the tides on the English coasts would be profoundly modified if the Straits were completely closed.

It will be noticed that between Yarmouth and Holland the cotidal lines cross one another. Such an intersection of lines is in general impossible; it is indeed only possible if there is a region in which the water neither rises nor falls, because at such a place the cotidal line ceases to have a definite meaning. A set of observations by Captain Hewitt, R.N., made in 1840, appears to prove the existence of a region of this kind at the part of the chart referred to.

§ 7. *Historical Sketch.@@1*—The writings of various Chinese, Arabic and Icelandic authors show that some attention was paid by them to the tides, but the several theories advanced are fantastic. It is natural that the writings of the classical authors of antiquity should contain but few references to the tides, for the Greeks and Romans lived on the shores of an almost tide­less sea. Nevertheless, Strabo quotes from Posidonius a clear account of the tides on the Atlantic coast of Spain, and connects the tides correctly with the motion of the moon. He also gives the law of the tide in the Indian Ocean as observed by Seleucus the Babylonian, and the passage shows that Seleucus had unravelled the law which governs the diurnal inequality of the tide in that sea.

We shall not give any details as to the medieval speculations on the tides, but pass on at once to Newton, who in 1687 laid the foundation for all that has since been added to the theory of the tides when he brought his grand generalization of universal gravitation to bear on the subject. Johann Kepler had indeed at an early date recognized the tendency of the water of the ocean to move towards the centres of the sun and moon, but he was unable to submit his theory to calculation. Galileo expresses regret that so acute a man as Kepler should have produced a theory which appeared to him to reintroduce the occult qualities of the ancient philosophers. His own explanation referred the phenomenon to the rotation and orbital motion of the earth, and he considered that it afforded a principal proof of the Copernican system.

In the 19th corollary of the 66th proposition of bk. i. of the *Principia,* Sir Isaac Newton introduces the conception of a canal circling the earth, and he considers the influence of a satellite on the water in the canal. He remarks that the movement of each molecule of fluid must be accelerated in the conjunction and opposition of the satellite with the

@@@1 The account from the time of Newton to that of Laplace is founded on Laplace's *Mécanique céleste,* bk. xiii. ch. i. molecule, that is to say when the molecule, the earth’s centre and the satellite are in a straight line, and retarded in the quadra­tures, that is to say when the line joining the molecule and the earth’s centre is at right angles to the line joining the earth’s centre and the satellite. Accordingly the fluid must undergo a tidal oscillation. It is, however, in propositions 26 and 27 of bk. iii. that he first determines the tidal force due to the sun and moon. The sea is here supposed to cover the whole earth and to assume at each instant a figure of equilibrium, and the tide-generating bodies are supposed to move in the equator. Considering only the action of the sun, he assumes that the figure is an ellipsoid of revolution with its major axis directed towards the sun, and he determines the ellipticity of such an ellipsoid. High solar tide then occurs at noon and midnight, and low-tide at sunrise and sunset. The action of the moon produces a similar ellipsoid, but of greater ellipticity. The superposition of these ellipsoids gives the principal variations of the tide. He then proceeds to consider the influence of latitude on the height of tide, and to discuss other peculiarities of the phenomenon. Observation shows, however, that spring tides occur a day and a half after full and change of moon, and Newton falsely attributed this to the fact that the oscillations would last for some time if the attractions of the two bodies were to cease.

The Newtonian hypothesis, although it fails in the form which he gave to it, may still be made to represent the tides if the lunar and solar ellipsoids have their major axes always directed toward a fictitious moon and sun, which are respectively at constant distances from the true bodies; these distances are such that the full and change of the fictitious moon as illuminated by the fictitious sun occur about a day or a day and a half later than the true full and change of moon. In fact, the actual tides may be supposed to be generated directly by the action of the real sun and moon, and the wave may be imagined to take a day and a half to arrive at the port of observation. This period has accordingly been called “ the age of the tide.” In what precedes the sun and moon have been supposed to move in the equator; but the theory of the two ellipsoids cannot be reconciled with the truth when they move, as in actuality, in orbits inclined to the equator. At equatorial ports the theory of the ellipsoids would at spring tides give morning and evening high waters of nearly equal height, whatever the declinations of the bodies. But at a port in any other latitude these high waters would be of very different heights, and at Brest, for example, when the declinations of the bodies are equal to the obliquity of the elliptic, the evening tide would be eight times as great as the morning tide. Now observation shows that at this port the two tides are nearly equal to one another, and that their greatest difference is not a thirtieth of their sum. Newton here also offered an erroneous explanation of the phenomenon.

In r738 the Academy of Sciences of Paris offered, as a subject foτ a prize, the theory of the tides. The authors of four essays received prizes, viz. Daniel Bernoulli, Leonhard Euler, Colin Maclaurin and Antoine Cavalieri. The first three adopted not only the theory of gravitation, but also Newton’s method of the superposition of the two ellipsoids. Bernoulli’s essay contained an extended development of the conception of the two ellipsoids, and, under the name of the equilibrium theory, it is commonly associated with his name. Laplace gives an account and critique of the essays of Bernoulli and Euler in the *Mécanique céleste.* The essay of Maclaurin presented little that was new in tidal theory, but is notable as containing certain important theorems concerning the attraction of ellipsoids. In 1746 Jean-le-Rond D’Alembert wrote a paper in which he treated the tides of the atmosphere; but this work, like Maclaurin’s, is chiefly remarkable for the importance of collateral points.

The theory of the tidal movements of an ocean was therefore, as Laplace remarks, almost untouched when in 1774 he first undertook the subject. In the *Mécanique céleste* he gives an