Channel, and return by another. In this *Newte*, just below the setting on of the Head, on each Side, are three little rugged fleshy Branches, which he spreads like Fins, and which help to poise his Body. Observing these with the Microscope, I found each of them divided (something like a Leaf of *Polypody*) into a great many pointed Branchings, in each of which (as in Toes) I can see the Blood come to the extream Point on one Side, and return on the other; and this is the more entertaining, because 30 or 40 of these Branchings will sometimes appear at one View, and the Blood seen distinctly circulating in all. For, as Mr. *Cowper* rightly observes, the Globules of the Blood of these Creatures are very large, so that I can see the Circulation in them very well, even with the smallest Magnifiers, which take in a great *Area*. And from what has been said of this Course of Blood, I am perswaded, that these Organs in the *Newte* are not only design'd to be serviceable in their Swimming, but (though they have *Lungs* like a *Frog*) may be also Analogous to the *Gills* in *Fishes*.

In my Examination of the Waters of our Ditches (in which I daily find new Varieties of *Animalcula*) I had the good luck to meet with great Numbers of those round Bodies mention'd by Mr. *Leuwenhoek*

hoek in the *Tranſactions*, N° 261. which are there ſo well deſcribed, that I ſhould not have again ſpoke of them, only that I ſaw a very ſurprizing Phænomenon while I was obſerving them. Each of thoſe Spherical Bodies (which are ſmaller than a Muſtard-Seed) have a conſtant progreſſive Motion, and at the ſame time a ſlow Revolution about their own Axis, and contain within them other ſmall Globules, ſome more, ſome leſs; but I never found above ten in any one; and theſe I have ſeen move and change their Poſition within the other, which Mr. *L.* ſays he never obſerved. While I had one of theſe Bodies on a Glaſs Plate before my Microſcope, I ſaw (as he deſcribes it) one of the contain'd Globules ſlip out of it; and while the great one lay ſtill, for want of ſufficient depth of Water to float in, this little one that came out had immediately a very quick Rotation on its Axis; and what was moſt ſurprizing, at the ſame time it kept an equable Revolution about the bigger Globe, as the Center of its Orbit, always very nearly at the ſame diſtance, tho' I could not perceive any Vortex in the Water which bore it: and what is yet more remarkable, I ſaw it ſtop, and then make its Revolution round the Central Body the contrary way, the Rotation on its own Axis always continuing. And when the Water was ſo far evaporated that all lay at reſt, by the Addition of new Water the ſame Motions were renew'd. This I thought a very pretty Repreſentation of the Planetary Motions about the Sun, and I doubt not but a *Carteſian* would have been not a little pleas'd, to ſee in Nature ſuch an Inſtance of ſuch Revolutions of an inanimate Body in ſuch a Medium as Water. Indeed I think it not eaſy to account for theſe Motions of theſe Globules; nor will I, to ſolve the Difficulty, ſay in contradiction to Mr. *Leuwenhoek* that I believe them animate, tho' I have formerly ſeen ſome not very unlike them both in Shape and Motion, which I am ſatisfy'd are Animals.

I find all the *Earwigs*, which I have examin'd by a Microſcope, infeſted with great Numbers of minute Inſects, which ſtick like Lice on many Parts of their Bodies, and eſpecially juſt under the ſetting on of their Heads. They are alike on all, and I never found the ſame on any other Animal; they are white and ſhining like Mites, but much ſmaller, are round back'd, flat bellied, and have long Legs, eſpecially the two foremoſt. —*Of* Earwigs.

4.] I have made proof of my new Set of Microſcopes made by Mr. *Wilſon*, † and have found the way of applying them very readily. The Contrivance of the Ivory Box and hollow Screw for Approach, with the illuminating Convex at the End of it, is of great ſervice both by Day and Candle-light, and the Sliders with the plain and concave Glaſs Plates for Objects very convenient. But the Braſs Tool I think capable of Improvement: I purpoſe to have one made with ſome new Accommodations, *viz.* a fine threaded Steel Screw

Microſcopical *Remarks and Obſervations, by—communicated by Sir* C. H. n. 284. p. 1357.

† *Vid.* ſupra, V. iv. p. 199.

Screw for a more steady Approach, and some new Turns and Motions to the Arm which carries the Object, &c. And I propose also to have a Brass Arm to slide up and down on the square Rod of my deep Microscope, to which I would with a Screw fix either the Ivory Box, or the Handle of the Brass Tool, to be set by that means in a settled Posture to any Height or Inclination required, which will be very necessary when an illuminating Glass is applied to either.

As for the Glasses themselves, I think them very good and well wrought, and (tho' not so neatly set) to go far beyond any I have seen of *Mellins*. The greatest Magnifiers especially augment more, and yet shew an Object more distinct than his. My greatest shew an Hair of my Head to any Eye considerably above an Inch diameter, and some Eyes judge it at least two Inches; but supposing it a bare Inch, and that (as Mr. *Hooke* affirms) 640 Hairs breadth make one Inch, the Length and Breadth of an Object will by it be augmented 640 times, the Surface 409600, and the Solidity 262144000.

But the best of ours must needs fall short in Power and Goodness of Mr. *Leuenhoek*'s Glasses, whose Skill both in making and using them I fear we shall not easily reach. I know many question the Sincerity of his Relations; but I can do him that Right to affirm, that as far as I am able to follow him (and I have tried many of his Experiments) I find him always faithful in Matter of Fact, and therefore question not his Veracity in other things. 'Tis not fair to say I have looked on such Objects, and found no such thing as he mentions. There is more than an hasty cursory View required in Observations of this kind; there must be Patience and Attendance, and some Skill in managing the Glasses, Objects, and Light to the best advantage: Besides, there are many lucky Hints and Coincidences, and all this to little purpose, without a strong and good natural Sight, and an Eye used to Glasses; for I scruple not to say, that a discerning and critical Eye, as well as a nice and good Ear, is gained and improved by Experience.

——On a Louse.

In a living *Louse* I could plainly see the Motion of the Muscles, (when he stirr'd his Legs) all which are joined in a longish dark Spot in the Middle of his Breast, where the Tendons seem all united. The like Motion of Muscles is also visible in the Head when he stirs his Horns, and in the several Articulations of his Legs. I saw also clearly a Multitude of various Branchings of Arteries and Veins, and the Pulse regularly beating in several Arteries. But the most entertaining Sight is the *Peristaltick Motion* of the Intestines, which is continued from the Stomach through all the Guts to the *Anus*. I have observed the like *Peristaltick Motion* in a *Flea*, and in several sorts of small transparent *Maggots* and *Caterpillars*. But a *Louse* will bear rougher handling, and live confined between two concave Plates, if not crushed, four or five Days.

I

I thought a *Mite* would alſo prove a good Subject for the like purpoſe, but found them not ſo ſo tranſparent as I expected. However, I plainly ſaw that all the Briſtles on the Body of one of them (which to a common ſingle Glaſs, and to the greateſt Magnifier of my three-glaſſed Microſcope look like plain ſmooth Hairs) were, when viewed with a large Augmenter, all ſpicated, or bearded like the Ear on the Seed-head of ſome Graſſes. The Appearance was like *Fig.* 93. which ſhews part of the Briſtle; but I cannot expreſs the Beauty and Regularity of it; and every Briſtle on the whole Body and Legs, both long and ſhort, had the ſame Formation. But all Mites are not ſo; for of ſeven or eight incloſed together, I found but one whoſe Briſtles were of this Make; in the reſt the Horns only were ſpicated. Whether they were of different kinds, or rather only of different Sexes, I ſhall not determine; they were all taken out of the ſame Cheeſe at the ſame time, and were in other Parts very like. Their Mouths open horizontally (to the right and left) like that of a Waſp, and hard-headed Maggot; and after their being ſome Days ſhut up together I found ſome dead, and the Survivors preying on them; which gave me an Opportunity of obſerving their manner of feeding, which was very remarkable; for they thruſt one Mandible forward, and bring the other backward at the ſame time, and this alternately, and by that means ſeem to grind their Food. —*On* Mites. Fig. 93.

If you would bring one of the greateſt Magnifiers to obſerve a Mite, or the like minute Animal, you muſt lay him on a thin *Muſcovy* Plate in one of the Sliders, and cover him with a Concave, and take good care not to cruſh the Object between the Plates in your Approach.

I pull'd off an Handful of *Muſcles*, which ſtuck on a piece of a Rock that was covered by the Sea every Tide. Theſe I brought with me, that I might obſerve the Organs by which they fix themſelves ſo firmly to a Stone, that even a Storm will not waſh them off. I found that theſe were Threads which came from that part which is called the Beard of the Muſcle, which had on their Extremity a flat ſpungy Subſtance, that adhered only by Impoſition, like the wet Pieces of Leather which Boys faſten to Stones, and they are deſcrib'd, and well pictured by Mr. *Leuwenhoek*. But my principal end in gathering theſe Muſcles was, that I might view and examine the Inhabitants of thoſe little white Shells, which ſtick like Puſtules on Muſcle-ſhells (as they do likewiſe upon Lobſters, Oyſters, Stones, *&c.*) Theſe are alſo mentioned by Mr. *L.* who gives a Picture of one of theſe little Creatures taken out of its Shell. His Draught is very accurate, only that in the twelve long Branches growing from the Head, the Briſtles are there pictured coming out quite round on each Joint of every Branch; whereas they only grow on the inſide, (all the hind Part being perfectly bare) and look not unlike a ruffled —*On* Muſcles, *&c.*

Feather stript on one side. I cannot guess at the Use of these curious Ramifications, unless they serve to draw in Food to the Creature, which cannot move out of its Place. For, keeping them alive in Sea-Water, I saw them often put them out through the Slit of the *Operculum*, which closes the Top of the Shell, and draw them in again. This, as I remember, the Naturalists call a *Balanus*, and class it with the *Concha Anatifera*. I never saw the latter; but that being much larger, if (as 'tis probable) it has the like Organs, we may easily account for the Mistake of even some observing Men, who affirm they have seen them feathered, and think them Birds *in fieri*. Some of the Muscles which I brought, were little above a Quarter of an Inch long. I took one of these out of the Shell, and exposed it to the Microscope on a thin Plate of *Muscovy* Glass; and holding it to the Light of a Candle, I saw in the thinner Parts a vast number of Veins and Arteries, and the Blood circulating in them more distinctly than ever I saw it in any other Animal. For I had this Advantage in the Observation, that the Object lay always quiet, without changing Place; and my Plate was so thin, that I could bring to it what Magnifiers I pleased, and look without disturbance as long as I pleased: For whereas other Animals will not easily be brought to lie still any considerable time, and will not live long when exposed to a Microscope; this lay always in the Posture it was placed, and the Motion of the Blood continued with little Alteration six or seven Hours, only by keeping the Object moistened with Sea-Water, and might have lasted much longer if I had not thrown it away. I repeated the same Experiment for two or three Days with some of the remaining Muscles, with little difference in the Success.

A small Worm. The other day I spied running among some Fruit a small Worm, which I could perceive to have a Multitude of Legs; it was not half an Inch long, and the Body not thicker than an Hog's Bristle. This I put alive into a small Tube, and found it a perfect *Scolopendra*, whose Body was made up of sixty Incisures, at every one of which was a pair of Legs (one on each side) and each Leg had five Articulations. On his Head were two Horns, each of sixteen Joints, and under it a Pair of terrible Forcipes, red, crooked, and pointed like the Talons of an Hawk, and I often saw him open and shut them, and wipe his Horns thro' them. These Forcipes are not unlike, and probably for the same Use as those on the Head of a Spider; but they are difficultly seen (because generally kept close) in a living Spider; but you may readily find them open'd, and in their perfect Shape, in the Spider's *Exuviæ*, or cast Coats.

A Tick. I found a small black flat *Tick*, (after walking in a Thicket) sticking on my Arm, and it had got its Forepart so far into the Skin, that I had much ado to separate it with the Point of a Needle, so as to preserve it entire and unhurt. I observed the Snout of this to be shaped not very unlike the jagged *Proboscis* of the *Serra Piscis*.

The

The forepart of it *a*, being like the End of a broad-pointed Sword, is clear and transparent, and has three Teeth on each Edge; below which there comes out another serrated Part *bb*, on each side, almost at right Angles; but this is partly hid (when you look on the Back) by a thin Horn *c* on the side of the Head. I broke off one of the Horns at *d*, and then it appear'd as in the Figure. I afterwards examin'd the Snouts or Proboscis of *Dog-Ticks*, to see if they had the like Conformation, and found their Appearance as in *Fig.* 95. the Snout *a* being so Fig. 95. covered by the two clumsy thick Horns *bb*, that the serrated Edges could not be perceiv'd; but separating the Horns (with some Difficulty,) they appear'd in the Posture of *Fig.* 96. and I could then plainly see Fig. 96. eight Teeth or Jags on each Side, as here express'd; but the Snout of a *Dog-Tick* has not the additional serrated Part, which is in the *Wood-Tick*. I could also perceive a Pipe or Channel run through the Snout, and see some Bubbles move up and down in it, which I have endeavour'd to represent.

Animalcu'a *in* Pepper-Water.

I have found some of the *Animalcula* in *Pepper-Water*, almost incredibly minute, which appear even to my greatest Magnifiers not so large as a Mite to a naked Eye; and in the bigger sort I can plainly see the little Feet, by which they perform such brisk Motions, which I never could find before. But I doubt not but your own Microscopes have shew'd you what is discoverable in these Liquors, and therefore I shall say no more of them. Only I cannot omit mentioning one sort of Animal in them, which I never discover'd till within these three or four Days: These are very slender long *Worms*, of which my Pepper-Water is prodigiously full: They are all of the same Thickness; but their Lengths are very different, some being twice and some thrice as long as others; and at a Medium I judge the Proportion of their Length to their Breadth at least as fifty to one. Even to the largest Magnifiers they look like Shreds of Horse-hair (to a naked Eye) from a Quarter to three Quarters of an Inch long. Upon a modest Estimate, their Thickness is not the hundredth part of an Hair's Breadth; and consequently, if you imagine an Hair of your Head split into above 7800 equal Fibres, each Fibre would be as thick as one of these Creatures. Their Motion is equable and slow, and generally they wave their Bodies but little in their Progression, tho' sometimes they make greater Undulations. But what is more remarakable, they swim with the same Facility both backward and forward, so that I cannot distinguish at which end the Head is; and I have seen the same Worm go forward with one end, and back again with the other end foremost above twenty times together. And sometimes they will (like Leeches) fix one end on the glass Plate (on which I lay the Water) and move the loose Part of their Body round about very oddly. These I take leave to call *Capillary Eels*, Fig. 97. and I have given, as well as I could, a Representation of their Ap-

pearance to a great Magnifier, in the ſeveral Poſtures I have ſeen them ſwim.

The Duſt *of the* Puff-Ball.

I find the Duſt of the *Fungus Purverulentus*, or *Puff-Ball*, to be the minuteſt Powder that I ever ſaw: To a naked Eye (when 'tis cruſhed) it appears like a Smoak or Vapour, and with a common Microſcope you cannot diſtinguiſh the Particles. But when 'tis view'd with the greateſt Magnifiers, each Grain is viſible, and exactly alike, and appears a perfect Spherule of an Orange Colour, ſomething tranſparent, whoſe Axis is not above the fiftieth Part of the Diameter of an Hair. So that a Cubical Veſſel of an Hair's Breadth of a Side would hold 125000 of them. This was the Duſt of that *Fungus* which is bigger than your two Hands put together: And I obſerv'd ſince in another Puff-Ball of the ſize of a ſmall Crab (which I take to be a different kind) that all the Globules were darker, and that every one had a little Tail or Stalk affixed to it. I at firſt imagined that theſe (tho' ſo minute) might be Seeds; but I found that the Smut of Corn was compoſed of the like regular Globules, and about the ſame Size. My way of obſerving theſe, and the like Duſts, is to breathe gently on a thin *Muſcovy* Plate, and then covering lightly with the Powder, to blow it off again; for enough will adhere, and they ſhould not lie in Confuſion.

I have met with great variety of very beautiful minute Flies and Inſects on Leaves and Flowers; eſpecially one very pretty *Grub*, which I found plentifully adhering to *Nettle-Leaves*, which is a wonderful thin Creature, has a ſort of a Covering all over his Back like a broad Shield, which he lies under like a Tortoiſe, and is all over beſet and fringed round with Spikes.

Animalcula *in the* Semen *of a* Buck.

A *Buck*, which by Miſchance had his Leg broke, was kill'd: It being rutting time, I thought I might with the greateſt Advantage obſerve the *Semen Maſculum*. As ſoon as he was kill'd, I took out one of the *Teſticles*, with the adjoining *Seminal Veſſels*, and found the *Vaſa deferentia* very turgid, and full of a milky Fluid. After various Methods of viewing this Liquor, I ſaw the *Animalcula* (in prodigious Numbers) very perfectly in ſeveral Poſtures moving very briſkly, and ſhew'd them to others, who own'd they appear'd as plain as Tadpoles to a naked Eye. The greateſt Taſk was to lay them thin enough before the Microſcope; for when the Matter is too thick, you ſee nothing diſtinctly, but only a confus'd Motion; and when thin ſpread, it dries immediately, ſo that you muſt be very quick with it, or you will loſe your Labour. I diluted ſome of the *Semen* with warm Water, (juſt ſo much as would a little change the Colour of the Water) and by that means could ſee them more diſtinct and ſeparate, even with ſmaller Magnifiers; and they then kept their Shapes long, even till next Day, when put in a ſmall Tube, but were without Motion. To my beſt Glaſſes they appear'd about the Size, and in the Poſtures repreſented in *Fig.* 98.

Fig. 98.

In

In my Observations of the *Animalcula* in *Waters*, I have many of the same Species in the several Infusions, and even in Waters that have been expos'd any time without any particular Mixture, such as you find in the Hollow of a Cabbage-leaf, or on the *Dipsacus*, &c. and I am confident that many of these are the same Creatures under different Dresses. For I have noted such a regular Process in them, and such a constant Order of their Appearance, that I am of opinion most of them are the Product of the Spawn of some invisible *Volatile Parents*, and generated like Gnats, and many other Sorts of Flies, which are bred, and undergo many Changes in the Water, before they take Wing. But I give this only as a Conjecture. Some of them also may probably be originally *Water Insects*, or *Fish*, *sui generis*, and are small enough to be raised in Substance or in Spawn with the Vapours, and again to fall with the Rain, and may grow and breed again in the Water when kept; and this will seem less strange, when I affirm that I have seen Fishes, some as small as Cheese-Mites, of different Sorts, very wonderfully made, which are of the crustaceous kind, shell'd with many Joints, with very long Horns, fringed Tails, and have many Legs like Shrimps, curiously made; and that some of these carry their Eggs or Spawn under their Tails in one Bag, another sort in two distinct Bags, and some kinds on the Fringes of their Legs like Lobsters. But as to the *Animalcula* in *Pepper-Water*, those in *Fig.* 99. are very common, and described by Mr. *Leuwenhoek* in some of the first Transactions. I have seen the Tails of some of these nine or ten times as long as their Body, (which is about $\frac{1}{3}$ of an Hair's Breadth Diameter) but generally they are four or five times as long. As they move, they will often twitch up the Tail in the Posture as at *b*, and this Spring is so strong, as when the Tail is intangled (as generally it is) by the End, they bring back their whole Body by the Jerk, and Convolution of the Tail, which soon returns to its first Straightness. To a good Glass the End of the Tail seems to have a Knob on it as in *a*, and the Folding appears as in *b*; but examining it with one of the greatest Magnifiers, I found the Knob to be only a close spiral Revolution like the Worm of a Bottle-Screw, and that the whole Tail when twitched up was also a Spiral. I have endeavour'd to represent this Appearance (to the great Magnifier) in *c* and *d*. I have also seen them sometimes as in *e*. I have farther observ'd, that when these lie still, they thrust out a fringed or bearded Mouth, which they can draw in again; and that a rapid Stream runs constantly toward their fore Part, as if they drew in Water: But I rather believe this Current is made by a nimble tremulous Motion of some minute Fins or Legs, which my Glasses will not discover.

Animalcula *in* Waters.

Fig. 99.

Those *Animalcula* mark'd *Fig.* 100. are also plentiful in all the Waters, and are the largest of all; and I can see them in a good Light and Position (without any other Assistance) with my bare

Fig. 100.

Eye, their Length being about the Breadth of an Hair. Theſe have a very quick Motion, and are perpetually beating about like a Spaniel in a Field, and by their frequent Turns and Returns, ſudden Stops, and caſting off, ſeem to be always hunting for Prey. Their Bodies are very thin, that which I take to be the Back being much darker than the other Side; and you ſhall ſee them frequently turn ſometimes one Side, and ſometimes the other, towards your Eye, and many times you may ſee part of each. Their Edges are as it were fringed with a multitude of very minute Feet, which are moſt conſpicuous about the Head and hinder Parts, where are alſo ſome Briſtles longer than the Feet, which ſhew like a Tail; *a* ſhews one of theſe with the Back, and *b* one with the Belly toward you: And in *c* and *d* I have endeavour'd to repreſent it, as it often appears, in other Poſtures. I put ſome ſhort Shreds of my Hair into their Water to compare their Magnitudes by, and ſaw that they could uſe their Feet in running as well as ſwimming, for they would often ſtand on an Hair, and go on it forward and backward from End to End, often ſtooping down, and bending themſelves in ſeveral Poſtures.

Among theſe are generally another ſort (but not above $\frac{1}{5}$ of their Size) whoſe Feet are alſo very viſible; ſome of them are ſhaped almoſt like a Flounder, and others are rounder behind; for by their Motions and Actions I judge them the ſame Creatures. Theſe alſo will ſtand and run on an Hair, or any Filth in the Water, they are marked *ab*, *Fig.* 101. Fig. 101.

I have likewiſe ſeen them double as at *c*, and go forward ſo, like Flies in Copulation. I was ſurprized at the firſt View of this, thinking it a ſingle Animal of that Shape; but have ſince often obſerv'd them both join and ſeparate, and two of them following a third, ſometimes the firſt, and ſometimes the ſecond laying hold of it, and driving off the other.

The little Feet of theſe *Animalcules* are moſt diſtinguiſhable when the Water is juſt drying off, for they being then ſtranded, cannot change their Place; and if you watch that nick of time, you may ſee them move their Feet very nimbly, and diſtinguiſh them ſome little time after the Water is evaporated.

I thought thoſe which I call'd *Capillary Eels* had been peculiar to *Pepper-Water*, but have ſince obſerv'd the ſame (tho' but few) in ſome ſtanding Water which drain'd from an Horſe Dunghil. This Liquor was Mum-colour'd, and the moſt pregnant of all that I had ever ſeen; and it would look incredible if I ſhould tell you what a prodigious Number of all ſorts I eſtimated to be in a Quantity of it of the Magnitude of a Pepper-Corn, for they appeared as thick as Bees in a Swarm, or Ants on an Hillock, ſo that I was obliged to dilute the Water to obſerve the particular Sorts. I found in this not only almoſt all the *Animalcula* I had ſeen in the other Infuſions, but many Sorts which I never met with before. Among them were

in

in great plenty thoſe which are repreſented in *Fig.* 102 ; their extreme Parts look bright, and the Middle dark, and ſeem beſet with Briſtles, and their Tail is pointed with a long Sprig at its End ; their Motion is ſlow and waddling. Fig. 102.

But the prettieſt Object was a great Number of a kind of Eels, which appear moſt diſtinctly when the Water is almoſt dry, which make briſk Shoots, and have a pretty wriggling Motion ; they are of different Lengths, and are about the Thickneſs of what I call Capillary Eels. I have drawn ſome of them in *Fig.* 103. with ſome of the Capillary Eels among them, that you may better judge of their Proportions. Fig. 103.

I preſerved ſome of this *Dunghil-water* by me ſeven or eight Days, and found the Number of theſe little Eels decreaſing every day, till I could hardly find one in it, tho' they were as plentiful as before in the Water newly taken up. And on the contrary I obſerved great Numbers in the kept Water, which are very ſcarce in the freſh : Among theſe is one ſort very ſingular in its Shape and Motions ; its Body is ſpherical, only a little pointed like a Pear, and it ſeems very pliable like a Bladder fill'd with Water, in which are a vaſt Number of dark Particles in confuſed Agitation. Their moſt remarkable Motion is a revolving one ; they will turn ſometimes above an hundred times, ſometimes not half ſo faſt, in a Minute the ſame way, and then ſtop, and turn the contrary way ; and all this without moving a Hair's Breadth out of their Place. They will alſo go forward, turn and return, and fetch a large Compaſs with many Deviations, and in their Progreſſion they always (even in the ſhorteſt Turns) keep their pointed End foremoſt, the revolving Motion ſtill continuing. And when the Water dries, their Skin breaks, and the incloſed Liquid diffuſes. I have given their Shapes in *Fig.* 104. Theſe are of different Magnitudes. Fig. 104.

There is another ſort, repreſented in *Fig.* 105. in great numbers, which are near as long as the biggeſt kind formerly mentioned. Theſe have briſk Motions, and are very active, and have many Feet before, very viſible. They will often contract, and again lengthen themſelves as they ſwim ; but eſpecially when the Water dries, they will ſhrink themſelves up into a globular Figure, and the Feet then ſtand out, which you may ſee move very nimbly a conſiderable time after. Theſe alſo are of different Sizes ; *a a* ſhews them at their Length, and *b b* repreſents them contracted. Fig. 105.

I have alſo given the Figure of another oddly made Animal not uncommon among the reſt, which is as large as the former, and in its Motion (which is very nimble) keeps always the ſharp end foremoſt. I have obſerved ſome Variety in theſe (tho' I take them to be of the ſame Species) ſome of them being clear, and curiouſly ſtriated from the point to the thick end, others only having the Fore-part Fig. 106.

clear,

clear, and the Bottle dark, as is ſhew'd at *a* and *b*; but I cannot by any Glaſs find the Organs by which they move.

I have found a curious Mechaniſm in a ſmall *Diving Inſect* which inhabits ſtanding Water. 'Tis like a ſmall *Fly*, with an Head like an Houſe Cricket; but in the Place of Wings it has two Paddles on the Shoulders, and on the End of the hinder Legs, (which are longer than the other four) inſtead of Feet and Claws, are perfect Oars. I have alſo taken notice in two or three ſorts of Flies, that behind the Eyes, on the Top of the Head, are placed three Protuberances (in Equilateral Triangles, with the Point foremoſt) with a black ſhining Globe in each, like a Ball in a Socket, and are ſo diſpoſed as if made to look directly backwards. They are perfectly ſmooth, and without thoſe Hemiſpherical Diviſions viſible in the Cornea of the Eyes of the Fly and Beetle kind, but appear more like thoſe of a Spider.

I have tried ſeveral ways of killing the *Animalcula* before mentioned, by mixing Salts, Spirits and Acids, *&c.* with their Water, the leaſt Touch of which will immediately deprive them of Motion and Life. But I never yet ſucceeded in any Trial of recovering or reviving them, after the Water was evaporated, by the addition of freſh Water; tho' ſome have affirmed they may be revived by that means, even an Hour after; nay, ſomebody in one of the *Tranſactions* ſays they will recover after the Water is boiled. Many of thoſe I have mentioned burſt when the Water dries; and tho' ſome keep their Shapes a little while, yet they too alter in a few Minutes, and I cannot imagine them recoverable.

Of Microſcopes, &c. by Mr. Leuwenhoek. n. 273. p. 903.

5.] About three Years ago I was ſhew'd a Magnifying Glaſs, whoſe chiefeſt Excellency was, that one could ſee an Object a great diſtance from the ſaid Glaſs. As ſoon as ever I had put the Glaſs to my Eye, I concluded that there was a Hole or Cavity in it, by which the remote Object came to be ſeen: And when I came to view the Glaſs by one of my own which I had about me. I did not only diſcover one deep Pit or Cavity in it, but ſeveral other leſſer, which had not been ground out; ſo that upon the whole it ſeem'd a very inconſiderable Glaſs.

Laſt Winter came to me a Fellow, whoſe Buſineſs it is to grind Glaſſes, and bragged mightily of a Magnifying Glaſs that he had, whereby he could ſee into Metals and Minerals, I told him that the Pores of Metals were ſo cloſe and impervious, that it was impoſſible ever to ſee through them; and that Leaf-Gold, tho' never ſo thin beat, would teach us that. Hereupon he put his Glaſs into my Hands, adding, that I ſhould ſee the Light of the Candle through a Copper Circle which ſtood before the Magnifying Glaſs, and accordingly I ſaw a very imperfect Light through the Copper Circle. I told him that this was nothing; that he might cheat the Ignorant; but

Fig. 84

Fig. 85.

Fig. 86.

Fig. 88.

Fig. 87.

Fig. 89.

Fig. 101.

Fig. 96.

Fig. 95

Fig. 90.

Fig. 91.

Fig. 94.

Fig. 102.

Fig. 97.

Fig. 100.

Fig. 92.

Fig. 98.

Fig. 93.

Fig. 99.

Fig. 103.

Fig. 104.

Fig. 105.

Fig. 106.

but that this *Phænomenon* was only occaſioned by a ſmall Part of the Glaſs that was not ground; and then I took an extraordinary Glaſs, which immediately diſcovered thoſe Parts that were not ground, and ſhewed him the ſame.

It has often happen'd, that in the burſting of Glaſs, or of Sparks flying out of Wood-coals (my Eye being a little too near) ſmall Particles of the Glaſs or Fire came into my Eye, and cauſed it to ſmart; upon which, I uſed to arm my Eyes with Spectacles againſt the like Accidents for the future.

Now I obſerve, when I look through one of my Glaſſes by Candle-light, that near the upper Part of my Eye, in the *Tunica Cornea*, there appears a fine ſmall Flame of a Candle inverſed, no bigger than the common Letters we uſe in writing, and oppoſite to it appear two round clear Lights, ſo very ſmall that the Flame of the Candle is not to be perceived therein.

From hence I conclude, that the *Tunica Cornea* of the Eye, by the Wound it received from thoſe Particles of Glaſs, has loſt ſomething of its Roundneſs, which occaſioned thoſe Appearances; and that when the wounded Part ſtood juſt before the Sight, it obſtructed it, *&c.*

I obſerved alſo, that in ſeveral Places of the *Tunica Cornea*, there lay Veins no longer than the breadth of two or three Hairs put together, wherein I could perceive the Globules of Blood very diſtictly; theſe Veſſels were ſo ſmall, that they could contain but one Globule in the Diameter of them, and the Blood had no manner of Motion.

The Veſſels ſeem to me to be broken off from other Blood-Veſſels: and when the Particles of Blood are a little crouded together, or when one of thoſe longiſh Veſſels are ſomewhat bended, it appears to the Sight as if one ſaw a thick Cloud.

With this Cloud of ſmall Particles the Eyes are ſurrounded, but more one time than another; for ſome are diſperſed, and then others ariſe in their Places. When we view theſe Veſſels with their Globules of Blood, through one of my Glaſſes, againſt a Candle, or other ſtrong Light, they ſeem to be in a continual Motion, whereby thoſe Particles that are in the *Tunica Cornea*, be their Motion never ſo ſmall, ſeem to us as if they were moving in the Air; but by ſtrict Examination we ſhall find, that they are one and the ſame Particles, which ſometimes appear aſcending, and at other times deſcending.

Beſides the aforementioned Blood-Veſſels, we find in the *Tunica Cornea* round Particles that lie ſcattered about, which Particles I judge to be Globules of Blood. An ignorant Perſon ſeeing theſe Particles in continual Motion, (for ſometimes they appear aſcending, and ſometimes deſcending) would be apt to ſay, that theſe Particles were not in his Eye, but in the Air before the Glaſs; and perhaps too, that the deſcending Particles were the Influxes of the Stars, and thoſe that ſeemed aſcending, the Exhalations of the Earth, or other Bodies.

It

It has often befallen too, when I looked againſt a ſtrong Light thro' my Microſcopes, that I ſaw an infinite Number of exceeding ſmall Particles, that had all a glittering Motion.

I never imagined that theſe Particles were in the Air, as others would; but rather that they were in the Cryſtalline Humour of the Eye, between the *Tunica Cornea* and the *Cryſtallina*, the Motion of which ſmall Particles is occaſioned by preſſing the *Tunica Cornea* when we ſhut our Eye cloſe together.

Of the Regularity *in the* Births *of both* Sexes, *by Dr.* J. Arbuthnot. *n.* 328. *p.* 186.

VI. Among innumerable Footſteps of Divine Providence, to be found in the Works of Nature, there is a very remarkable one to be obſerved in the exact Balance that is maintained between the Numbers of Men and Women; for by this means it is provided, that the Species may never fail, nor periſh, ſince every Male may have its Female, and of a proportionable Age. This Equality of Males and Females is not the Effect of Chance, but Divine Providence, working for a good End, which I thus demonſtrate:

Let there be a Die of two Sides, M and F, (which denote Croſs and Pile:) Now to find all the Chances of any determinate Number of ſuch Dice, let the Binome $M + F$ be raiſed to the Power, whoſe Exponent is the Number of Dice given; the Co-efficients of the Terms will ſhew all the Chances ſought. For example, in two Dice of two Sides $M+F$ the Chances are $M^2+2\ MF+F^2$. that is, one Chance for M double, one for F double, and two for M ſingle and F ſingle; in four ſuch Dice there are Chances $M^4+4\ M^3F+6\ M^2F^2+4\ MF^3+F^4$, that is, one Chance for M quadruple, one for F quadruple, four for triple M and ſingle F, four for ſingle M and triple F, and ſix for M double and F double; and univerſally, if the Number of Dice be n, all their Chances will be expreſſed in this Series.

$$M^n + \frac{n}{1} \times M^{n-1}F + \frac{n}{1} \times \frac{n-1}{2} \times M^{n-2}F^2 + \frac{n}{1} \times \frac{n-1}{2} \times \frac{n-2}{3} \times M^{n-3}F^3 +, \&c.$$

It appears plainly, that when the number of Dice is even, there are as many M's as F's in the middle Term of this Series, and in all the other Terms there are moſt M's or moſt F's.

If therefore a Man undertake with an even Number of Dice to throw as many M's as F's, he has all the Terms but the middle Term againſt him; and his Lot is to the Sum of all the Chances, as the Co-efficient of the middle Term is to the Power of 2 raiſed to an exponent equal to the Number of Dice: So in two Dice his Lot is $\frac{2}{4}$ or $\frac{1}{2}$; in three Dice, $\frac{6}{16}$ or $\frac{3}{8}$; in ſix Dice, $\frac{70}{64}$ or $\frac{5}{16}$; in eight, $\frac{70}{256}$ or $\frac{35}{128}$, *&c.*

To find this middle Term in any given Power or Number of Dice, continue the Series $\frac{n}{1} \times^n \frac{n-1}{2} \times^{n-2}$, *&c.* till the Number of Terms are equal to $\frac{1}{2}$ n. For example, the Co-efficient of the middle Term of the tenth Power is $\frac{10}{1} \times \frac{9}{2} \times \frac{8}{3} \times \frac{7}{4} \times \frac{6}{5} = 252$; the tenth Power of 2 is 1024: If therefore A undertakes to throw with ten Dice in one Throw an equal Number

Number of M's and F's, he has 252 Chances out of 1024 for him, that is, his Lot is $\frac{252}{1024}$ or $\frac{63}{256}$, which is leſs than $\frac{1}{4}$.

It will be eaſy by the Help of Logarithms, to extend this Calculation to a very great Number, but that is not my preſent Deſign. It is viſible from what has been ſaid, that with a very great Number of Dice, A's Lot would become very ſmall; and conſequently (ſuppoſing M to denote Male, and F Female) that in the vaſt Number of Mortals, there would be but a ſmall part of all the poſſible Chances, for its happening at any aſſignable time, that an equal Number of Males and Females ſhould be born.

It is indeed to be confeſſed that this Balance of Males and Females is not Mathematical but Phyſical, which alters much the foregoing Calculation; for in this Caſe the middle Terms will not exactly give A's Chances, but his Chances will take in ſome of the Terms next the middle one, and will lean to one ſide or the other; and it is not only highly improbable (if mere Chance govern'd) that they would never reach as far as the Extremities; but the Number of Times can be determined, in which it is an even Wager that the Males ſhall be born in any given Proportion to the Females. This Overbalance is wiſely prevented by the Oeconomy of Nature; and to judge of the Wiſdom of the Contrivance, we muſt obſerve that the external Accidents, to which Males are ſubject (who muſt ſeek their Food with Danger) do make a great havock of them, and that this Loſs exceeds far that of the other Sex, occaſioned by Diſeaſes incident to it, as experience convinces us. To repair that Loſs, provident Nature, by the Diſpoſal of its wiſe Creator, brings forth more Males than Females; and that in almoſt a conſtant Proportion. This appears from the annexed Tables, which contain Obſervations for 82 Years of the Births in *London*. Now, to reduce the whole to a Calculation, I propoſe this

Problem. A lays againſt B, that every Year there ſhall be born more Males than Females: To find A's Lot, or the Value of his Expectation,

It is evident from what has been ſaid, that A's Lot for each Year is leſs than $\frac{1}{2}$; (but that the Argument may be ſtronger) let his Lot be equal to $\frac{1}{2}$ for one Year. If he undertakes to do the ſame thing 82 times running, his Lot will be $\frac{1}{2}|^{82}$, which will be found eaſily by the Table of Logarithms to be $\frac{1}{4\ 8360\ 0000\ 0000\ 0000\ 0000\ 0000}$. But if A wager with B, not only that the Number of Males ſhall exceed that of Females, every Year, but that this Exceſs ſhall happen in a conſtant Proportion, and the Difference lie within fix'd Limits; and this not only for 82 Years, but for Ages of Ages, and not only at *London*, but all over the World; (which 'tis highly probable is Fact, and deſigned that every Male may have a Female of the ſame Country and ſuitable Age) then A's Chance will be near an infinitely ſmall Quantity, at leaſt leſs than any aſſignable Fraction. From whence it follows, that it is Art, not Chance, that governs.

There ſeems no more probable Cauſe to be aſſigned in Phyſics for this Equality of the Births, than that in our firſt Parents Seed there were at firſt form'd an equal Number of both Sexes.

Scholium. From hence it follows, that Polygamy is contrary to the Law of Nature and Juſtice, and to the Propagation of Human Race; for, where Males and Females are in equal Number, if one Man takes twenty Wives, nineteen Men muſt live in Celibacy, which is repugnant to the Deſign of Nature; nor is it probable, that twenty Women will be ſo well impregnated by one Man, as by twenty.

	Chriſtened.			Chriſtened.	
Anno	*Males.*	*Females.*	*Anno*	*Males.*	*Females.*
1629	5218	4683	1663	5411	4881
30	4858	4457	64	6041	5681
31	4422	4102	65	5114	4858
32	4994	4590	66	4678	4319
33	5158	4839	67	5616	5322
34	5035	4820	68	6073	5560
35	5106	4928	69	6506	5829
36	4917	4605	70	6278	5719
37	4703	4457	71	6449	6061
38	5359	4952	72	6443	6120
39	5366	4784	73	6073	5822
40	5518	5332	74	6113	5738
41	5470	5200	75	6058	5717
42	5460	4910	76	6552	5847
43	4793	4617	77	6423	6203
44	4107	3997	78	6568	6033
45	4047	3919	79	6247	6041
46	3768	3395	80	6548	6299
47	3796	3536	81	6822	6533
48	3363	3181	82	6909	6744
49	3079	2746	83	7577	7158
50	2890	2722	84	7575	7127
51	3231	2840	85	7484	7246
52	3220	2908	86	7575	7119
53	3196	2959	87	7737	7214
54	3441	3179	88	7487	7101
55	3655	3349	89	7604	7167
56	3668	3382	90	7909	7302
57	3396	3289	91	7662	7392
58	3157	3013	92	7602	7316
59	3209	2781	93	7676	7483
60	3724	3247	94	6985	6647
61	4748	4107	95	7263	6713
62	5216	4803	96	7632	7229

Chriſt-

Chriſtened.			Chriſtened.		
Anno	*Males.*	*Females.*	*Anno*	*Males.*	*Females.*
1697	8062	7767	1704	6113	5738
1698	8426	7626	1705	8366	7779
1699	7911	7452	1706	7952	7417
1700	7578	7061	1707	8379	7687
1701	8102	7514	1708	8239	7723
1702	8031	7656	1709	7840	7380
1703	7765	7683	1710	7640	7288

Rules for Correcting *the Common* Computus *of* Intereſt, *&c. by Mr.* T. Watkins. n. 340. p. 111. *Of* Compound *Intereſt.*

VII. The Suppoſition whereon the Method of computing by Compound Intereſt is founded; *viz.* That all Intereſt Money, Rents, *&c.* are, or may be conſtantly received, and put out again at Intereſt, the Moment they become due, without any Charge, or Trouble, being impracticable; therefore all Computations by this Method (except of Fee-Simples or other Perpetuities) muſt needs be erroneous. Thus for inſtance, the Amount of a Sum of Money, or Annuity, for want of Deductions out of the Profits, for the unavoidable Trouble, Charge, and Delay in the Management, will be too great; and for the ſame reaſon, the preſent Value of a Sum of Money payable in any time to come, will be too little; alſo the preſent Value of an Annuity (being only the Amount of the difference between the Annuity, and Intereſt of the ſaid preſent Value) will be too much. But in long Terms of Years, as that difference becomes leſs, ſo does the Error, as the Term is greater; and in Fee-Simples it vaniſhes; the contrary to which happens in Amounts of Sums of Money, and Annuities.

All which is propoſed to be rectified, only by a juſt Reduction of the Rate, and Annuity; (which is done by deducting ſo much *per Cent.* thereout, as the whole Trouble, and Charge of Management is ſuppos'd to amount to, and reducing the Remainder, by a Diſcount equivalent to the ſuppoſed Loſs of Time) and then by working with the Rate ſo reduced, for Sums of Money, and with the Rate and Annuity reduced in the like Proportion for Annuities, according to the common Method of Compound Intereſt; as follows. Put r for the Rate of Intereſt of 1 *l.* c for the Charge and Trouble of the Management of 1 *l.* Then is $r - cr$ = the Rate after deducting the ſaid Charge, = (putting d for $1-c$) dr. And for the Diſcount put t for the time loſt, that is for ſuch part of the Period of time, in which the Payments are made (whether Yearly, Half Yearly, Quarterly, or otherwiſe) as is ſuppoſed to be ſpent in receiving and putting them out again at Intereſt. Then, dtr, being = the Intereſt of 1 *l.* for that time; ſay, as $1 + dtr : 1 :: dr : \frac{dr}{1 \times dtr}$ = (putting e for $1 + dtr$) $\frac{dr}{e}$, which is equal to the reduced Rate, near enough for practice, for which put $\mathfrak{r}$. But if the utmoſt Accuracy be required, the Diſcount itſelf muſt be made with regard to

the like Loſs of Time, which is done by a Series of Diſcounts raiſed thus; $e\ (=1+tdr) : tdr :: dr : \frac{td^2r^2}{e} :: \frac{td^2r^2}{e} : \frac{t^2d^3r^3}{e^2}$ &c.

Whence $dr - \frac{td^2r^2}{e} + \frac{t^2d^3r^3}{e^2} - \frac{t^3d^4r^4}{e^3}$ &c. = (putting q for $\frac{tdr}{e}$)

$\overline{1-q+q^2-q^3}$ &c. $\times dr. = \frac{dr}{e}\ (=\overline{1-q}\times dr) + \overline{q^2-q^3}$ &c. $\times dr$,

is $=\mathfrak{r}$, = the true Rate reduced. Put $s = 1+\mathfrak{r}$, n = the Time, p = the preſent Sum or Value, m = the Amount. Then will $\overline{1+\frac{dr}{e}+\overline{q^2-q^3}\ \&c.\times dr}\Big|^n \times \overline{p=1+\mathfrak{r}}\Big|^n \times p = p\ s^n$, be exactly $= m$: But $\overline{1+\frac{dr}{e}}\Big|^n \times p = m$ is ſufficient for Practice. And for the Amounts and preſent Values of Annuities;

Put A = Annuity *per annum*.
a = Annuity $\frac{1}{2}$ yearly, quarterly, &c.
R = Yearly Rate of Intereſt of 1 *l*.
r = Rate $\frac{1}{2}$ yearly, quarterly, &c.
$\mathfrak{r}$ = Reduc'd Rate yearly, $\frac{1}{2}$ yearly, quarterly, &c.
n = Number of Years, $\frac{1}{2}$ Years, Quarters, &c.

Then will $A\frac{\mathfrak{r}}{R} = a\frac{\mathfrak{r}}{r}$ be = reduced Annuity, taken yearly, half yearly, quarterly, or otherwiſe; and by Compound Intereſt 'twill be $\frac{\overline{1+\mathfrak{r}}|^n-1}{\mathfrak{r}} \times a\frac{\mathfrak{r}}{r} = \frac{\overline{1+\mathfrak{r}}|^n-1}{r}a = \frac{\overline{1+\mathfrak{r}}|^n-1}{R}A = \frac{s^n-1}{R}A = m$, and $\frac{s^n-1}{Rs^n}A\ (=\frac{m}{s^n}) = p$. Whence the Theorems for ſolving all the other Caſes are eaſily deduced. And if the Rate be required, when 'tis for a Sum of Money, the Solution is obvious: when for the Amount or Value of an Annuity, ſince $\overline{1+r}|^n = \frac{mr+a}{a} = \frac{a}{a-pr}$ are the Equations, whence Theorems for the Rate are uſually derived, which by this Correction become $1+\mathfrak{r}|^n = \frac{mr+a}{a} = \frac{a}{a-pr}$. That the ſame $\mathfrak{r}$ may be had on both ſides the Equation, put $u\mathfrak{r}$ for r, and 'twill be $\overline{1+\mathfrak{r}}|^n = \frac{mu\mathfrak{r}+a}{a} = \frac{a}{a-pu\mathfrak{r}}$; then, by the Rate aſſumed as near the

the Truth as may be, find the Value of u $(= \frac{1}{d} + tr = \frac{1}{d - t d \mathfrak{r}})$ and in any Theorem for the Rate, putting $m\,u$ for m, and $p\,u$ for p, the Reſult will be the Rate reduced nearly: and by repeated Operations correcting $\mathfrak{r}$ and thereby u, the true $\mathfrak{r}$, and thence R the whole Rate, may be found.

The only difficulty that remains, is the right aſſuming the Quantities c and t, the Impoſſibility of doing which with perfect Exactneſs, I ſuppoſe to be the Reaſon why neither this, nor any Method of Correction to the like purpoſe, has yet been taken notice of by the Writers on this Subject; and what may therefore be very likely to be objected to this. But the ſame Objection I take to be of equal Force againſt the Eſtimates of any other Uncertainties whatſoever, as Eſtates for Lives, Inſurances, *&c.*

Firſt, then, for the Quantity c, which is put for the Trouble and Charge of Management, *viz.* of collecting and placing out the Money on good Security, together with all Contingences attending the ſame, as travelling Charges, Expences, Attorney's Bills, *&c.* of all which, the principal Article is the Charge of Collection or Receiver's Fees, which is commonly a fix'd Rate, cuſtomarily allow'd in the Place, or upon the Eſtate it ſelf, out of which the Purchaſe is made, if it be a Rent; and for Intereſt Money, or any other Annuity, the like Eſtimate is to be made, whether the Proprietor acts for himſelf, or by another. Then for the Charge of placing out the Money at Intereſt when receiv'd; though this be for the moſt part defray'd by the Borrower, yet becauſe it highly concerns the Lender to ſee it be ſecurely done, there are uſual Allowances made to Agents and Scriveners, to encourage their Care and Fidelity therein; beſides the Time, Expence and Trouble of the Proprietor himſelf, in finiſhing Contracts, inſpecting Securities, *&c.* and whatever is ſav'd in this Article, we muſt ſuppoſe to be fully made up by an Equivalent Degree of Riſque in the Security.

In the next place, for the loſs of time; though 'tis alſo impoſſible for this to be exactly aſcertain'd, nor perhaps ſo nearly as the former, ſince it depends very much on the Diligence of the Manager: Yet if the uſual times of Payment of the particular Rent or Annuity to be purchaſed, with a moderate degree of diligence in the Manager, and the uſual Indulgence practis'd by Men of Buſineſs in this Caſe towards one another be obſerv'd, a reaſonable Eſtimate may be alſo made of the loſs of time. In which 'tis to be noted, that Intereſt Money being uſually paid in ſmall Sums, when any Sum of Money to be made up of ſeveral ſuch Payments, is intended to be put out at Intereſt, the whole muſt lie dead, till the laſt Payment be made; alſo that the Principal lies dead ſometimes as well as the Intereſt: and that on the other hand, to ſave time, Borrowers may be found out, and treated with during the time of Collection; but this Advantage is in a great meaſure loſt by the difficulty

culty of fixing the Time or *Quantum* of a Loan, till the whole be paid in. Note alſo, that if the Charge of Collection, or Loſs of time, on the Rent, or Annuity, of any particular Eſtate or Place, be found to differ from that of the Intereſt of the Purchaſe Money, and ſo much exactneſs be required, as that the Computation be made with regard to ſuch difference: it muſt be done, either by aſſuming a proper Medium for both, or more accurately thus: For the reduc'd Rate of the $\left\{\begin{matrix}\text{Annuity}\\ \text{Intereſt-Money}\end{matrix}\right\}$ put $\left\{\begin{matrix}z\\ \mathfrak{r}\end{matrix}\right\}$ Then $r : z :: a : a\frac{z}{r}$, and $\mathfrak{r} : \overline{1+\mathfrak{r}|^n} - 1 :: a\frac{z}{r} : \frac{\overline{1+\mathfrak{r}|^{n-1}}}{r} a \times \frac{z}{\mathfrak{r}} = m = \overline{1+\mathfrak{r}|^n} \times p$.

To give a Specimen of this Method in Numbers, firſt the Quantities c and t are to be aſſum'd, which are not here to be accommodated to any particular Place or Eſtate, but to be taken in general: And firſt for c the Charge of Management; the uſual Rates of Collectors Fees in theſe Kingdoms, as I am inform'd, are 6*d.* 12*d.* and 18*d. per* Pound, but the moſt uſual 12*d.* which is 5 *per Cent.* However, to be within compaſs, I ſhall take 4 *per Cent.* for the Medium, including what further Trouble and Charge may attend the Receipt of the Money, beſides Receivers Fees; and 2 *per Cent.* for all the other Charges before mention'd, in placing it out at Intereſt, both which make 6 *per Cent.* ſo that c is $= 0{,}06$, and $d\ (= 1 - c) = 0{,}94$. Next for t the Loſs of Time; ſince few Annuities are paid yearly, and a Diſcount being given for the Loſs of Time, we are to loſe no more than is diſcounted for, therefore I chuſe Half-yearly Payments for the Examples, being the moſt uſual, which with little Alteration may ſerve for quarterly; and conſidering the before-mention'd Circumſtances relating to the Time, I look upon two Months the leaſt, and ſeven or eight Months the moſt, that can well be ſuppos'd to be ſpent, one time with another, in receiving and putting out the Money, upon a moderate Management; between which the Medium is about four Months and a half, which being $\frac{3}{4}$ of $\frac{1}{2}$ a Year, gives $\frac{3}{4} = t$: and if $\frac{dr}{e}$ be $= \mathfrak{r}$, the yearly Rates of 4, 5, 6, 8 and 10 *per Cent.* will produce for Half-yearly Rates reduc'd of 1 *l.* 0.018539, 0.023093, 0.027616, 0.036569 and 0.0454 each $= \mathfrak{r}$.

But if $\mathfrak{r}$ be $= \frac{dr}{e} + \overline{q^2 - q^3}$ &c. $\times dr$, 'twill be, 0.01854219, 0.02309991 55, 0.027627775, 0.036596289 and 0.04545235, each $= \mathfrak{r}$, (ſo that each Rate loſes by this Eſtimate about $\frac{1}{11}$ Part.) Whence the following Amounts, and preſent Values of 1 *l. per Annum* computed Half-yearly, are produc'd and compar'd with thoſe of the uſual Method computed yearly, to agree with the common Tables.

Years

Years.	*Amounts of* 1 l. per An. *at* 5 per Cent. *by*		*Differences.*	*Amounts of* 1 l. per An. *at* 6 per Cent. *by*		*Differences.*
	Comp. Int.	*Co. Int. cor.*		*Comp. Int.*	*Co Int. cor.*	
5	5,52563	5,13104	,39459	5,63709	5,22138	,41571
10	12,57789	11,57846	,99943	13,18079	12,07854	1,10225
20	33,06595	29,85996	3,20599	36,78559	32,91054	3,87505
30	66,43885	58,72546	7,71339	79,05819	68,83976	10,21843
40	120,79977	104,30079	16,49898	154,76197	130,80733	23,95464
60	353,58372	289,88164	63,70208	533,12818	422,01429	111,11389
80	971,22882	752,53436	218,69446	1746, 5999	1288, 2484	458,3515
100	2610,02516	1905,92671	704,09845	5638, 3680	3864, 9753	1773,3927
	The ſame at 8 *per Cent.*			The ſame at 10 *per Cent.*		
5	5,86660	5,40633	,46027	6,10510	5,59705	,50805
10	14,48656	13,15092	1,33564	15,93743	14,32680	1,61063
20	45,76196	40,13759	5,62437	57,27500	49,17930	8,09570
30	113,28321	95,51623	17,76698	164,49402	133,96428	30,52974
40	259,05652	209,15737	49,89915	442,59257	340,21900	102,37357
60	1253,2133	920,90040	332, 3129	3034,81648	2062,57167	972,24481
80	5886,9354	3918,0576	1968, 8776	20474,0027	12255,3348	8218, 6679
100	27484,5157	16539,0989	10945,4168	137796,127	72575,3926	65220,7344

Years.	*Preſ. Values* of 1 l. per An. *at* 5 per Cent. *by*		*Differences.*	*Preſ. Values of* 1 l. per An. *at* 6 per Cent. *by*		*Differences.*
	Comp. Int.	*Co. Int. cor.*		*Comp. Int.*	*Co. Int. cor.*	
5	4,32948	4,08343	,24605	4,21236	3,97582	,23654
10	7,72174	7,33314	,38860	7,36009	7,00322	,35687
15	10,37966	9,91935	,46031	9,71225	9,30843	,40382
20	12,46221	11,97753	,48468	11,46992	11,06373	,40619
30	15,37245	14,91902	,45343	13,76483	13,41805	,34678
40	17,15909	16,78200	,37709	15,04630	14,78309	,26321
50	18,25593	17,96190	,29403	15,76186	15,57456	,18730
70	19,34268	19,18247	,16021	16,38454	16,29953	,08501
100	19,84791	19,79231	,05560	16,61755	16,59510	,02245
F.S.	20,00000	20,00000	,00000	16,66666	16,66666	,00000

Note, That this Correction is alſo applicable to the Valuations of Eſtates for Lives, in which the firſt Step being to find an Equivalent in Years of Continuance, brings them to the Caſe of Eſtates for Years. *Of* Simple *Intereſt.*

The Abſurdity of the Suppoſition, on which the uſual Method of computing preſent Values by Simple-Intereſt, is founded, *viz.* That the Rent or Annuity is conſtantly received, and put out again at Intereſt, as it becomes due ; but that the Intereſt of the Purchaſe Money lies dead during the whole Term, is ſo apparent, and the Errors ariſing from it ſo groſs, that the Writers who have laid down this Method, have at the ſame time caution'd againſt the Uſe of it for any more than 6 or 7 Years, the Error for that time being not conſiderable.

The ſame Suppoſition does alſo occaſion the Miſcomputation of Amounts, or rather the Miſapplication of them to their proper Caſes.

Where-

Wherefore, ſince the Simple-Intereſt of Money is of equal Value *pro rata*, and of the ſame regard with Rents or Annuities, being each the original Profits iſſuing alike from a principal Stock, Eſtate or Value, and equally improveable; This general Rule may ſerve for a juſt Correction of this Method, *viz.* That ſuppoſing in any Caſe an Intereſt ought to be, or not to be allowed to either of thoſe Profits, the ſame be done in the like Caſe to the other. Thus, in the Caſe of Debts, or Amounts of Sums of Money, Rents, or Annuities for the time paſt, it's uſual in practice to allow no Intereſt to either: For tho' the Law, to curb the exorbitant Avarice of Uſurers, and for other Reaſons, does more expreſly diſallow Intereſt upon Intereſt for a Debt; our Courts both of Law and Equity, as I am inform'd, will be as far from allowing the Charge of Intereſt againſt a Tenant for Rent in Arrear; except on a *nomine pœnæ* (which is now become almoſt obſolete) ſo that in this Caſe (putting a and r for the Annuity and Rate yearly, Half-yearly, or otherwiſe) as $prn+p$ is the Amount of a Sum of Money, ſo is an the Amount of an Annuity or Rent in Arrear, and not $\frac{n-1}{2} r+1 \times an$, as Arithmeticians commonly make it. But in the Computation of preſent Values, or Amounts for the time to come, the ſame being made on the Expectation of a conſtant regular Income of the Profits, without any extraordinary Interruption, an Intereſt ought to be allow'd to both, eſpecially in preſent Values, which are found by ſetting the Amounts of both againſt each other: ſo that in theſe Caſes, putting $x=n-1$, if $\overline{\frac{1}{2} x r+1} \times an$ be made the Amount of a Rent or Annuity; then $\overline{\frac{1}{2} x r+1} \times prn+p$, will be the proper Amount of a Sum of Money, and not $prn+p$: and conſequently $\frac{\overline{\frac{1}{2} x r+1} \times an}{\overline{\frac{1}{2} x r+1} \times rn+1}=p$ will be the preſent Value of a Rent or Annuity, the ſubſequent Intereſt being remitted on both ſides in lieu of the Loſs of Time and Charge of Management; which ſuch as are apt to depreciate long Futurities, may think the propereſt Method of approaching the true Value. But I rather look upon the former Method of Compound Intereſt corrected as more exact, as well as more general, the Intereſt remitted in this, being in ſhort terms leſs, and in long Terms more than an Equivalent for the Trouble, Charge and Delay in the Management. But it is however the moſt exact of any of the Methods, that have yet been deduc'd from Simple-Intereſt. The reduc'd Rate may alſo in ſome Caſes be properly made uſe of for Amounts, but not for preſent Values, except for ſhort Terms; and then, ſince $r:a::\overline{\frac{1}{2} x \mathfrak{r}+1} \times \mathfrak{r} n : \overline{\frac{1}{2} x \mathfrak{r}+1} \times an \frac{\mathfrak{r}}{r}$, 'twill be $\overline{\frac{1}{2} x \mathfrak{r}+1} \times an \frac{\mathfrak{r}}{r}=m=\frac{1}{2} x \mathfrak{r} \times 1 \times p \mathfrak{r} n+p$, and $\frac{\overline{\frac{1}{2} x \mathfrak{r}+1} \times an}{\overline{\frac{1}{2} x \mathfrak{r}+1} \times \mathfrak{r} n+1} \times \frac{\mathfrak{r}}{r}=p$.

Exam-

Examples of this Method, compar'd with thoſe of the former, will ſtand as follows ; in which all is computed Half-yearly, except the laſt Column of Compound Intereſt.

Amounts of 1 *l.* at 5 *per Cent.* computed 6 ſeveral Ways.

Years.	1 *Simple Int.* $prn+p=m$	2 *Id. for Bonds* Id. till pr $n=p$	3 *Sim. Int. cor.* $\frac{1}{2}xr+1\times prn+p=m$	4 *Id. by the red. rate.* $\frac{1}{2}xr+1\times pr$ $n+p=m$	5 *Comp. Int. cor.* $\frac{n}{1+r}\times p=m$	6 *Comp. Int.* $\frac{N}{1+K}\times p=m$
5	1,25	1,25	1,27813	1,25501	1,25655	1,27628
10	1,5	1,5	1,61875	1,56338	1,57892	1,62889
20	2,	2,	2,48750	2,34021	2,49300	2,65330
30	2,5	2,	3,60625	3,33048	3,93625	4,32194
40	3,	2,	4,97500	4,53419	6,21504	7,04000
60	4,	2,	8,46250	7,58194	15,49408	18,67919
80	5,	2,	12,95000	11,48345	38,62672	49,56144
100	6,	2,	18,43750	16,23874	96,29634	131,50126
	Amounts of 1 l. *at* 6 per Cent. *by the ſame Theorems.*					
5	1,3	1,3	1,3405	1,31063	1,31328	1,33822
10	1,6	1,6	1,7710	1,69758	1,72471	1,79084
20	2,2	2,	2,9020	2,70048	2,97463	3,20713
30	2,8	2,	4,3930	4,00870	5,13039	5,74349
40	3,4	2,	6,2440	5,62223	8,84844	10,28572
60	4,6	2,	11,0260	9,76525	26,32086	32,98769
80	5,8	2,	17,2480	15,12954	78,29488	105,79599
100	7,	2,	24,9100	21,71510	232,89852	339,30208
	Amounts of 1 l. *at* 10 per Cent. *by the ſame Theorems.*					
5	1,5	1,5	1,6125	1,54749	1,55970	1,61051
10	2,	2,	2,4750	2,30157	2,43268	2,59374
20	3,	2,	4,9500	4,42951	5,91793	6,72750
30	4,	2,	8,4250	7,38381	14,39643	17,44940
40	5,	2,	12,9000	11,16449	35,02190	45,25925
60	7,	2,	24,8500	21,20493	207,25717	304,48165
80	9,	2,	40,8000	34,55084	1225,5335	2048,4003
100	11,	2,	60,7500	51,20222	7258,5398	13780,6127

Years.	*Preſ. Values of* 1 l. per An. *at* 5 per Cent. *by*			*Preſ. Values of* 1 l. per An. *at* 6 per Cent. *by*		
	Sim. In. Cor.	*Co. Int. cor.*	*Comp. Int.*	*Sim. In. Cor.*	*Co. Int. cor.*	*Comp. Int.*
5	4,35208	4,08343	4,32948	4,23349	3,97582	4,21236
10	7,64478	7,33314	7,72174	7,25579	7,00322	7,36009
15	10,10821	9,91935	10,37966	9,39341	9,30843	9,71225
20	11,95980	11,97753	12,46221	10,92350	11,06373	11,46992
30	14,45407	14,91902	15,37245	12,87275	13,41805	13,76483
40	15,97990	16,78200	17,15909	13,99744	14,78309	15,04630
50	16,96682	17,96190	18,25593	14,69544	15,57456	15,76186
70	18,10986	19,18247	19,34268	15,47252	16,29953	16,38454
100	18,91525	19,79231	19,84791	15,99759	16,59510	16,61755
F.S.	20,00000	20,00000	20,00000	16,66666	16,66666	16,66666

The Theorems to the preceding Columns of Amounts (of which the fourth and fifth are infinitely variable in the Reſult, by aſſuming *c* and *t* in the reduc'd Rates at pleaſure) may ſerve to anſwer all ſimple Caſes of Amounts that occur in Buſineſs: To inſtance in ſome,

1. The firſt Column contains the Amounts of ſuch Debts, or Sums of Money, as carry a ſimple Intereſt till the Principal be paid.

2. The ſecond Column anſwers the common Caſe of Debts due by Bond, that by Law are allow'd not to exceed the Penalty, which is generally double the principal Debt.

3. The third Column anſwers the Caſe of a Security or joint Obligor, that has duly and conſtantly paid the Intereſt, and at laſt the principal Sum of a Debt, from which he has a Counter-Bond from the principal Debtor, to ſave him harmleſs, againſt whom he may make his Charge from this Column.

4. In caſe the Parties ſhall agree that the Debt ſhall lie for any time certain, or uncertain; and for the much greater eaſe, advantage and Satisfaction of both of them, no Intereſt to be call'd for, till the Principal it ſelf is paid; but to carry Intereſt as it becomes due, the Lender allowing for the Time and Charge he muſt have been at, in receiving and putting out his Intereſt, the fourth Column will fit this Caſe, or elſe the fifth as a greater or leſs Degree of Lenity is agreed upon in favour of the Borrower.

5. The fifth Column is alſo proper in the following Caſe, *viz.* if it be demanded what Eſtate in reverſion, after a certain number of Years, any Sum in Hand will purchaſe; the firſt ſtep being to find the Amount of that Sum to the Time the Reverſion commences, it's had in this Column.

6. The laſt Column gives the Amount of a Sum of Money, according to the common Method of Compound Intereſt, but being computed with that extraordinary rigor as has been ſaid, (except ſome ſmall Allowance for the Loſs of Time, by being done yearly) 'tis hardly ſuitable to any Caſe.

Other

Other Caſes might be enumerated, to which the foregoing Theorems might be equitably apply'd; beſides ſuch extraordinary ones, wherein it may appear to Arbitrators, or a Court of Equity, that either Party deſerves Favour, either by way of Compenſation for Injuries ſuffer'd from the other, by means of any fraudulent or oppreſſive Practices, or otherwiſe, for which no other redreſs is provided.

Of Intereſt Accounts.

The Inequality of the uſual Method of ſtating *Intereſt Accounts*, as practis'd in our Courts of Equity, will beſt appear by an Example, for which I ſhall take the common general Caſe of an Intereſt-Account to be ſtated on a Mortgage, *viz.* ſuppoſe 1000 *l.* to be let out at 6 *per Cent.* on a Mortgage of 120 *l. per Annum*, payable Half-Yearly, and the Mortgagee after five Years end, to have Poſſeſſion till the Arrear of Intereſt, accruing Intereſt and Principal be diſcharged: *Quære*, How long that will be? ſuppoſing alſo, for the Sake of Brevity in the Account, the Payments to be equally, and punctually made as they become due. By the Chancery Method, the Rent is firſt apply'd to diſcharge the Arrear of Intereſt; and then the Remainder of every Half-Year's Rent, after deducting the ſame Half-Year's Intereſt, is applv'd towards the Diſcharge of the Principal, and thereby the Principal and Intereſt continually leſſens, till the whole be paid off. Now by this means the Mortgagee, after the Arrear is diſcharged, pays Compound Intereſt, with the utmoſt rigor, for ſo much *per Annum* of the Rent, as exceeds the Intereſt of the whole Principal Money, and receives but Simple-Intereſt for his Debt; which however ſtrange it may ſeem, is eaſily prov'd, by applying the proper Theorems of Simple and Compound-Intereſt to this Caſe, in which the Annuity, Principal Money, Rate and Arrear of Intereſt are given, and the Time requir'd; the Reſult being the ſame with that of the Chancery Method, except a very ſmall Difference only when any part of the Time is expreſs'd by a Fraction: *viz.* putting *L* for Logarithm, $a = a - pr = 30$, $s = 1 + r = 1{,}03$, $t =$ time of contracting the Arrear $= 10$ Half-years, $n =$ any Number of Half-years ſpent in diſcharging the whole or any Part, $N =$ Number of Years required; the Equation for the Arrear will be $prt + prn = an$; and for the Principal and accruing Intereſt $prn + p = prn + \frac{s^n - 1}{r} \times a$. Whence $\frac{prt}{2a} + \frac{La - La}{2Ls} = N = 16{,}7249$ Years $=$ the time demanded; *i. e.* $\frac{prt}{2a} =$ the time of diſcharging the Arrear, and $\frac{La - La}{2Ls} = 11{,}7249$ Years, $=$ the time in which the Principal and accruing Intereſt is diſcharged; during which it's evident, the Mortgagee pays full Compound-Intereſt for 60 *l. per Annum* of the Rent. For the Correction of which Inequality, in the firſt place, to the end that neither Branch may exceed, or be depriv'd of its due Profits; this general

Rule is propos'd as neceſſary to be always obſerv'd, *viz.* that Amounts of the Produce on each Side be ſtated ſeparately, and ſet againſt each other in the Account, in order to a Balance. And in the common Caſes of Mortgages, Government, and Stock-Securities, *&c.* where the Debt is paid off by a Rent, Annuity, Penſion, Dividend, or other Payments iſſuing in the ſame manner, and with the like Trouble, Charge, *&c.* as Intereſt-Money does; I preſume this Rule will alſo be eaſily admitted, *viz.* that the ſame equitable Advantage be impartially allow'd on both Sides; for which the Method of Simple Intereſt, as corrected under the foregoing Head, ſeems truly adapted; whereby the original Profits on each ſide are ſuppos'd to be deem'd, either as Intereſt, or elſe as principal Money. And ſince the Amounts both of an Annuity and Sum of Money, for the Time paſt, as they are ſtated, on the firſt of theſe Suppoſitions (t being there $= 0$) are likewiſe vouch'd by our Laws, and the Practice of our Courts, to be good when ſeparately us'd; I think it's very evident, that the Account ought to be ſtated by ſetting thoſe Amounts againſt each other thus, $p\,r\,t + p\,r\,n + p = a\,n$, (whence $\frac{1 + t\,r}{2\,a}\,p = N$, $= 21{,}6666$ Years) and that this Method is moſt proper for general Uſe, in the Caſes mention'd: Unleſs it ſhould be thought fit, in Conſideration of the various Ways found out for the ready Improvement of Money, to allow a further Advantage on both ſides, by charging the Original Profits as Principal Money, and giving a Simple-Intereſt there too, which ſtill falls ſhort of the Advantage allow'd to Rents by the Chancery Method. And this is to be done two ways, *viz.* either by applying an Amount of Rent to pay off the Arrear firſt, and afterwards another Amount of Rent to diſcharge the Principal, and accruing Intereſt; or elſe by letting the Profits with all Arrears and other Charges run on at Simple-Intereſt on each ſide, till the End of the Term: *viz.* putting $x = n - 1$, $y = t - 1$, $a = a - p\,r$, $f = 2 - r \times a$, $g = f - 2\,p\,t\,r^2$, $\mu = \overline{\frac{1}{2}\,y\,r + 1} \times p\,r\,t$ = Arrear of Intereſt; by the firſt of theſe 'twill be, for the Arrear, $\mu + p\,t\,r^2\,n = \overline{\frac{1}{2}\,x\,r + 1} \times a\,n$, and for the Principal and accruing Intereſt, $\overline{\frac{1}{2}\,x\,r + 1} \times a\,n = p$; Whence $\frac{\sqrt{8\,\mu\,a\,r + g^2} - \sqrt{8\,p\,a\,r + f^2} - f + g}{4\,a\,r}$ $= N = 18{,}7653$ Years. By the other 'twill be, for the whole, $\mu + p\,t\,r^2\,n + p = \overline{\frac{1}{2}\,x\,r + 1} \times a\,n$. Whence $\frac{\sqrt{\mu + p} \times 8\,a\,r + g^2 - g}{4\,a\,r} = N =$ $18{,}1648$ Years. The Lender will have to alledge for the firſt of theſe two Ways, that as the Rent is not hindred by any other parallel Charge

Charge from making the utmoſt Produce it can, ſo for that reaſon ought his Principal-Mony to have the Advantage of the Arrears being firſt diſcharged; which alſo agrees with the Chancery Method in this Particular.

Laſtly, another way of ſtating this Account, may be taken from that Notion of Simple-Intereſt, whereby the Annuity only is charged as Principal-Money: And then 'twill be, for the Arrear, $prt+prn=an$, and for the Principal and accruing Intereſt, $\frac{1}{2}xr+1 \times an = p$: Whence $\frac{\sqrt{8par+f^2}-g}{4ar}(=\frac{prt}{2a}+\frac{\sqrt{8par+f^2}-f}{4ar}=N=$ 17,3072 Years; which appears to be the ſame with the Chancery-Method, only that the Compound-Intereſt in that, is turned into Simple in this; and as it ſtill retains part of the ſame Inequality, to the Advantage of the Borrower, it ſeems only fit to be obſerved in ſuch Caſes wherein the Borrower may be thought to merit Favour; as when the Debt is paid out of the Profits of Trade, ariſing by extraordinary Riſque or Induſtry. But ſince ſuch a Rule of Diſtinction is hardly poſſible to be reduced to general Practice, the uſe of this Theorem ſeems reſtrained to ſuch Caſes only, wherein the Parties themſelves, or a Court of Equity ſhall think it reaſonable.

For the further Illuſtration of theſe Rules, the following Specimen is added, which ſhews at ſight, how the Reſults of the ſeveral Methods differ, as the Rent, Arrear, or Rate of Intereſt, is greater or leſs; and conſequently of how much more or leſs Concern it is to the Parties, as well as to the due Adminiſtration of Juſtice, to have regard thereto.

I muſt alſo obſerve for the Sake of ſuch as are unacquainted with ſpecious Arithmetic, that though for brevity's ſake, the foregoing Theorems and Examples are laid down, and wrought in Algebraic Terms; yet the ſame Accounts may be ſtated after the Chancery-manner itſelf, according to the ſeveral Principles before deliver'd, that (inſtead of a continual Deduction of the Rent or Annuity out of the Principal and Intereſt of the Debt, which occaſions the Error before-mentioned) the preceding General Rule of ſtating ſeparate Amounts be obſerv'd, which may be done by continually adding the Profits together on each ſide, in the ſame manner, as if the Parties were to make a ſeparate Charge againſt each other; which is the rather to be noted, as being the only Courſe that can be taken, in caſe the Sums or Times of Payment ſhould differ, but the reſpective Reſults will notwithſtanding be analogous to the Examples.

The Time requir'd in ———	Years (computed Half-yearly)			
To diſcharge a Mort. of 1000 *l.* by a Rent of	120 *l. per annum.*		90 *l. per annum.*	
At the Rate of Int. *per annum* of ———	5 *per C.*	6 *per C.*	5 *per C.*	6 *per C.*
No Arrear of Intereſt.				
By the Chancery Method ———	10,9141	11,7249	16,4205	18,5835
By the ſame turning the Comp. Int. into Sim.				
By Simp. Int. cor. the Original Profits charged as } Princ. and the Arrear Intereſt { contin^d at Int. firſt diſcharg'd	11,2579	12,3072	17,5335	20,7400
	14,2857	16,6666	25,0000	33,3333
5 Years Arrear of Intereſt.				
By the Chancery Method ———	14,4853	16,7249	22,6705	28,5835
By the ſame turning the Comp. Int. into Sim.	14,8293	17,3072	23,7835	30,7400
By Simp. Int. cor. the Original Profits charged as } Princ. and the Arrear Intereſt { contin^d at Int. firſt diſcharg'd	15,3191	18,1648	24,7148	32,7064
	15,5897	18,7653	25,4899	34,8052
	17,8571	21,6666	31,2500	43,3333
10 Years Arrear of Intereſt.				
By the Chancery Method ———	18,0569	21,7249	28,9205	38,5835
By the ſame turning the Comp. Int. into Sim.	18,4007	22,3072	30,2335	40,7400
By Simp. Int. cor. the Original Profits charged as } Princ. and the Arrear Intereſt { contin^d at Int. firſt diſcharg'd	20,3161	25,5998	33,6320	48,0874
	21,2895	27,5587	36,1932	53,8107
	21,4286	26,6666	37,5000	53,3333
15 Years Arrear of Int.				
By the Chancery Method ———	21,6283	26,7249	35,1705	48,5835
By the ſame turning the Comp. Int. into Sim.	21,9721	27,3072	36,2835	50,7400
By Simp. Int. cor. the Original Profits charged as } Princ. and the Arrear Intereſt. { contin^d at Int. firſt diſcharg'd	26,1353	34,2913	43,9764	65,8386
	28,0209	37,7141	48,5159	74,5664
	25,0000	31,6666	43,7500	63,3333

All which is ſubmitted to the Conſideration of more diſcerning Judgments, eſpecially the Applications of the Rules to particular Caſes, for exemplifying the Theorems. But if any of thoſe Rules or Theorems ſhould be objected againſt, meerly becauſe they tend to introduce ſome Alterations in the preſent Practice; I ſhall for anſwer only add, that in former Ages, when our Laws relating to theſe Matters had their riſe, (the Profits of *England* ariſing chiefly from Huſbandry and Tillage, and little from Trade,) the Caſh of the Kingdom was but low, the Rates of Intereſt very high to the Advantage of Uſurers, and thoſe Ways for the ready Improvement of Money accommodated to all People's uſe, not known; (much like to which we are told was the State of the Jewiſh Affairs, when they were forbidden to take Uſury of any but Strangers.) But latter Ages have produc'd vaſt Alterations in all theſe Reſpects, which having happen'd by inſenſible Degrees, may be one Reaſon, why neither our Legiſlature, nor Courts of Judicature have yet taken ſuch Notice thereof, as Time and Leiſure, with the Tender of proper and practical Methods of Computation, may hereafter induce them to do.

VIII.

A Solution of the XV Problem *of Mr.* de Moivre, *in his Treatise of the* Value *of* Chances, *by Mr.* N. Bernoulli. n. 341. p. 133.

VIII. Whereas the ſynthetical Method, which Mr. *de Moivre* makes uſe of for finding the Chance of every Gameſter, cannot be apply'd to Practice when there are more Players than three, becauſe of the Law of the Progreſſion of theſe Series which offer themſelves, which is hardly to be perceived; I will here ſhew in what manner the Analyſis may be proſecuted, when the Stakes continually increaſe; for which end I ſhall give the analytical Demonſtration of three Theorems which I have found, and long before I ſaw Mr. *Moivre*'s Book de *Menſura Sortis*, on occaſion of three Queſtions propoſed to me by a Friend about that Game, which the *French* call *Jeu de la Poule*; that is, for finding the Probability of winning, the Gain or Loſs of each Player, and the Duration of the Game.

Theor. I. If any number of Gameſters A, B, C, D, E, *&c.* the Number of which is $n+1$, and their Skill equal, each lay down the Stake 1, and play upon theſe Conditions; firſt that two of them, A and B ſhall begin the Game. Secondly, that he that is beat ſhall yield his Place to the third C, ſo that this Third ſhall take up the Conqueror; and he that wins this Game ſhall play with the Fourth D, and ſo on. Thirdly, that he ſhall win all the Stakes who ſhall ſucceſſively beat all the Gameſters. I ſay that the Probability of winning of any two Gameſters that immediately follow one another in the Order of Play, is in the Ratio of $1+2^n$ to 2^n, and therefore that the Expectations of the Gameſters A, B, C, D, E, *&c.* are in Geometrical Progreſſion.

Demonſtration. Let the Expectations of winning of A or B be $=a$, of $C=c$, of $D=d$, of $E=e$, &c. Now as it may happen, that any of the Players entring the Game the firſt time may find an Adverſary, who has already been ſucceſſively Conqueror, either not at all, or once, or twice, or three times, *&c.* Let the Expectation of that Gameſter in the firſt caſe be $=z$, in the ſecond $=y$, in the third $=x$, in the fourth $=u$, in the fifth $=t$, *&c.* Alſo ſince any Gameſter may be beat by an Adverſary, who has before ſucceſſively conquer'd either none, or one, or two, or three, *&c.* of the Gameſters, ſo that going out of Play he may leave an Adverſary who has been Conqueror either once, or twice, or three times, *&c.* let the Expectation or Probability of winning of him who goes out, in the firſt caſe be equal to h, in the ſecond to k, in the third to l, in the fourth to m, *&c.* All theſe things being ſuppoſed, we ſhall have the nine following Series of Equations, mark'd N°. 1. N°. 2. N°. 3. *&c.* as far as N°. 9. *Tab.* 1. The Method of finding them in ſhort is this.

Among the Equations N°. 1. is found for Inſtance $f=\frac{1}{8}t+\frac{1}{8}u+\frac{1}{4}x+\frac{1}{2}y$. For the Player F will play either with the Gameſter

ſter A, or B, or C, or D, or E. Now that the firſt or ſecond may happen, it is neceſſary that either A or B may be Conqueror 4 times ſucceſſively, the Probability of which Event is $\frac{2}{16}$ or $\frac{1}{8}$. That the third may happen, it is neceſſary that C may be Conqueror three times, the Probability of which Event is alſo $\frac{1}{8}$. That the fourth may happen it is neceſſary that D may be Conqueror twice ſucceſſively, the Probability of which is $\frac{1}{4}$. That the fifth thing may happen it is neceſſary that E ſhould conquer once, the Probability of which Event is $\frac{1}{2}$. Therefore the Probability of winning of the Gameſter F is equal to $\frac{1}{8}t + \frac{1}{8}u + \frac{1}{4}x + \frac{1}{2}y$. Thus among the Equations N°. 2. it is for inſtance $x = \frac{1}{2}l + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \text{--} \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$. For he that plays with an Adverſary who has already been twice Conqueror, may beat either all the Gameſters, or ſome of them, or none. The Probability of the firſt Event is $\frac{1}{2^n}$, of the ſecond is $\frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \text{--} \frac{1}{2^n}$, and of the third $\frac{1}{2}$. If the firſt Event happens, the Probability of winning is a compleat Certainty, or 1; if the ſecond, he goes out leaving a Gameſter who has beat once; if the third, he goes out leaving a Gameſter who has beat three times ſucceſſively, and therefore his whole Chance is $\frac{1}{2}l + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \text{--} \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$. By a like Reaſoning are found the Equations N°. 3. For the Gameſter who being beat by his Adverſary goes out of the Game, leaving for Example a Player who has won only one Game, acquires the Chance either of C, or of D, or of E, or of F, *&c.* according as the Adverſary by whom he is beat has conquer'd either all the Gameſters except one, or all except two, or all except three, *&c.* Whence it follows that $b = \frac{1}{2^{n-1}} \times c + \frac{1}{2^{n-2}} \times d + \frac{1}{2^{n-3}} \times e + \frac{1}{2^{n-4}} \times f$, *&c.* The Equations N°. 4. are found by ſubtracting the Equations N°. 2. from one another. And the Equations N°. 5. by ſubtracting the Equations N°. 3. from one another. The Equations N°. 6. are found by ſubſtituting

TABULA. II.

Intrat Depositum		Sors	Exit Depositum		Sors	Deposit.	
$n+1$	0	Z	$n+1+p$		H	$n+1+$	$A-Z$
$n+1+p$	1	Y	$n+1+2p$		K	$n+1+p$	$C-Y$
$n+1+2p$	2	X	$n+1+3p$		L	$n+1+2p$	$D=\frac{1}{2}X+\frac{1}{2}\times\overline{Y+yp}$
$n+1+3p$	3	V	$n+1+4p$		M	$n+1+3p$	$E=\frac{1}{4}V+\frac{1}{4}\times\overline{X+xp}+\frac{1}{2}\times\overline{Y+2yp}$
$n+1+4p$	4	T				$n+1+4p$	$F=\frac{1}{8}T+\frac{1}{8}\times\overline{V+up}+\frac{1}{4}\times\overline{X+2xp}+\frac{1}{2}+\overline{Y+3yp}$

N.° 1

N.° 2

$$Z=\tfrac{1}{2}\times\overline{H-p}+\tfrac{1}{4}\times\overline{H-p+hp}+\tfrac{1}{8}\times\overline{H-p+2hp}+\tfrac{1}{16}\times\overline{H-p+3hp}+\text{---}\tfrac{1}{2^n}\times\overline{H-p+nhp-hp}+\tfrac{1}{2^n}\times\overline{np+n+1}$$

$$Y=\tfrac{1}{2}\times\overline{K-p}+\tfrac{1}{4}\times\overline{H-p+2hp}+\tfrac{1}{8}\times\overline{H-p+3hp}+\tfrac{1}{16}\times\overline{H-p+4hp}+\text{---}\tfrac{1}{2^n}\times\overline{H-p+nhp}+\tfrac{1}{2^n}\times\overline{np+p+n+1}$$

$$X=\tfrac{1}{2}\times\overline{L-p}+\tfrac{1}{4}\times\overline{H-p+3hp}+\tfrac{1}{8}\times\overline{H-p+4hp}+\tfrac{1}{16}\times\overline{H-p+5hp}+\text{---}\tfrac{1}{2^n}\times\overline{H-p+nhp+hp}+\tfrac{1}{2^n}\times\overline{np+2p+n+2}$$

$$V=\tfrac{1}{2}\times\overline{M-p}+\tfrac{1}{4}\times\overline{H-p+4hp}+\tfrac{1}{8}\times\overline{H-p+5hp}+\tfrac{1}{16}\times\overline{H-p+6hp}+\text{---}\tfrac{1}{2^n}\times\overline{H-p+nhp+hp}+\tfrac{1}{2^n}\times\overline{np+3p+n+2}$$

N.° 3

$$H=\tfrac{1}{2^{n-1}}\times\overline{C+ncp-cp}+\tfrac{1}{2^{n-2}}\times\overline{D+ndp-2dp}+\tfrac{1}{2^{n-3}}\times\overline{E+nep-3ep}+\tfrac{1}{2^{n-4}}\overline{F+nfp-4fp}+\text{---}$$

$$K=\tfrac{1}{2^{n-2}}\times\overline{D+ndp-dp}+\tfrac{1}{2^{n-3}}\times\overline{E+nep-2ep}+\tfrac{2}{2^{n-4}}\times\overline{F+nfp-3fp}+\text{---}$$

$$L=\tfrac{1}{2^{n-3}}\times\overline{E+nep-ep}+\tfrac{1}{2^{n-4}}\times\overline{F+nfp-2fp}+\text{---}$$

$$M=\tfrac{1}{2^{n-4}}\times\overline{F+nfp-fp}+\text{---}$$

N.° 4

$$Y-Z=\tfrac{1}{2}K-\tfrac{1}{2}H+\tfrac{1}{4}hp+\tfrac{1}{8}hp+\tfrac{1}{16}hp+\text{---}\tfrac{1}{2^n}\times hp=\tfrac{1}{2}K-\tfrac{1}{2}H+2p-\tfrac{1}{2}hp=-\tfrac{1}{2^{n-0}}\times C-\tfrac{ncp}{2^n}+2p$$

N.° 6

N.° 8

$$X-Y=\tfrac{1}{2}L-\tfrac{1}{2}K+\tfrac{1}{4}hp+\tfrac{1}{8}hp+\tfrac{1}{16}hp+\text{---}\tfrac{1}{2^n}\times hp=\tfrac{1}{2}L-\tfrac{1}{2}K+2p-\tfrac{1}{2}hp=-\tfrac{1}{2^{n-1}}\times D-\tfrac{ndp}{2^{n-1}}-\tfrac{cp}{2^n}+2p$$

$$V-X=\tfrac{1}{2}M-\tfrac{1}{2}L+\tfrac{1}{4}hp+\tfrac{1}{8}hp+\tfrac{1}{16}hp+\text{---}\tfrac{1}{2^n}\times hp=\tfrac{1}{2}M-\tfrac{1}{2}L+2p-\tfrac{1}{2}hp=-\tfrac{1}{2^{n-2}}\times E-\tfrac{nep}{2^{n-2}}-\tfrac{dp}{2^{n-1}}-\tfrac{cp}{2^n}+2p$$

N.° 5

N.° 7

$$K-H=-\tfrac{1}{2^{n-1}}\times\overline{C+ncp-cp}+\tfrac{1}{2^{n-2}}\times dp+\tfrac{1}{2^{n-3}}\times ep+\tfrac{1}{2^{n-4}}fp+\text{---}=-\tfrac{1}{2^{n-1}}\times C-\tfrac{ncp}{2^{n-1}}+hp$$

$$L-K=-\tfrac{1}{2^{n-2}}\times\overline{D+ndp-dp}+\tfrac{1}{2^{n-3}}\times ep+\tfrac{1}{2^{n-4}}\times fp+\text{---}=-\tfrac{1}{2^{n-2}}\times D-\tfrac{ndp}{2^{n-2}}-\tfrac{cp}{2^{n-1}}+hp$$

$$M-L=-\tfrac{1}{2^{n-3}}\times\overline{E+nep-ep}+\tfrac{1}{2^{n-4}}fp+\text{---}=-\tfrac{1}{2^{n-3}}\times E-\tfrac{nep}{2^{n-3}}-\tfrac{dp}{2^{n-2}}-\tfrac{cp}{2^{n-1}}+hp$$

N.° 9

$$Z=A$$
$$Y=C$$
$$X=2D-C-cp$$
$$V=4E-2D-C-2dp-2cp$$

N.° 10

N.° 8

$$C-A=Y-Z=-\tfrac{1}{2^n}\times C-\tfrac{ncp}{n}+2p$$

$$2D-2C-cp=X-Y=-\tfrac{1}{2^{n-1}}\times D-\tfrac{ndp}{2^{n-1}}-\tfrac{cp}{2^n}+2p$$

$$4E-4D-2dp-cp=V-X=-\tfrac{1}{2^{n-2}}\times E-\tfrac{nep}{2^{n-2}}-\tfrac{dp}{2^{n-1}}-\tfrac{cp}{2^n}+2p$$

N.° 11

$$C=\frac{A\times 2^n+ap\times 2^n-ncp}{1+2^n}$$

$$D=\frac{C\times 2^n+cp\times\overline{2^{n-1}-\frac{1}{2}}+ap\times 2^{n-1}-ndp}{1+2^n}$$

$$E=\frac{D\times 2^n+dp\times\overline{2^{n-1}-\frac{1}{2}}+cp\times\overline{2^{n-2}-\frac{1}{4}}+ap\times 2^{n-2}-nep}{1+2}$$

N.° 12

$$=\frac{A+ap\times 2^n-ncp}{1+2^n}$$

$$=\frac{\overline{C+cp}\times 2^n-ndp}{1+2^n}$$

$$=\frac{\overline{D+dp}\times 2^n-nep}{1+2^n}$$

ſtituting the Values found by the Equations N°. 5. in the Equations N°. 4. The Equations N°. 7. are found by ſeeking the Values of z, y, x, u, *&c.* by the Equations N°. 1. And theſe Values being ſubſtituted in the Equations N°. 4. the Equations of N°. 8. will be had, which being compared with the Equations N°. 6. give the Equations of N°. 9. from whence it follows that $1+2^n \,.\, 2^n :: a \,.\, c :: c \,.\, d :: d \,.\, e$, *&c. Q. E. D.*

Corol. Hence the Probabilities of winning of all the Gameſters are eaſily found, which they have either before the Game begins, or in whatever State they can arrive in the Progreſs of the Game. For Example, if there are three Gameſters A, B, C, then will $n=2$, and $1+2^n \,.\, 2^n :: 5 \,.\, 4 :: a \,.\, c$. That is, the Probabilities of winning of A, B, C, before A beats B, or B beats A, will be as the Numbers 5, 5, 4, and therefore the Probabilities themſelves are as $\frac{5}{14}$, $\frac{5}{14}$, $\frac{4}{14}$. For all taken together ought to make 1, or perfect Certainty. After A has beat B, the Probabilities of winning of B, C, A, will be b, y, or c, and (becauſe A has an equal Expectation of the Victory, and to win B's Stake,) $\frac{1+b}{2}$ reſpectively; that is, becauſe by the firſt Equation N°. 3. 'tis $b = \frac{1}{2^{n-1}} \times c = \frac{1}{2} c$, and $c = \frac{4}{14} = \frac{2}{7}$ as is now found, their Probabilities will be $\frac{1}{7}$, $\frac{2}{7}$, $\frac{4}{7}$, as Mr. *de Moivre* has found, *Corol.* 1. *Prop.* 15. pag. 242.

If there are four Gameſters A, B, C, D, it will be $n=3$, and $1+2^n \,.\, 2^n :: 9 \,.\, 8$, and therefore the Probabilities of the Players at the beginning of the Game will be as 9, 9, 8, $\frac{8 \times 8}{9}$, or as 81, 81, 72, 64; that is, a, b, c, d, will be $\frac{81}{298}$, $\frac{81}{298}$, $\frac{72}{298}$, $\frac{64}{298}$. After A has beat B, the Probabilities of B, D, C, A, will be b, d, c, $\frac{1+3b}{4}$. But it is by the firſt Equation, N°. 3. $b = \frac{1}{2^{n-1}} \times c + \frac{1}{2^{n-2}} \times d = \frac{1}{4} c + \frac{1}{2} d \,.\, c = \frac{72}{298} = \frac{36}{149}$, and $d = \frac{64}{298} = \frac{32}{149}$, as juſt now found. Therefore theſe Probabilities will be $\frac{25}{149}$, $\frac{32}{149}$, $\frac{36}{149}$, $\frac{56}{149}$ reſpectively. After A has beat B and C, the Pro-

babilities of winning of C, B, D, A, will be k, $\frac{c}{2}$, x, $\frac{1+b}{2}$, or (becauſe by the ſecond Equation N°. 3. 'tis $k = \frac{1}{2^{n-2}} \times d = \frac{1}{2} d$ and by the third Equation N°. 7. 'tis $x = 2d - c$,) $\frac{16}{149}$, $\frac{18}{149}$, $\frac{28}{149}$, $\frac{87}{149}$. And it may be obſerved, that the Truth of the Calculation will be confirmed from hence, that the Sums of three Probabilities, that is, of $\frac{1}{7} + \frac{2}{7} + \frac{4}{7}$ in the firſt Example, and $\frac{25}{149} + \frac{32}{149} + \frac{36}{149} + \frac{56}{149}$, as alſo of $\frac{16}{149} + \frac{18}{149} + \frac{28}{149} + \frac{87}{149}$ in the laſt Example, are each equal to 1, or to perfect Certainty.

Theorem II. The ſame things being ſuppos'd as before, and this Condition being added, that he that is beaten ſhall always forfeit the Sum p, which ſhall increaſe the Stakes; that the Stakes ſo increaſed gradually ſhall belong to him who ſhall be Conqueror of all the Gameſters ſucceſſively; the Probabilities of winning of A (or B) C, D, E, *&c.* being ſtill denoted by the ſmall Letters a, c, d, e, *&c.* reſpectively, and their Expectations or Shares of the Stake which each expect by the reſpective great Letters A, C, D, E, *&c.* I ſay it will always be

$$C = \frac{A + ap \times 2^n - ncp}{1+2^n} \quad D = \frac{C + cp \times 2^n - ndp.}{1+2^n} \quad E = \frac{D + dp \times 2^n - nep}{1+2^n} \quad F, \&c.$$

Demonſtration. Let the Probability of winning of him that plays with his Adverſary be denoted as before by the ſmall Letters z, y, x, u, t, *&c.* who has already conquer'd ſucceſſively either none, or one, or two of the Gameſters. And by the ſame Capitals Z, Y, X, V, T, *&c.* his Expectation which he has in thoſe different Caſes, the Stakes being $n+1$, $n+1+p$, $n+1+2p$, $n+1+3p$, *&c.* reſpectively. Alſo thus by the ſmall Letters b, k, l, m, *&c.* let the Probability of winning be denoted, of the Gameſter beat by his Adverſary, who before had conquer'd either none, or one, or two, *&c.* of the Gameſters ſucceſſively; as alſo by the Capitals H, K, L, M, *&c.* let be denoted the Expectation of the ſame in thoſe different Caſes, the Stakes being $n+1+p$, $n+1+2p$, $n+1+3p$, *&c.* reſpectively. Theſe things being ſuppos'd, by the ſame way of reaſoning as before, the twelve following Series of Equations will be found mark'd in the ſecond Table N°. 1. N°. 2. N°. 3. *&c.* For Example among the

Equations

Equations N°. 1. it is $E = \frac{V}{4} + \frac{X + xp}{4} + \frac{T + 2yp}{2}$. For the Gameſter E will play either with the Gameſter A, or with B, or C, or D. If he plays with A or B, his Expectation will be $= V$, becauſe he plays with an Adverſary who has already beat three Adverſaries, the Stakes being $n+1+3p$. If he plays with the Gameſter C, his Expectation will be $= X + xp$; for he plays with an Adverſary who has already beat two Gameſters, and therefore if the Stake were $n+1+2p$, his Expectation would be $= X$. But becauſe when E plays the Stake is $= n+1+3p$, becauſe of three Gameſters already beat, who forfeit the Sum p; to the Expectation X muſt be added that part of one Forfeiture p, which the Gameſter E may hope for. Now this part is $= xp$, becauſe the Probability of his winning is x, and therefore his whole Expectation will be $= X + xp$. Thus if he plays with the Gameſter D, his Expectation will be $= Y + 2yp$. The Part $2yp$ is added to Y, which would be his Expectation, the Stakes being $n+1+p$, which part is due to him becauſe of the two Forfeitures $2p$, by which the Stakes $n+1+3p$ is greater than $n+1+p$. In a like manner will be had the Equations N°. 2, 3, 4, and 5. And by ſubſtituting the firſt Equation, N°. 2. *Tab.* I. in the Equations N°. 4. are had the Equations N°. 6. And by ſubſtituting the firſt Equation N°. 3. *Tab.* I. in the Equations N°. 5, are had the Equations N°. 7. which afterwards being ſubſtituted in the Equations N°. 6. are had the Equations N°. 8. The Equations N°. 9. are found by ſeeking the Values of Z, Y, X, V, *&c.* by the Equations N°. 1. *Tab.* I. and II. or N°. 2. *Tab.* II. and N°. 7. *Tab.* I. And theſe Equations being ſubſtituted in the Equations N°. 4, are had the Equations N°. 10. which being compared with the Equations N°. 8. (in which for z is ſubſtituted a, by Equat. 1. of *Tab.* I.) give the Equations N°. 11. And theſe Equations N°. 11. compared with the Equations N°. 9. T. 1. give the Equations N°. 12. which conſtitute the Theorem which was to be demonſtrated.

Corol. Hence alſo are eaſily found the Chances or Expectations of all the Gameſters, and thence their Gain or Loſs. For example, let there be three Gameſters A, B, C; 'tis $C = \frac{\overline{A + ap} \times 2^n - ncp}{1+2}$ $= (\text{becauſe } n = 2) \frac{4A + 4ap - 2cp}{5} = (\text{becauſe } a = \frac{5}{14}, \text{ and } c = \frac{2}{7},$ by the *Corollory* of *Theor.* I.) $\frac{4A + \frac{6}{7}p}{5}$. Now ſince the Expectations of all the three taken together, that is $A+A+C$, ought to be equal to the whole Stake at firſt, that is to 3, it will be $2A + \frac{4A + \frac{6}{7}p}{5} = 14A$

$= \frac{14A + \frac{6}{7}p}{5} = 3$, and $14A = 15 - \frac{6}{7}p$, or $A = \frac{15}{14} - \frac{3}{49}p$, which is equal to the Expectation of either of the Gameſters A or B. Therefore the Expectation of the third Gameſter C is $C = \frac{4A + \frac{6}{7}p}{5}$

$= \frac{6}{7} + \frac{6}{49}p$. From which Expectations if 1 is ſubtracted, which each ſtaked at the beginning, there will remain in the other $\frac{1}{14} - \frac{3}{49}p$, and here $\frac{6}{49}p - \frac{1}{7}$; as Mr. *De Moivre* has found.

Example 2. Let there be four Gameſters A, B, C, D. It will be $C = \frac{\overline{A + ap} \times 2^n - ncp}{1 + 2^n} =$ (becauſe $n = 3$) $\frac{8A + 8ap - 3cp}{9} =$ (becauſe $a = \frac{81}{298}$, and $c = \frac{36}{149}$, by *Corol.* of *Theor.* 1.) $\frac{8A + \frac{216}{149}p}{9}$. Alſo $D = \frac{\overline{C + cp} \times 2^n - ndp}{1 + 2^n} = \frac{8C + 8cp - 3dp}{9} =$ (becauſe $d = \frac{32}{149}$, by the ſame,) $\frac{8C + \frac{192}{149}p}{9} = \frac{64A + \frac{3456}{149}p}{81}$. Whence will be had the Equation $2A + C + D = 2A + \frac{8A + \frac{216}{149}p}{9} + \frac{64A + \frac{3456}{149}p}{9} =$ $\frac{298A + \frac{5400}{149}p}{81} = 4$, or $149A + \frac{2700}{149}p = 162$, and $A = \frac{162}{149} - \frac{2700}{22201}p$. Hence $C = \frac{8A + \frac{216}{149}p}{9} = \frac{144}{149} + \frac{1176}{22201}p$, and $D = \frac{64A + \frac{3456}{149}p}{81} = \frac{128}{149} + \frac{4224}{22201}p$. Now ſubtracting Unity, which each ſtaked at the beginning of the Game, there will remain $\frac{13}{149} - \frac{2700}{22201}p$ for the Gameſter A or B, $\frac{1176}{22201}p - \frac{5}{149}$ for C, and $\frac{4224}{22201}p - \frac{21}{149}$ for D; each of which will ſhew the Gain or Loſs, according as the affirmative or negative part ſhall prevail. And by a like Method will be had all the Chances which they acquire in every State of the Game which they may arrive at.

Theorem III. The ſame things being ſuppoſed as before, if the Spectators Q, R, S, T, V, *&c.* are preſent, whoſe Number is n,

that is, one less than the Number of Gamesters, the first of which Q affirms, that the Set will be over after $n+p$ Games are finish'd, R after $n+p-1$, S after $n+p-2$, T after $n+p-3$, V after $n+p-4$, *&c.* exactly and not before, and let q, r, s, t, u, *&c.* be the Chances of Q, R, S, T, V, *&c.* respectively. I say it will be $q = \frac{1}{2}r + \frac{1}{4}s + \frac{1}{8}t + \frac{1}{16}u + \&c.$

Demonstration. Let that Gamester be call'd A, who is suppos'd to win after $n+p$ Games. He is to come in after p Games, and then is to play with an Adversary, who has already successively beat either one, or two, or three, *&c.* of the Gamesters. Now that the first Case may happen, and that the Gamester A may successively beat all his Adversaries but one, that is $n-1$ Adversaries; since it is equally probable as that his Adversary should beat $n-1$ of the Gamesters, that is, (because he has already beat one of his Adversaries,) that the Set may conclude after $n+p-1$ Games are finish'd; and let the Probability of this Event be $=r$: The Probability that the Gamester A may beat one Adversary more, or that the Set shall end after $n+p$ Games, will be equal to $\frac{1}{2}r$. Thus that the second Case may happen, and that A may beat all the Gamesters except two, is equally probable as that the Set shall end after $n+p-2$ Games, and therefore that then A shall beat still two of the Gamesters, that is, that the Set shall end after $n+p$ Games, the Probability will be $=\frac{1}{4}s$. After the same manner in the third Case, that A may beat all the Gamesters, the Probability will be $= \frac{1}{8}t$; in the fourth $\frac{1}{16}u$; and so on. Wherefore indifferently that the Set may conclude after $n+p$ Games, the Probability is $\frac{1}{2}r + \frac{1}{4}s + \frac{1}{8}t + \frac{1}{16}u$, *&c.* $= q$. *Q. E. D.*

Corol. 1. It will be easy to find from hence what the Probability will be, that the Set shall finish in any given number of Games. For a Series of Fractions beginning from the Fraction $\frac{1}{2^{n-1}}$, whose Denominators increase in a continued duple Proportion, and the Numerator of each Fraction is the Sum of the Numerators of so many Fractions immediately foregoing as there are Units in $n-1$, will give all the Probabilities successively that the Set shall end at n, $n+1$, $n+2$, $n+3$, *&c.* Games exactly. And consequently if so many Terms of this Series are added together, as there are Units in $p+1$, their Sum will

will expreſs the Probability that the Set ſhall end at leaſt after $n+p$ Games are finiſh'd. For Example, if there are four Gameſters, and therefore $n=3$, we ſhall have this Series $\frac{1}{4}, \frac{1}{8}, \frac{2}{16}, \frac{3}{32}, \frac{5}{64}, \frac{8}{128}, \frac{13}{256}, \frac{21}{512}$, *&c.* from which if another is derived, $\frac{1}{4}, \frac{3}{8}, \frac{8}{16}, \frac{19}{32}, \frac{43}{64}, \frac{94}{128}, \frac{201}{256}$, *&c.* the Terms of which are the Sums of the Terms of the foregoing Series, the ſame Terms will denote the Probability, that the Set will finiſh at leaſt after 3, 4, 5, 6, *&c.* Games.

Corol. 2. Any Term of the former Series, except the firſt, as alſo the Sum of all the Terms, that is, any Term of the latter Series, may be thus expreſs'd in a general Form. If $n+1$ is the Number of Gameſters, and if p is the Number of Terms, the laſt Term of the former Series will be $\frac{1}{2^n} - \frac{p-n+1}{1\times 2^{2n}} + \frac{p-2n\times p-2n+3}{1\times 2\times 2^{3n}} - \frac{p-3n\times p-3n+1\times p-3n+5}{1\times 2\times 3\times 2^{4n}} + \frac{p-4n\times p-4n+1\times p-4n+2\times p-4n+7}{1\times 2\times 3\times 4\times 2^{5n}}$, *&c.* And the Sum of all the Terms, or the laſt Term of the latter Series will be $\frac{p+1}{1\times 2^n} + \frac{p-n\times p-2n+3}{1\times 2\times 2^{2n}} + \frac{p-2n\times p-2n+1\times p-2n+5}{1\times 2\times 3\times 2^{3n}} - \frac{p-3n\times p-3n+1\times p-3n+2\times p-3n+7}{1\times 2\times 3\times 4\times 2^{4n}}$, *&c.*

Corol. III. Any one may undertake, before the Game begins, to pay the Sum $n+1$, for which the Gameſters play, and all the Forfeitures, if at firſt there is given into his Hand the Sum $n+1+2^n-1\times p$.

I ſhall leave the Demonſtration of the two foregoing Corollaries to be found by the Curious in theſe Matters.

TABLE

TABLE I.

Comes in		Goes out	
	Chance		Chance
0	z	1	b
1	y	2	k
2	x	3	l
3	u	4	m
4	t		

N°. 1.

$a = z$

$c = y$

$d = \frac{1}{2}x + \frac{1}{2}y$

$e = \frac{1}{4}u + \frac{1}{4}x + \frac{1}{2}y$

$f = \frac{1}{8}t + \frac{1}{8}u + \frac{1}{4}x + \frac{1}{2}y$

N°. 2.

$z = \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \cdots \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$

$y = \frac{1}{2}k + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \cdots \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$

$x = \frac{1}{2}l + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \cdots \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$

$u = \frac{1}{2}m + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \cdots \frac{1}{2^n} \times b + \frac{1}{2^n} \times 1$

N°. 3.

$b = \frac{1}{2^{n-1}} \times c + \frac{1}{2^{n-2}} \times d \frac{1}{2^{n-3}} \times e + \frac{1}{2^{n-4}} \times f + \cdots$

$k = \frac{1}{2^{n-2}} \times d + \frac{1}{2^{n-3}} \times e + \frac{1}{2^{n-4}} \times f + \cdots$

$l = \frac{1}{2^{n-3}} \times e + \frac{1}{2^{n-4}} \times f + \cdots$

$m = \frac{1}{2^{n-4}} \times f + \cdots$

N°. 4.

N°. 4.

$$z - y = \frac{1}{2} b - \frac{1}{2} k = \frac{1}{2^n} \times c = a - c$$

$$y - x = \frac{1}{2} k - \frac{1}{2} l = \frac{1}{2^{n-1}} \times d = 2c - 2d$$

$$x - u = \frac{1}{2} l - \frac{1}{2} m = \frac{1}{2^{n-2}} \times e = 4d - 4e$$

N°. 5.

$$b - k = \frac{1}{2^{n-1}} \times c$$

$$k - l = \frac{1}{2^{n-2}} \times d$$

$$l - m = \frac{1}{2^{n-3}} \times e$$

N°. 6.

$$\frac{1}{2^n} \times c$$

$$\frac{1}{2^{n-1}} \times d$$

$$\frac{1}{2^{n-2}} \times e$$

N°. 7.

$$z = a$$
$$y = c$$
$$x = 2d - y = 2d - c$$
$$u = 4e - x - 2y = 4e - 2d - e$$

N°. 8.

$$a - c$$

$$2c - 2d$$

$$4d - 4e$$

N°. 9.

$$c = a \times \frac{2^n}{1 + 2^n}$$

$$d = c \times \frac{2^n}{1 + 2^n}$$

$$e = d \times \frac{2^n}{1 + 2^n}$$

Of a New Paſſage *of the* Drink *and* Urine; *by Monſ.* Morin. *Communicated by Monſ.* Blondel. n. 278. p. 1101.

IX. Monſieur *Morin* (in the Aſſembly of the *Academy* of *Sciences*) having obſerved the extreme Swiftneſs with which the Drink paſſes ſometimes, as they find that drink *medicinal* Waters, thence conjectured that it did not always go the way which *Anatomy* ſhews us it takes ordinarily; and that therefore it ought to have another ſhorter Paſſage, which is not yet diſcovered. A ſtrong Proof of this his Conjecture is, that thoſe who purge with an Infuſion of *Caſſia*, render in a very ſhort time by Urine, a Tincture as black almoſt as the Infuſion they have taken; which would not conſtantly happen, if the Drink took always the ordinary Way. In order to diſcover this unknown Paſſage for the Urine, he began with the Explication of the Uſe of the Drink, which is to help the Digeſtion, and to ſerve for a *Vehicle* to the *Chyle*: He ſaid, that the *Urine* is nothing elſe but the Drink itſelf, which having ſerved for this Purpoſe, is afterwards caſt out more or leſs loaded; that thoſe who drink much without eating, as when they take the Waters, render their Urine very ſuddenly, and that without Colour. On the contrary, they that drink little and eat much, render theirs ſlower and high coloured; and laſtly, they who both eat and drink very much, render theirs at firſt one Part leſs coloured, and afterwards another Part high coloured later.

From

From whence, and from what he had before ſaid, he inferr'd, that the Drink, beſides the ordinary Paſſage which it has to the Bladder by the *Emulgent* Veins, *Kidneys*, and *Ureters*, has likewiſe another by the Pores of the *Stomach*, and of the *Bladder*. He called thoſe the firſt *Urines*, which paſs by this new Way, and the ſecond *Urines*, thoſe that paſs the ordinary way. He afterwards proved the Poſſibility of this new *Syſtem* by Experiments. He ſaid, that having taken the *Ventricle* and *Bladder* out of a dead Body, and filled them with Water, it run all out through the Pores; and turning them inſide outwards, the Water that was put in them, run through after the ſame manner; and that laſtly, letting them ſwim in Water, it eaſily ſoaked through into them. From which he concludes, that in a living Body, it ought to paſs with much greater Facility by the *Tenſion* of the Stomach; for the *Aliment*, like a Sponge, ſoaks up the *Liquor* in which it ſwims, and ſo ſwells up the *Stomach*, which in its turn again preſſing the Food, ſqueezes out the Liquor from it, and forces it to filter through its Pores. With this Preſſion it is eaſy to conceive, that the Drink muſt paſs eaſier through the Pores of the *Stomach* than the Water, which was put into the *Stomach*, taken out of the dead Body; and that this *Liquor* re-entering into the *Bladder*, makes the firſt *Urine:* It is evident likewiſe, that this Preſſion is never ſtrong enough to preſs out all the *Liquor* from the *Stomach*, and ſo there remains enough to carry on the *Aliment* and *Chyle*; after which it comes away high loaded and coloured, and makes what he calls the ſecond *Urines*. He added, that the Paſſage of the Drink into the Capacity of the lower Belly did not cauſe the *Dropſy*, becauſe that Liquor aided by the Preſſure of the Parts that encompaſs it, finds an eaſy Entrance into the *Bladder*, and none into the *Inteſtines*, becauſe of the thick *Mucus* that lines them. The Eaſineſs of this Paſſage is the Cauſe that *Mineral* Waters run away ſo ſuddenly by the firſt Ways, and by the ſecond; but much more by the firſt, when there is but little Nouriſhment in the Stomach; for there runs more or leſs Urine by the firſt Ways than by the ſecond, in proportion to the *Aliment* taken, and to the *Surplus* of what is neceſſary for the Digeſtion, reſpect being had likewiſe to what paſſes inſenſibly by Tranſpiration.

This *Syſtem* being ſo laid down, he gave the Reaſons of two conſiderable *Phænomena*.

The firſt was, the different Colour of the Urine that is made at different Times; which proceeded from hence, that thoſe that paſs by the firſt Ways are but little charged, whereas the other that paſs by the ſecond Ways, having ſerved for a Vehicle to the Chyle, and circulated with the Maſs of Blood, are charged with the volatile and ſulphureous Parts, and other Excrements of the Blood, and conſtantly more coloured.

The ſecond *Phænomenon* was the Red, Greeniſh, and ſometimes Blackiſh Colour of the Urine of thoſe that are purged with the Infuſion

of *Caſſia.* This, according to him, is, becauſe the Tincture paſſes by the firſt Ways, as was experimented in the Stomach of a dead Man, where this Liquor paſſes indeed more ſlowly, and in a leſs Quantity, but always of a greeniſh Red. It is the ſame of the Red Tincture of the Urine after eating Beets; of the Violet Brown, which is obſerved after drinking of Mineral Waters; of the Smell of *Violets* after taking Pills of Turpentine, and of the ſtrong Smell after *Aſparagus*: all which comes from the firſt Urines, being charged with that Colour and Smell, which is not taken away by any thing that is mixed with it; whereas the ſecond Urine, which carries the Chyle and Aliment, has no other Colour or Smell than Urine ordinarily has. Monſieur *Morin* did not give this Syſtem as New, but as explained more exactly, and in ſome meaſure demonſtrated by the Experiments he reported.

Two Anatomical *Obſervations; by Mr.* W. Cheſelden, n. 337. p.

X. I have met with an *Ureter* double of two Thirds of its Length next the Kidneys, and diſtended by Stones paſſing thro' it.

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