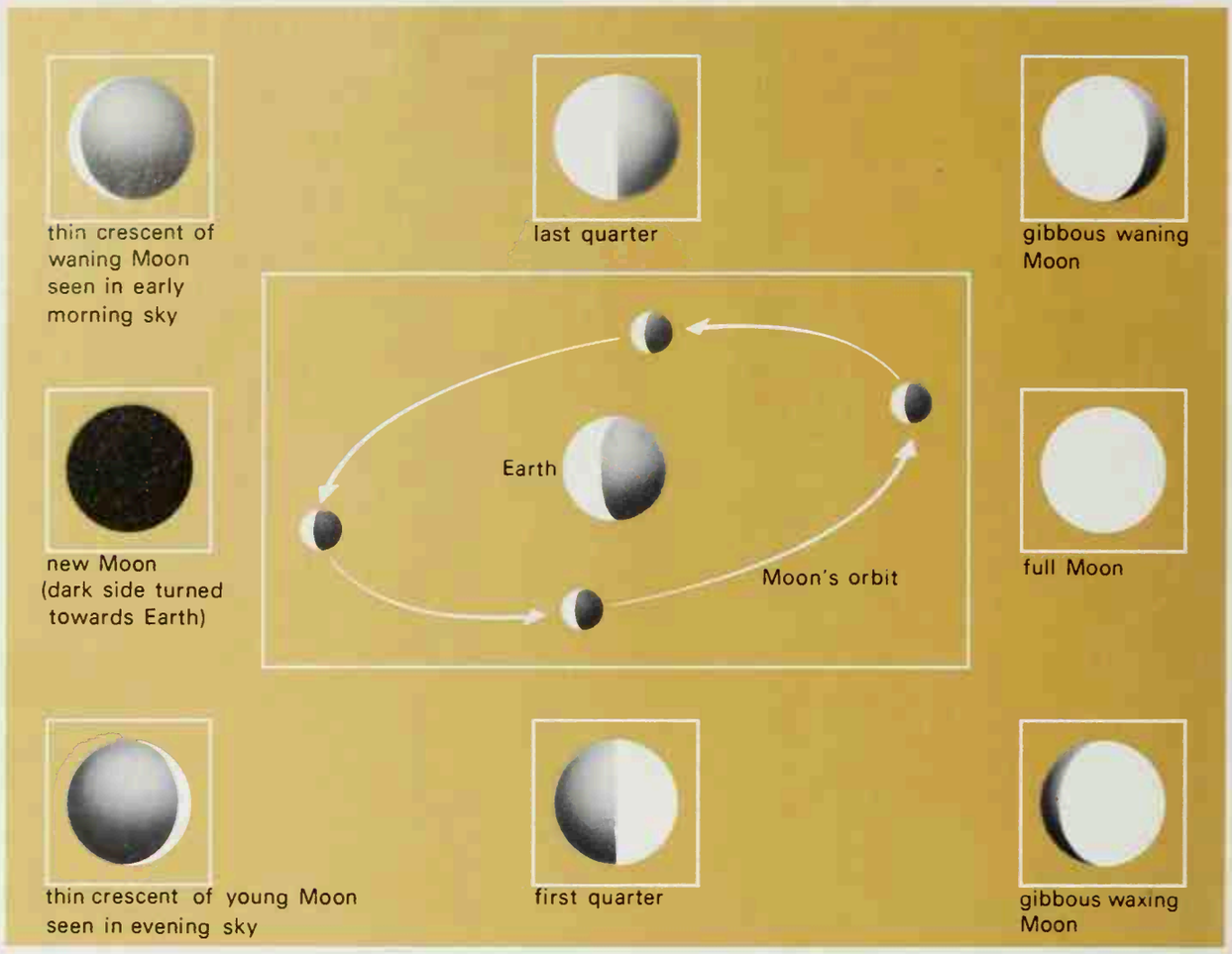

Fig. 1·6
The phases of the Moon as seen from out in space and by an observer on Earth.

the gravitational effects of the Sun and Moon on the Earth, but there is another component, due to the gravitational pull of the planets, which reduces the luni-solar effect. Combined, they move the vernal equinox 50·2619 arc sec. per year. This is because the gravitational pulls cause the Earth's axis to precess in space, just like a gyroscope does, and the result of this is that the direction in which the axis points also changes. It sweeps out a circle in the sky, taking 25 800 years to complete one rotation (Figs. 1·7 and 1·8). Thus, although the north pole now points towards the star Polaris, in 7 600 AD it will point close to Alderamin (α Cephei) and in 14 800 AD close to Vega (α Lyrae). The Earth's axis also 'wobbles', due to a lunar pull. This nodding or **nutation** has a period of 19 years, and although very small – it amounts to no more than a movement of the celestial pole of 9·23 arc sec. – it is important in parallax determinations.

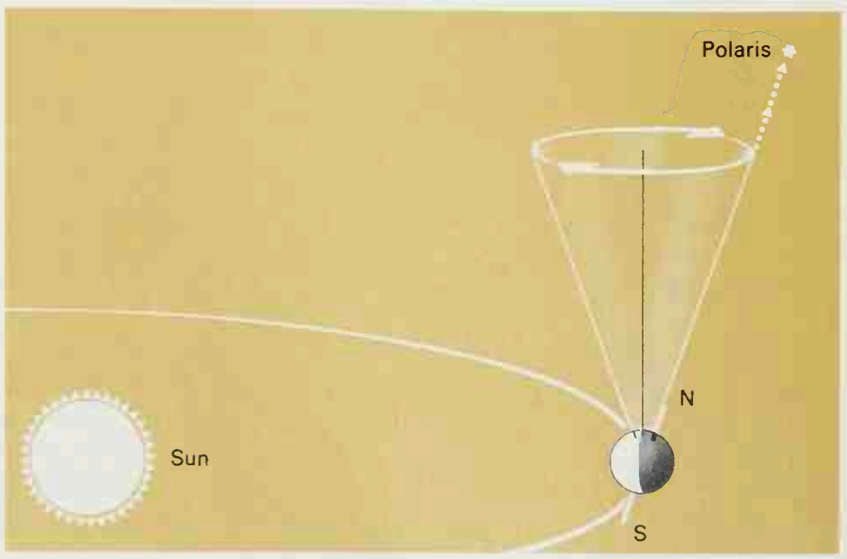

Fig. 1·7
Diagram of the way the Earth's axis moves with respect to the Earth's orbit, causing precession of the equinoxes.

Another effect of observing from a moving platform is that we see different constellations in the night sky at different seasons of the year, and also see all celestial bodies rise and set once every day due to the earth's axial rotation. For these reasons the determination of times has, until recently, always been the province of the astronomer. The Earth orbits the sun once a year, the **tropical year** being that time in which the Earth has completed one orbital circuit; observed from Earth it is the time between the Sun's apparent complete circuit of the stars. Its length is 365·2422 mean solar days. A **mean solar day** is the average time the Earth takes to rotate once and is so called because the motion of the Sun is used to determine the civil measurement of the day. A 'mean Sun' has to be used because the actual Sun does not move regularly across the sky for the simple reason that the Earth's orbit is an ellipse, making the Earth itself move at varying speeds as it orbits. The difference (apparent solar time – mean solar time) is known as the **equation of time**, apparent solar time being the time measured, for example, by a sundial.

The rotation of the earth can also be measured with respect to the stars and this gives **sidereal time**. Since the stars appear to make 366 revolutions in a year – 365 due to the rotation of the Earth on its axis, and one extra rotation because the Earth has orbited once round the Sun – the sidereal day is shorter than the solar day. Its length is 23 hours (h) 56 minutes (m)