XII. *The State of the* Tides *in* Orkney; *by Mr.* Murdoch Mackenzie.

Read May 25. 1749. NO Accounts of the Flux and Reflux of the Sea were ſatisfactory, till Sir *Iſaac Newton*'s penetrating Genius deduced their true Cauſe from the Laws of Gravitation. His Principles carried ſuch Conviction along with them, and gave ſuch an eaſy Solution of ſome of the moſt remarkable *Phænomena*, that Mankind ſeemed to imagine a thorough Knowledge of the Tides might be obtained from an attentive Conſideration of the Principles he had eſtabliſhed, without the Trouble of further Obſervations; but, as he, and all Philoſophers ſince his Time, have conſider'd only, or principally, the Influence of the Moon in elevating or depreſſing the Tides; their ſeveral Directions, Velocities, and other Affections, reſulting from the Influence of Land, Shoals, and Winds, remain ſtill as inexplicable, and as little known as ever.

As a diſtinct Knowledge of theſe Things is not only conducive to the Advancement of Science, but would greatly contribute to a convenient and ſafe Navigation, it may not be unacceptable to communicate ſuch Remarks on the Tides about the *Orkney* Iſlands, as came under my Obſervation, while I was employed in ſurveying and navigating that and other adjacent Places; hoping it may incite others to explore the various Motions of that Element, on which ſuch a conſiderable Part of the World are daily employed, in a more extenſive and accurate manner than has yet been done.

From

From ſome Obſervations on the Tides in *Orkney*, I incline to think the Water begins to riſe and fall ſooner near the Shore than at a Diſtance from it.

When Spring-Tide is at its greateſt Altitude, or Depreſſion, the Water continues in a quieſcent State near half an Hour: Neap-Tides continue ſo about an Hour and a half.

The Motion of the Water, both in Aſcent, Deſcent, and Progreſſion, is accelerated from the firſt to the fourth Hour, commonly; from the fourth to the laſt Hour its Velocity diminiſhes. This, however, admits of ſome Variation from the Influence of Winds.

The greateſt Spring-Tides, and leaſt Neap-Tides, are commonly on the third or fourth Day, after the Syzygies and Quadratures; but in this alſo the Winds have a conſiderable Influence; Weſt and South weſt Winds making the greateſt Floods, and leaſt Ebbs; North and North eaſt Winds, on the contrary, making the greateſt Ebbs and leaſt Floods in *Orkney*, and on the North Coaſt of *Scotland*. When Flood-Tide is raiſed higher than ordinary by Winds, the ſubſequent Ebb is not ſo low as it would have otherwiſe been. When a high Flood is raiſed by the Moon, the ſucceeding Ebb is proportionally low.

Ordinary Spring Tides riſe 8 Feet perpendicular, ordinary Neap Tides $3\frac{1}{2}$; extraordinary high Spring-Tides riſe 14 Feet; extraordinary low, only 5; extraordinary high Neap-Tides riſe above 6 Feet; extraordinary ſmall Neap-Tides not above 2. Low-water Neap Tide, at a mean, I judge is about 3 Feet above Low water Spring-Tide, and High-water Spring-Tide about 3 Feet above High water Neap-Tide: Yet the

Riſe

Riſe and Fall vary ſo much, that it would require a longer Courſe of Obſervations than I have had Opportunity of making, to determine what is moſt frequent in this Caſe.

When a Stream of Tide is interrupted by Land, or Rocks, or is confined within a Chanel, or long Arm of the Sea growing uniformly narrower, the Water will riſe higher there than in neighbouring Places, where it is not ſo affected. If the Chanel, or Arm of the Sea, has ſeveral Windings, or Reaches, as they are called in the *Thames*, the ſuperior Elevation will not be ſo conſiderable.

The following Obſervations of the Riſing and Falling of the Water, were made in the Day-time, in the Bay of *Kirkwall, anno* 1748.

Auguſt 8. Wind W. a Breeze.
Laſt Quarter 4th Day.
Moon's Apogee diſtant 24°.
Moon's Declination 27° N.
Moon bearing at firſt W. by N.

		Feet	Inch.
The Water roſe	1*ſt* Hour . . .	0	$\frac{1}{2}$
	2*d* . . .	0	2
	3*d* . . .	0	$4\frac{1}{2}$
	4*th* . . .	0	$9\frac{1}{2}$
	5*th* . . .	0	$5\frac{1}{2}$
	6*th* and to the End .	0	$5\frac{1}{2}$
	In all	2	5

Auguſt

Auguſt 15, Wind E N E. ſmall Breeze.
New Moon 3d Day.
Moon's apparent Diſtance 65°.
Moon's Declination 7° S.
Moon bearing S S E.

		Feet	Inch.
The Water fell	1ſt Hour . . .	0	1½
	2d . . .	0	4½
	3d . . .	1	4
	4th . . .	1	8
	5th . . .	1	5
	6th . . .	0	10
	In all	5	9

Auguſt 23, Wind W. almoſt calm.
Firſt Quarter, 3d Day.
Moon's Perigee diſtant 13°.
Moon's Declination 25° S.
Moon bearing E by N.

		Feet	Inch.
The Water roſe	1ſt Hour . . .	0	6
	2d . . .	1	0
	3d . . .	1	8
	4th . . .	1	0
	5th . . .	0	8
	6th . . .	0	7
	In all	5	9

Aug. 29, Wind S *b* W. Breeze at firſt, afterwards calm.
Full Moon 3d Day.
Moon's Perigee Diſt. 68°.

Moon's

Moon's Declination 6° N.
Moon bearing N N W.

		Feet	Inch.
The Water fell	1*ſt* Hour . . .	1	0
	2*d* . . .	0	10
	3*d* . . .	1	4
	4*th* . . .	1	2
	5*th* . . .	2	10
	6*th* . . .	1	0
	In all	8	5

Aug. 27, Wind W S W. a ſmall Breeze, the Day of Full Moon, Moon's Perigee Diſtance 36°, Decl. 4° S. bearing N N W. the Water fell in all 8 Feet 4 Inches perpendicular.

Aug. 30, calm, 4th Day after Full Moon, Perigee Diſtance 80°, Decl. 13° N. Moon bearing N *b* W. the Water roſe 8 Feet 3 Inches.

Sept. 3, Wind S W. a ſmall Breeze, firſt Day of the laſt Quarter, Apogee Diſt. 50°. Decl. 27° N. Moon bearing W. the Water roſe 6 Feet 1 Inch.

Sept. 6, Wind E. a ſmall Breeze, 4th Day of the laſt Quarter, Apogee Diſt. 15°, Decl. 21° N. Moon bearing W. the Water roſe 3 Feet 9 Inches.

Sept. 15, Wind S. a moderate Breeze, 5th Day after New Moon, Perigee Diſt. 80°. Decl. 24° S. Moon bearing S *by* E. the Water fell 5 Feet 9 Inches.

To aſcertain all the Varieties in the riſing and falling of the Water, the Obſervations ought to have been continued much longer, the Night-Tides as well as Day-Tides obſerved; alſo the exact Times of

the Beginning and Ending of each, the Strength of the Wind and Weight of the Atmoſphere by a Barometer.

The foregoing Articles relate to the Riſing and Falling of the Water; the following to the various Motions of the Stream, and their Conſequences.

On the Coaſt of *Orkney*, and *Fair* Iſle of *Shetland*, the Body of the Flood comes from the North-weſt; on the Eaſt and Weſt Coaſts of *Lewis*, one of the Weſtern Iſles of *Scotland*, it comes from the South.

A League or two off the Coaſt, the Strength of the Stream is ſcarce ſenſible, except when it is confined by Land, or near Rocks or Shoals.

When the Tide begins to riſe or fall on the Shore, about that ſame time the Stream near the Shore begins to turn or reverſe its Direction, a few Irregularities excepted.

The Stream of Tide changes its Direction ſooner near Land than at a Diſtance from it; inſomuch that, in a Place two or three Miles from Land, the Turning of the Tide is two Hours, or more, later than on the adjacent Shore: At intermediate Diſtances the Streams turns at intermediate times. Hence a Veſſel may find a favourable Tide near Land, while it would be againſt her a Mile or two from it; and the contrary.

During the Continuance of Flood, the Stream varies its Direction gradually from the Eaſt toward the South, and the Stream of Ebb from the Weſt towards the North: That is, if the Stream, when it becomes firſt ſenſible, runs Eaſt, at the latter End of the

the Tide it will run South, if the Proximity of Land or Shoals does not hinder this Change of Direction.

The greateſt Velocity of Spring-Tide in *Orkney*, in the Chanels where it runs quickeſt, is about 9 Miles an Hour: The greateſt Velocity of Neap-Tide is about one third or fourth of Spring-Tide. The Tides are moſt rapid commonly between the third and fourth Hour. Spring-Tides acquire a conſiderable Degree of Strength in leſs than one Hour after their quieſcent State begins; Neap-Tides are hardly ſenſible in two Hours after.

In ſimilar Streights or Chanels, lying in the ſame Direction, and ſupplied from the ſame Part of the Ocean, the Velocity of the Streams will be in the direct *Ratio* of the Breadth of the Inlets, and the Inverſe of the Outlets.

If a Sound, or Streight between two Iſlands, or Continents, lies in the Direction of the main Body of the Tide, the Velocity of the Stream in that Streight will be greater (all other things alike) than in any other adjacent one, not lying in that ſame Direction.

If an Iſland lies directly in the Tide-way, the Stream will divide, or ſplit, before it reaches the Iſland, into two Branches, one of which will run toward one Side or End of the Iſland, and the other toward the other End of it; and, in paſſing by, will be reflected a little from the Land. Hence a Veſſel, in a Calm, carried along with a ſtrong Stream of Tide, is in no Danger of touching an Iſland, or viſible Rock, if the Water is deep enough near them.

If the Tide runs ſtronger, or more obliquely, by one End of an Iſland than the other, from the ſtrongeſt Stream, and from the moſt oblique, there will be a

languid Current toward the other; that is, the Tide, along that Side of the Iſland, will ſet longer one Way than the other.

If a ſtrong Stream of Tide runs acroſs the Mouth of a Bay that does not reach far into the Land; within that Bay there will be a ſlow Stream ſetting the contrary Way. Or, if a ſtrong Stream ſets directly, or nearly ſo, along the Extremity of a Point, or Promontory, that ſtretches ſtrait out from the Coaſt, between this Stream (before it reaches the Point) and the Coaſt, there will be a languid Current with a contrary Direction. By attending to this, one Veſſel may keep her Courſe, or gain a Port, while another is carried away with the Tide.

If a ſmall Iſland lies thwart a Tide-way, that Part of the Stream which runs along one End of it, will join what runs along the other, at ſome Diſtance beyond the Iſland, incloſing between them a curved Space, within which there will either be no ſenſible Current, or a ſlow one, contrary to the other Streams. The counter Current, in the middle of this almoſt ſtagnant Space, or Eddy, when it gets near the Iſland, ſplits in two; one Branch of which runs towards one Extremity of the Iſland, the other towards its other Extremity; where meeting the ſtronger direct Streams that form the Eddy, are by them again carried towards its *Vertex*.

Theſe Eddies may be of great Service to Ships or Boats, by ſheltering them from a rapid Stream, or even carrying them againſt it; or may enable them to croſs it with more Advantage, according to the different Places to which they are bound. The Oppoſition of the contrary Tides bounding

bounding the Eddy, makes that Part of the Sea rougher in blowing Weather, and of a darker Colour in Calms, than the reſt, by which the Limits and Direction of theſe Eddies are always diſtinguiſhed.

The Colliſion of the oppoſite and oblique Streams, near the Ends of the Iſland, will excite a circular Motion in the Water, and, if the Celerity of the Tide is conſiderable, will occaſion Whirlpools, or Cavities in the Sea, in Form of an inverted Bell, wide at the Mouth, or at the Surface of the Sea, and growing gradually narrower toward the Bottom: Their Width and Depth are in proportion to the Rapidity of the Streams that cauſe them, and are ſometimes ſo large as to be dangerous. Thoſe in *Petland Firth*, near the Iſlands *Stroma* and *Swona*, may, with Spring-Tide, turn any Veſſel quite round, but are never ſo large as to endanger one otherways: There have been Inſtances, however, of ſmall Boats dropping into, and being ſwallowed up by them. The *Hiatus*, or Cavity, is largeſt when it is firſt formed, and is carried along with the Stream, diminiſhing gradually in Dimenſions as it goes, until it quite diſappears. The Suction, or ſpiral Motion communicated to the Water, does not ſeem to extend far beyond the *Hiatus*. I paſſed, in a Boat, within 20 Yards of one, without being ſenſible of any Attraction; but indeed it was toward the latter End of the Tide, when its Strength was much abated: The Diameter of the Cavity, at that time, I judged to be between two and three Feet. When Fiſhermen are aware of their Approach toward a Whirlpool, or Well, as it is called in *Orkney*, and have Time to throw an Oar, or any other bulky Body into it before they

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are too near, the ſpiral Motion is interrupted, and the Continuity of the Water broke; which, ruſhing in on all Sides, immediately fills up the Cavity, and enables them to go over it ſafe. Hence in blowing Weather, or when there is a breaking Sea, tho' there may be a circular Motion in the Water, there can be no Cavity.

When there is a ſteep ſunk Rock near the Concourſe of ſuch ſtrong Tides, and not very deep below the Surface, a moſt amazing *Phænomenon* will happen: For, the Stream being interrupted in its Courſe, and falling ſuddenly over the Rock, is reflected from the Bottom upwards, ſwelling and bubbling on the Surface like boiling Water, and carrying Sand, Shells, Fiſhes, or other looſe Bodies along with it; which, with Boats, or whatever elſe is near, are driven with great Force from the Center all around toward the Circumference, upon which, a Gyration of the Water enſuing, a Whirlpool begins, which is carried along with the Stream, as was ſaid above, leſſening gradually till it is quite extinguiſhed: In a little time a new Eruption and Ebullition, like the former, begins, which proceeds in the ſame manner, till the Swiftneſs of the Stream abates, or the Tide riſes or falls too much above the Rock.

Queries concerning the Tides in a large Ocean; which, if reſolved from Obſervation, would render the Theory more perfect.

1. Since the Attraction of the Moon raiſes the Water directly below her, by diminiſhing its Gravity toward the Earth's Center, and, at that very ſame

ſame time, depreſſes it at a Quadrant's Diſtance, by augmenting the Gravity there, ſo that the ſuperior Altitude of one Part of the Ocean is immediately balanced by the ſuperior Gravitation of another; do not, therefore, the Tides in the Ocean riſe and fall without any progreſſive Motion, or ſenſible Velocity? And do not all Currents, or Streams of Tide (not cauſed by Winds) proceed from the Interruption which Land, or Shoals, give to the undulatory Motion which muſt accompany the perpendicular Aſcent or Deſcent of the Fluids?

2. Is it agreeable to Obſervation, that the Power of the Sun and Moon together, raiſes the Tides within the Tropics about 14 Feet, as *Newton*, *Halley*, and *Maclaurin* ſuppoſe? And how high are the Tides found to riſe in Parts of the Ocean of a greater Latitude? If the Water does not riſe and fall ſo much within the Tropics, as in Places more diſtant from the Equator, what hinders the greater Power to have a greater Effect? For the Moon muſt act with greateſt Force on thoſe Parts to which ſhe is vertical.

3. If the Times of high and low Water depend on the Moon's Appulſe to the Meridian, is it not high or low Water in all Parts of the Ocean, under the ſame Meridian, about the ſame time? And is the Difference of the Times, in Places under different Meridians, in any certain Proportion to their Difference of Longitude?

4. Since the Power of the Moon to raiſe the Tide in any Place is greateſt when ſhe is neareſt the Zenith, it is agreeable both to Obſervation and Theory, that the Water riſes and falls more when ſhe is above, than when below the Horizons of Places on the ſame Side

Side of the Equator with her; and the contrary: Are not the Tides alſo of longer Duration in that Caſe? Since a greater Portion of the Hemiſpheroid, into which the Sea is formed by the Moon's Attraction, is then above the Horizons of theſe Places, than is below them. If this is found to be Fact, it will alſo be found, that the Duration in different Places (other things alike) will be in ſome meaſure proportional to their Latitudes, and the Declination of the Moon.

5. In an oblique Sphere, all Azimuth Circles cut the Equator and its Parallels obliquely; and therefore the Moon muſt come ſooner to, or from, a given Azimuth, with one Declination than with another. In ſome Latitudes this Difference will amount to ſeveral Hours. Is it not then a falſe Rule to judge of the Times of high or low Water by the Moon's Azimuth, or to ſignify one by the other, as is the Cuſtom of Sailors?

XIII. *Some Account of the Remains of* John Tradeſcant's *Garden at* Lambeth; *by Mr.* W. Watſon *F. R. S.*

Read May 25. 1749. UPON a Viſit made to Mr. *John Tradeſcant*'s Garden at *South Lambeth*, *May* 21, 1749. by Dr. *Mitchell* and myſelf, were obſerved the under-mention'd exotic Plants.

This Garden was planted by the above-mention'd Gentleman about an hundred and twenty Years ſince, and was, except that of Mr. *John Gerard*, the Author of