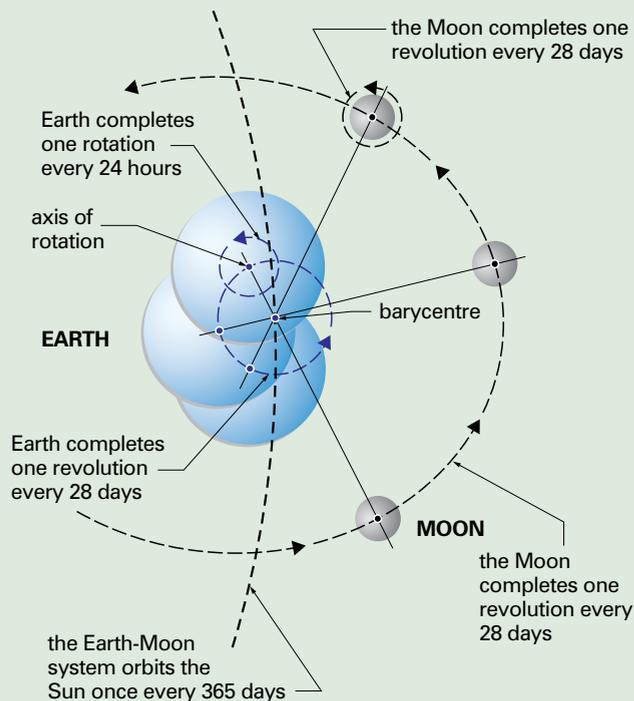


HAS A DAY ALWAYS LASTED 24 HOURS?

No, not always. The length of a day is determined by the time it takes for the Earth to complete one rotation on its axis, so the question can be rephrased: has the Earth's rate of rotation remained constant over time? The Moon's gravitational pull on the Earth is significant and has to be taken into account when we analyse the Earth's movements. In fact, the Earth and Moon behave as a double planet system and rotate around a common centre of gravity. Movements of the Earth are therefore quite complex. It rotates on its axis once every 24 hours, while revolving around the Earth-Moon centre of gravity, or barycentre, once every 28 days. In addition, the Earth-Moon pair orbits the Sun once every 365 days.

MOVEMENTS OF THE EARTH AND MOON



The Earth and Moon rotate around a common centre of gravity, the barycentre, which lies 4 800 km from the centre of the Earth. They complete one revolution around the barycentre every 28 days. Simultaneously, the Earth rotates on its own axis once every 24 hours, and both the Earth and Moon orbit the Sun once every 365 days.

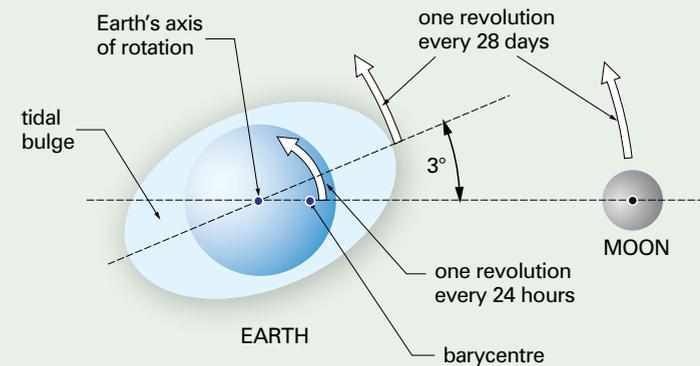
keep the tidal bulge aligned with the Moon, but continents, especially Africa and South America, get in the way and slow the water down, in effect creating friction. The tidal bulge simply cannot keep up and lags behind its ideal position directly below the Moon by about 3°.

Tidal friction is imperceptibly slowing the Earth's rotation, while the offset of the tidal bulge causes a slight gravitational tug on the Moon, speeding up its rotation. This tug also contributes to slowing the Earth's rotation, but as the Moon gains rotational energy, it moves further away from Earth. Although minute, these changes can be measured. Laser reflectors placed on the Moon by the Apollo astronauts revealed that the

Tidal effects influence Earth movements and also have to be considered. The Moon's gravitational pull drags ocean water towards it, creating a tidal bulge on one side of the Earth. On the opposite side, an equal bulge is created by the centrifugal force of the Earth's rotation around the barycentre. The Sun also has a tidal effect, but it is much weaker because of the greater distance between the Sun and the Earth. Nevertheless, it either amplifies or mutes lunar tidal cycles. We experience a higher-than-average spring tide when the Sun's pull is in the same direction as the Moon's, or a smaller neap tide when it is perpendicular to the Moon's pull.

If the Earth did not spin on its axis, the tidal bulge would lie directly below the Moon and it would gradually move around the Earth as the Moon progressed along its orbit, completing a full circuit in 28 days. However, the daily rotation of the Earth on its axis complicates matters, because it means that the tidal bulges must complete one circuit of the Earth in 24 hours rather than 28 days, thus resulting in two high tides and two low tides each day. The tidal bulge is effectively going in the opposite direction to the Earth's rotation and it has to move rapidly to keep up. At the equator its speed is about 1 700 km per hour! This means that a lot of water has to flow backwards and forwards to

DEFLECTION OF THE TIDAL BULGE



Gravitational attraction by the Moon pulls the ocean water upwards and towards it, creating a tidal bulge. This is counterpoised by a similar bulge on the opposite side of the Earth due to centrifugal force. The tidal bulge should theoretically always point directly towards the Moon as it orbits the Earth. However, the speed of the Earth's daily rotation and the position of continents complicates the way in which the tidal bulge follows the Moon, with the result that the tidal bulge is always about 3° ahead of where it should be. This is imperceptibly slowing the Earth's rotation and causing the Moon to recede from the Earth.

Moon is receding from Earth by 3.82 cm per year. Changes in the rate of the Earth's rotation have been noted by studying the time of total eclipses in ancient historical records, which show that an eclipse 2 000 years ago occurred about three hours earlier than predicted from the present rate of rotation. These observations answer the initial question, at least in part – days in the distant past were less than 24 hours.

But how can day length and the number of days in a year be determined in the geological past? Sedimentary rocks that were deposited under suitable conditions can reveal the answer. One such condition is provided by river deltas with strong tidal flows that were sheltered from intense wave activity. Sediment brought into such deltas by rivers is drawn into deeper water by the ebb tide and deposited as a discrete layer. Each ebb tide deposits a single layer, typically about a centimetre thick, but thicker during spring tides and thinner during neap tides. Rocks showing these characteristics are known as tidalites and the layers of varying thickness within them record the lunar tidal cycle. Annual cycles reflecting changing seasons are

also preserved, since more sediment is delivered during a rainy season, making the layers even thicker. By studying such deposits it is possible to determine the day length, the number of days in a lunar month and the number of months in a year. Mathematical analysis of historical Earth and Moon orbits is used to supplement and refine measurements obtained from these tidalites.

Such measurements reveal that 620 million years ago there were 21.9 hours in a day and about 400 days in a year, divided into 13.1 lunar months. Data from older rock suites is less secure, but suggests that 2 450 million years ago a day was about 19 hours long, and that there were 457 days and 14.5 lunar months in a year. Day length 3 300 million years ago may have been as short as 14 hours.

The Moon's rate of recession from Earth seems to have accelerated over time, from about 1.24 cm per year 2 450 million years ago, to the current 3.82 cm per year. The rate of recession has probably also fluctuated, possibly due to variable tidal friction brought about by the changing positions of the continents.

Under the right conditions, sedimentary deposition can record tidal cycles, with each tide depositing a very thin, single sedimentary layer. Such rocks, called tidalites, can be used to estimate the day length, lunar month and the number of days in the year in the distant past.

