THE MOON

The Moon is, apart from the Sun, the brightest object in the sky. Although the Sun and the Moon appear almost equal in size, they are quite different. The Sun is the central body of our Solar System, and all planets, including the Earth, orbit around it. The Sun measures 1.4 million kilometers across, and lies at a distance of roughly 150,000,000 kilometers. The Moon is much smaller and measures 'only' 3,476 kilometers across; approximately one quarter of the Earth's diameter. The Moon lies at an average distance of 384,400 kilometers from the Earth. It orbits, not the Sun, but our own planet, in a little more than 27 days.

Although we often refer to the Moon as 'shining' it does not of itself give any light. It only reflects the light it receives from the Sun. This is the reason why the appearance of the Moon changes as it orbits the Earth. This aspect of the Moon, sometimes visible as a thin crescent in the western sky, after sunset, and sometimes as a full disk, lightening up the middle of the night, is confusing to many people. The reason for this can be best explained in a diagram (figure 1).

The illustration is not drawn to scale, but shows you what happens. The Earth is at the center and the Moon's orbit is drawn as a circle. During its orbit around the Earth we see a different portion of the illuminated side of the Moon's surface. (In the figure the red arrows indicate our line of sight from the Earth.)

When the Moon is approximately between the Sun and the Earth, we see only its dark side. We call this a new Moon. The Moon is not visible at all. After one or two days we see a small crescent in the evening sky; a part of the illuminated side is peeping around the edge. After almost a week, half of the disk is lit and we call this the first quarter. Another week later we see the complete disk. This is a full Moon. Next comes the last quarter, and then back to new Moon again. From one new Moon to the next takes about 29.5 days, fully two days longer than it takes the Moon to orbit the Earth. The reason for this is that, in the time the Moon revolves around

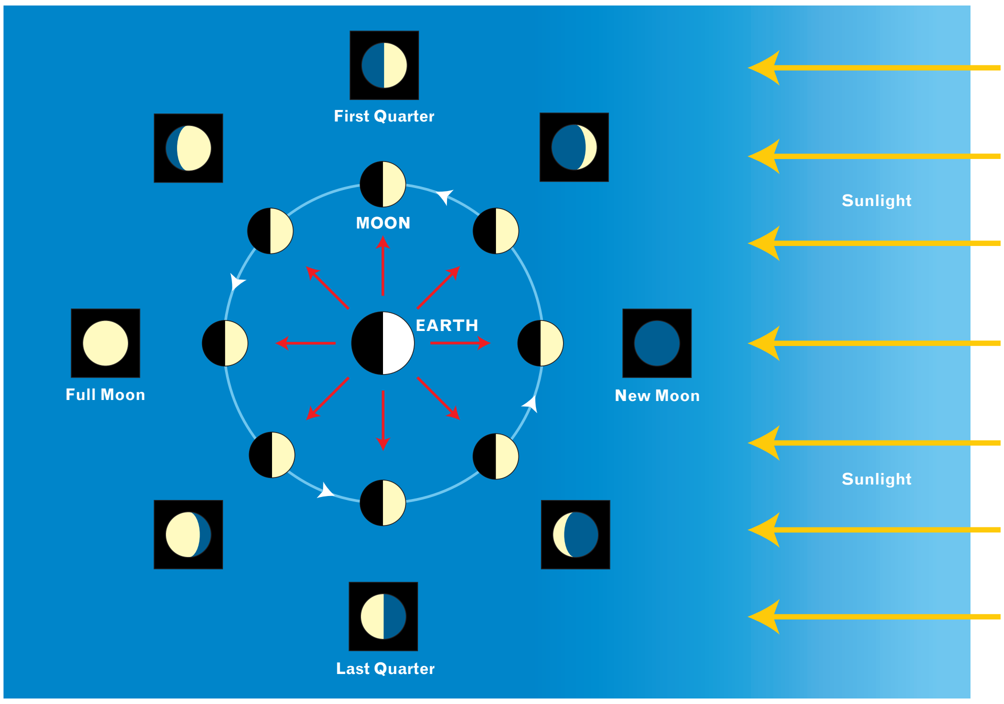

Figure 1

the Earth, the Earth also moves in its orbit around the Sun. In the 27 days it takes the Moon to orbit the Earth, the Sun's position in the sky also changes, moving in the same direction the Moon moves. It takes the Moon more than two days to 'catch up' with the Sun.

Observing the Moon

Even with a simple pair of binoculars you can see interesting features on the Moon's surface, and a small telescope will reveal even more details of our neighbor in space. The best time to watch the Moon is not when it is full, but rather around its first or last quarter. Then the Moon is illuminated by the Sun from one side and especially near the terminator, the line dividing the lit and the unlit halves of the Moon, there is strong relief, because the surface is illuminated from a very low angle, resulting in long shadows. At full Moon you do not see any relief, since you are then looking from approximately the same direction as the Sun's rays come from. But full Moon is an ideal time to study the differences between the dark and light areas of the surface.

On the Moon maps (on pages 4–5 and 6–7), you can identify the craters and other small features, by referring to the numbers in the list alongside the maps. To help you see which crater a number is referring to, a small black dot is placed in its center. On the first double-page Moon map (map A) the features are listed in numerical order, and for your convenience they are repeated in alphabetical order on the second spread, with the mirror-reversed map (map B). The reason the Moon is shown in two different ways is explained below and on page 3.

Larger features, like mountain ranges and the darker areas called *maria,* are labeled directly on the map. *Maria* is the plural form of the Latin word *mare*, meaning sea. The first observers who believed that these dark areas on the Moon really were seas gave the name. Although we now know there are no seas on the Moon, the name persists, as also do the names *lacus* (lake) and *oceanus* (ocean).

Most craters on the Moon are believed to be the result of the impact of meteors: pieces of rock and metal from space. The Earth is well protected against the impact of meteors by the atmosphere, which causes meteors to burn and vaporize. We call that a 'falling star' or 'shooting star', though it is not a star at all. Only fragments of large meteors reach the surface; we call these fragments meteorites. But the Moon does not have an atmosphere, so every meteor captured by the Moon's gravity will crash into the surface.

Because the Moon rotates 360° on its axis in exactly the same time that it takes to complete one orbit around the Earth, we always see the same side of the Moon. However the Moon's orbit is inclined about 5° to the *ecliptic* (page 37), making it move slightly above and below the plane of the Earth's orbit around the Sun, and the Moon's own spin axis is also tilted about 1.5°. The combined result is that we can occasionally see about 6.5° 'over' the North and South Poles of the Moon. Moreover, since the Moon's orbit is not really a circle, but an ellipse, it does not move at a constant speed, though its rotation speed remains the same. Thus, as seen from the Earth, it moves a little from left to right, as if it were shaking its head very slowly. Therefore, we can look around the edges, by up to 7°. Sometimes Mare Crisium (in the northeastern quadrant of the Moon) appears very close to the edge, and sometimes it is closer to the center, and has a less elliptical appearance. The elliptical appearance of Mare Crisium, as well as those of craters close to the visible edge, is of course caused by perspective.

Different orientations of the Moon

Naked-eye observers living in the northern hemisphere see the Moon with north up and south down. That is also the way they will see it in a pair of binoculars. However, using an astronomical telescope will usually show the Moon 'upside down'. That is why map A, on pages 4–5, shows the Moon with south at the top, so that will be practical for most observers using a telescope. For naked-eye or binocular observations the map has to be held upside down.

When you are living in the southern hemisphere, it will be the other way around. The map can be used directly for naked-eye and binocular observations, but when you use a telescope, you have to rotate it. To make things even more complicated, many observers use a telescope with a *star diagonal;* an eyepiece with a diagonal mirror or a prism. That makes observing more comfortable, but it inverts or 'flips' the image. Those observers have to use Moon map B, on pages 6–7. Here the whole image of the Moon is mirror-reversed.

In figure 2 you can see the four different orientations of the Moon with captions telling you when and where to use each map.

Figure 2

Moon Map A (pages 4–5)
Northern hemisphere:
For observers with an astronomical telescope.
Southern hemisphere:
For observing with the naked eye and with binoculars.

Moon Map A (pages 4–5), rotated
Northern hemisphere:
For observing with the naked eye and with binoculars.
Southern hemisphere:
For observers with an astronomical telescope.

Moon Map B (pages 6–7)
Southern hemisphere:
For observers using an astronomical telescope with star diagonal.

Moon Map B (pages 6–7), rotated
Northern hemisphere:
For observers using an astronomical telescope with star diagonal.

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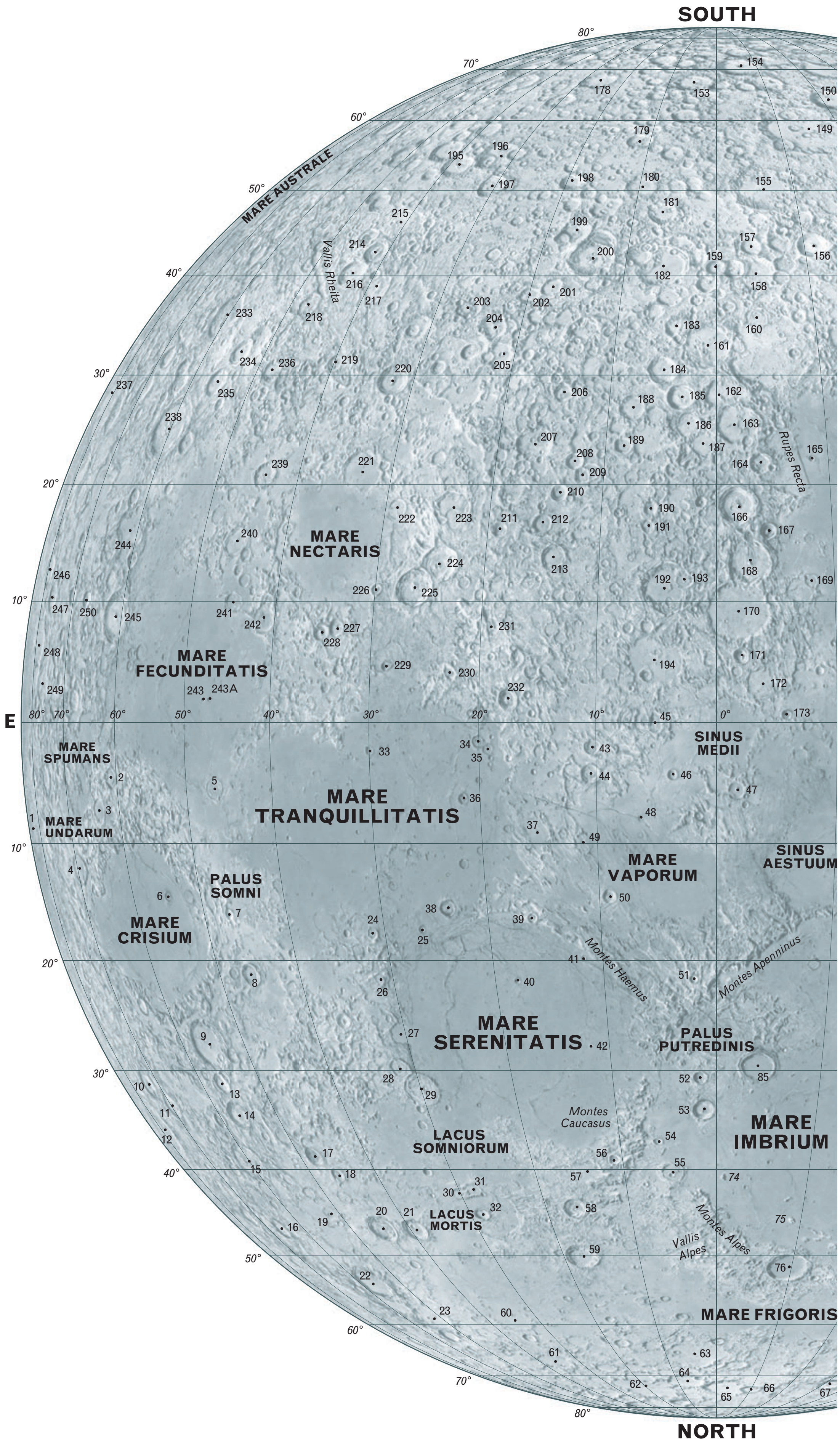
Moon Map A

Features in numerical order

1 Neper
2 Apollonius
3 Firmicus
4 Condorcet
5 Taruntius
6 Picard
7 Proclus
8 Macrobius
9 Cleomedes
10 Hahn
11 Berosus
12 Gauss
13 Burckhardt
14 Geminus
15 Messala
16 Mercurius
17 Franklin
18 Cepheus
19 Chevallier
20 Atlas
21 Hercules
22 Endymion
23 de la Rue
24 Vetruvius
25 Dawes
26 Littrow
27 Le Monnier
28 Chacornac
29 Posidonius
30 Mason
31 Plana
32 Bürg
33 Maskelyne
34 Sabine
35 Ritter
36 Arago
37 Julius Caesar
38 Plinius
39 Menelaus
40 Bessel
41 Sulpicius Gallus
42 Linné
43 Godin
44 Agrippa
45 Rhaeticus
46 Triesnecker
47 Pallas
48 Hyginus
49 Boscovich
50 Manilius
51 Conon
52 Autolycus
53 Aristillus
54 Theaetetus
55 Cassini
56 Calippus
57 Alexander
58 Eudoxus
59 Aristoteles
60 Gärtner
61 Arnold
62 Meton
63 W. Bond
64 Barrow
65 Goldschmidt
66 Anaxagoras
67 Philolaus
68 Anaximenes
69 Carpenter
70 J. Herschel
71 Pythagoras
72 Babbage
73 Harpalus
74 *Mons Piton*
75 *Mons Pico*
76 Plato
77 Le Verrier
78 Helicon
79 *Promontorium Laplace*
80 Bianchini
81 Sharp
82 *Promontorium Heraclides*
83 Mairan
84 *Mons Rümker*
85 Archimedes
86 Timocharis
87 Lambert
88 Euler
89 Delisle
90 Prinz
91 Aristarchus
92 Herodotus
93 *Vallis Schröteri*
94 Eratosthenes
95 Stadius
96 Copernicus
97 Gay-Lussac
98 Mayer
99 Gambart
100 Reinhold
101 Lansberg
102 Encke
103 Kepler
104 Marius
105 Reiner
106 Struve
107 Seleucus
108 Krafft
109 Cardanus
110 Cavalerius
111 Hevelius
112 Olbers
113 Riccioli
114 Grimaldi
115 Letronne
116 Billy
117 Hansteen
118 Sirsalis & Sirsalis A
119 Rocca
120 Crüger
121 Darwin
122 Byrgius
123 Gassendi



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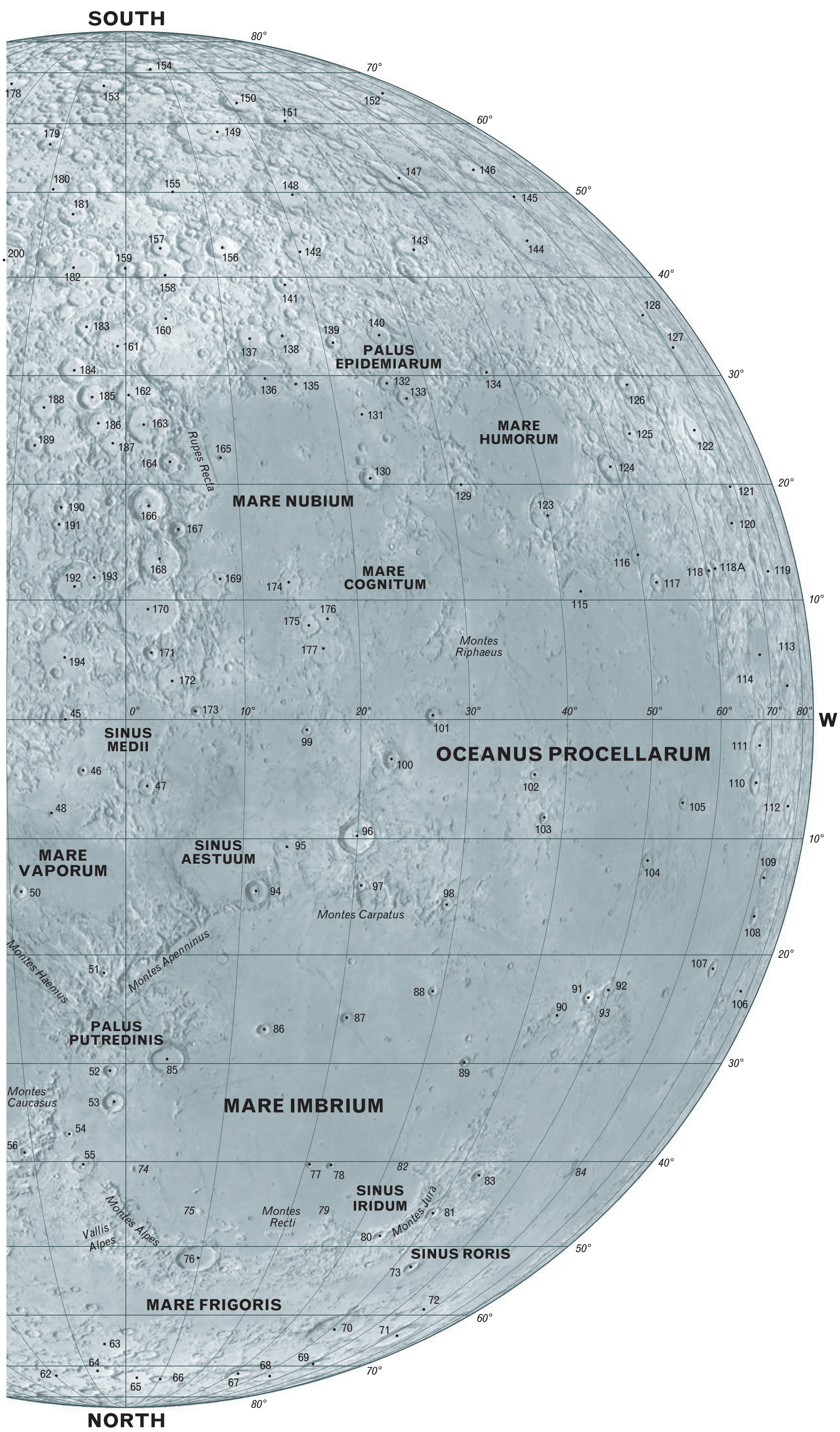
Moon Map A



Features in numerical order

124 Mersenius
125 Cavendish
126 Vieta
127 Lagrange
128 Piazzi
129 Agatharchides
130 Bullialdus
131 Kies
132 Mercator
133 Campanus
134 Vitello
135 Hesiodus
136 Pitatus
137 Gauricus
138 Wurzelbauer
139 Cichus
140 Capuanus
141 Heinsius
142 Wilhelm
143 Mee
144 Schickard
145 Wargentin
146 Phocylides
147 Schiller
148 Longomontanus
149 Clavius
150 Blancanus
151 Scheiner
152 Bailly
153 Curtius
154 Moretus
155 Maginus
156 Tycho
157 Saussure
158 Orontius
159 Nasireddin
160 Lexell
161 Walter
162 Regiomontanus
163 Purbach
164 Thebit
165 Birt
166 Arzachel
167 Alpetragius
168 Alphonsus
169 Davy
170 Ptolemaeus
171 Herschel
172 Flammarion
173 Mösting
174 Guericke
175 Parry
176 Bonpland
177 Fra Mauro
178 Manzinus
179 Jacobi
180 Cuvier
181 Licetus
182 Stöfler
183 Nonius
184 Aliacensis
185 Werner
186 Blanchinus
187 La Caille
188 Apianus
189 Playfair
190 Airy
191 Argelander
192 Albategnius
193 Klein
194 Hipparchus
195 Vlacq
196 Hommel
197 Pitiscus
198 Baco
199 Barocius
200 Maurolycus
201 Buch
202 Büsching
203 Riccius
204 Rabbi Levi
205 Zagut
206 Pontanus
207 Sacrobosco
208 Azophi
209 Abenezra
210 Geber
211 Tacitus
212 Almanon
213 Abulfeda
214 Fabricius
215 Janssen
216 Metius
217 Brenner
218 Rheita
219 Neander
220 Piccolomini
221 Fracastorius
222 Beaumont
223 Catharina
224 Cyrillus
225 Theophilus
226 Mädler
227 Isidorus
228 Capella
229 Torricelli
230 Hypatia
231 Zöllner
232 Delambre
233 Furnerius
234 Stevinus
235 Snellius
236 Reichenbach
237 Humboldt
238 Petavius
239 Santbech
240 Colombo
241 Goclenius
242 Gutenberg
243 Messier & Messier A
244 Vendelinus
245 Langrenus
246 Ansgarius
247 La Pérouse
248 Kästner
249 Gilbert
250 Kapteyn

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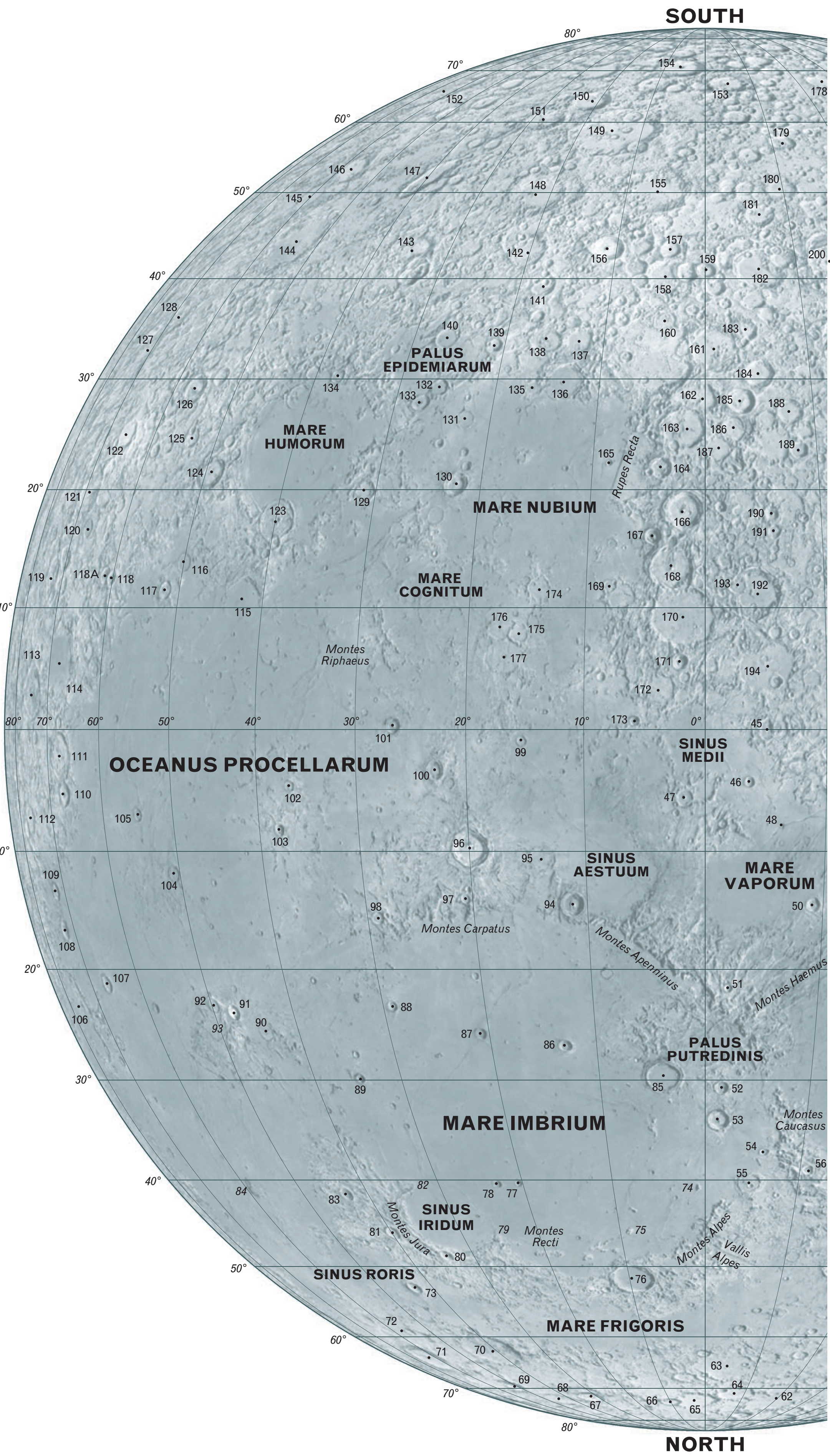
Features in alphabetical order

Abenezra	209	Cleomedes	9
Abulfeda	213	Colombo	240
Agatharchides	129	Condorcet	4
Agrippa	44	Conon	51
Airy	190	Copernicus	96
Albategnius	192	Crüger	120
Alexander	57	Curtius	153
Aliacensis	184	Cuvier	180
Almanon	212	Cyrillus	224
Alpetragius	167	Darwin	121
Alphonsus	168	Davy	169
Anaxagoras	66	Dawes	25
Anaximenes	68	de la Rue	23
Ansgarius	246	Delambre	232
Apianus	188	Delisle	89
Apollonius	2	Encke	102
Arago	36	Endymion	22
Archimedes	85	Eratosthenes	94
Argelander	191	Eudoxus	58
Aristarchus	91	Euler	88
Aristillus	53	Fabricius	214
Aristoteles	59	Firmicus	3
Arnold	61	Flammarion	172
Arzachel	166	Fra Mauro	177
Atlas	20	Fracastorius	221
Autolycus	52	Franklin	17
Azophi	208	Furnerius	233
Babbage	72	Gambart	99
Baco	198	Gärtner	60
Bailly	152	Gassendi	123
Barocius	199	Gauricus	137
Barrow	64	Gauss	12
Beaumont	222	Gay-Lussac	97
Berosus	11	Geber	210
Bessel	40	Geminus	14
Bianchini	80	Gilbert	249
Billy	116	Goclenius	241
Birt	165	Godin	43
Blancanus	150	Goldschmidt	65
Blanchinus	186	Grimaldi	114
Bonpland	176	Guericke	174
Boscovich	49	Gutenberg	242
Brenner	217	Hahn	10
Buch	201	Hansteen	117
Bullialdus	130	Harpalus	73
Burckhardt	13	Heinsius	141
Bürg	32	Helicon	78
Büsching	202	Hercules	21
Byrgius	122	Herodotus	92
Calippus	56	Herschel	171
Campanus	133	Hesiodus	135
Capella	228	Hevelius	111
Capuanus	140	Hipparchus	194
Cardanus	109	Hommel	196
Carpenter	69	Humboldt	237
Cassini	55	Hyginus	48
Catharina	223	Hypatia	230
Cavalerius	110	Isidorus	227
Cavendish	125	J. Herschel	70
Cepheus	18	Jacobi	179
Chacornac	28	Janssen	215
Chevallier	19	Julius Caesar	37
Cichus	139	Kapteyn	250
Clavius	149	Kästner	248



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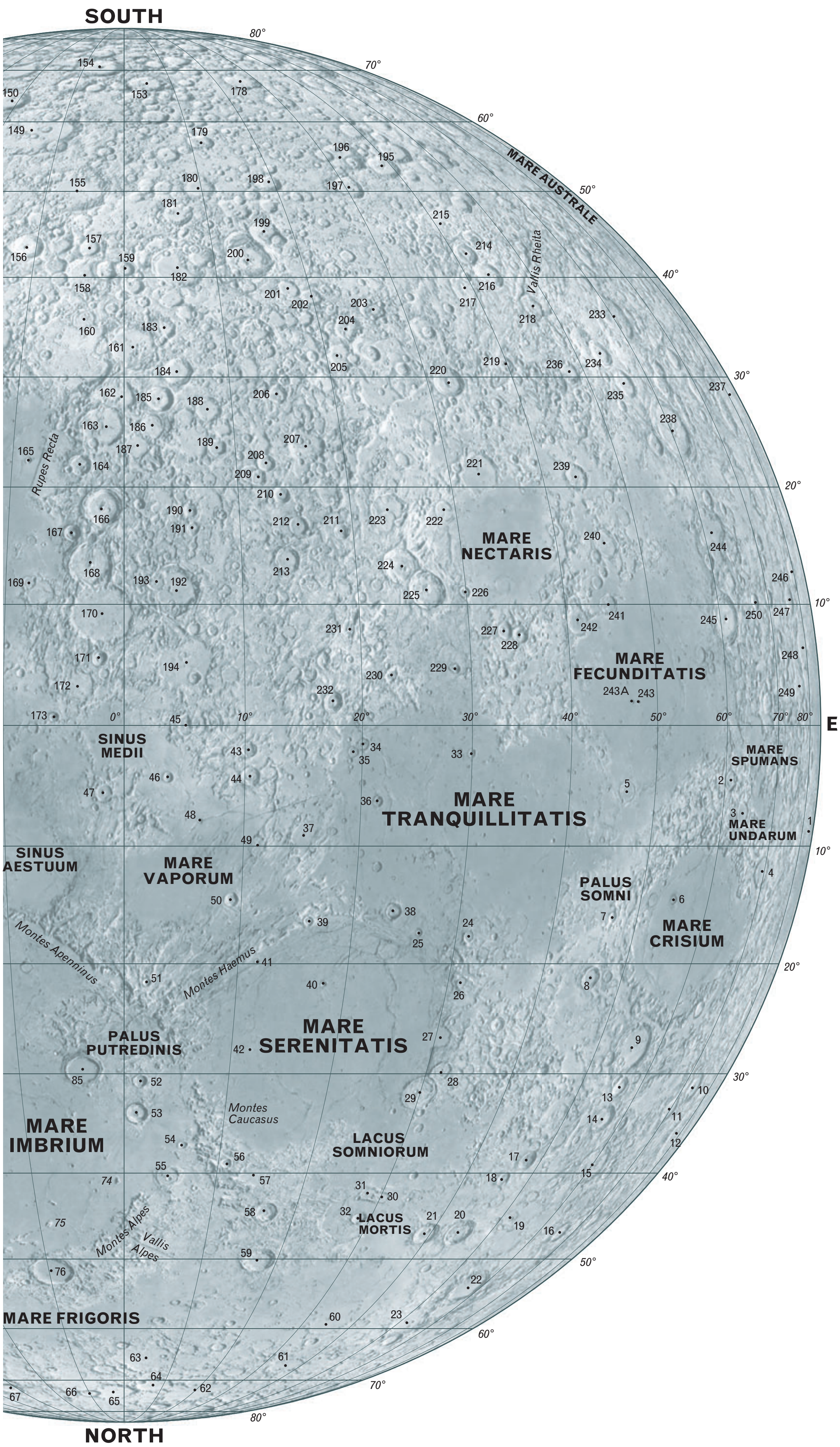
Features in alphabetical order



Kepler	103
Kies	131
Klein	193
Krafft	108
La Caille	187
La Pérouse	247
Lagrange	127
Lambert	87
Langrenus	245
Lansberg	101
Le Monnier	27
Le Verrier	77
Letronne	115
Lexell	160
Licetus	181
Linné	42
Littrow	26
Longomontanus	148
Macrobius	8
Mädler	226
Maginus	155
Mairan	83
Manilius	50
Manzinus	178
Marius	104
Maskelyne	33
Mason	30
Maurolycus	200
Mayer	98
Mee	143
Menelaus	39
Mercator	132
Mercurius	16
Mersenius	124
Messala	15
Messier & Messier A	243
Metius	216
Meton	62
Mons Pico	*75*
Mons Piton	*74*
Mons Rümker	*84*
Moretus	154
Mösting	173
Nasireddin	159
Neander	219
Neper	1
Nonius	183
Olbers	112
Orontius	158
Pallas	47
Parry	175
Petavius	238
Philolaus	67
Phocylides	146
Piazzi	128
Picard	6
Piccolomini	220
Pitatus	136
Pitiscus	197
Plana	31
Plato	76
Playfair	189
Plinius	38
Pontanus	206
Posidonius	29
Prinz	90
Proclus	7
Promontorium Heraclides	82
Promontorium Laplace	79
Ptolemaeus	170
Purbach	163
Pythagoras	71
Rabbi Levi	204
Regiomontanus	162
Reichenbach	236
Reiner	105
Reinhold	100
Rhaeticus	45
Rheita	218
Riccioli	113
Riccius	203
Ritter	35
Rocca	119
Sabine	34
Sacrobosco	207
Santbech	239
Saussure	157
Scheiner	151
Schickard	144
Schiller	147
Seleucus	107
Sharp	81
Sirsalis & Sirsalis A	118
Snellius	235
Stadius	95
Stevinus	234
Stöfler	182
Struve	106
Sulpicius Gallus	41
Tacitus	211
Taruntius	5
Theaetetus	54
Thebit	164
Theophilus	225
Timocharis	86
Torricelli	229
Triesnecker	46
Tycho	156
Vallis Schröteri	*93*
Vendelinus	244
Vetruvius	24
Vieta	126
Vitello	134
Vlacq	195
W. Bond	63
Walter	161
Wargentin	145
Werner	185
Wilhelm	142
Wurzelbauer	138
Zagut	205
Zöllner	231

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SEASONAL SKY MAPS

Looking up at the night sky you will probably see a disorderly, scattered arrangement of stars, but anyone who observes more frequently will start to see that the stars do not change places in relation to each other. Long ago, people began giving names to these fixed groupings of stars, and today we refer to these groups as *constellations*. Most people recognize one or two constellations; for example, they probably know what the Big Dipper (or Plough), a part of the Great Bear constellation, looks like. But why is it always in a different position in the sky? And why can't you find Orion during a night in June or July? This changing aspect of the sky is often confusing to the casual stargazer. So, the first thing you have to learn is how the sky moves.

It is important to know that the star patterns themselves do not change, at least not in a single human life span. It is only over a period of centuries that the positions of some neighboring stars change in a way that can be detected with the unaided eye. All these groupings of stars and constellations can be regarded as being fixed to a huge imaginary sphere, with the Earth placed in the center. No matter where on Earth you are, you can always see just one half of this sphere. So it is not hard to understand that, when you move to another part of the Earth, the visible half of the celestial sphere also changes. If you stand at the North Pole you will only see the northern half of the heavens, while at the South Pole you will see only the southern half. But there is more to it than that. Two more factors affect the appearance of the sky. Firstly there is the daily rotation of the Earth around its axis, which causes the Sun to rise in the east and set in the west. The same thing happens with the other objects in the sky. In fact, it appears to us as if the entire heavenly sphere rotates around an axis that is an extension of the Earth's axis. Apart from that there is the orbital movement of the Earth, which makes the appearance of the sky change over the seasons. If you look at one constellation, let us say Orion, at midnight on the first day of January and take note of its position, and then look every successive night at about the same time, you will notice that the stars reach the same position a few minutes earlier each night. One month later, on the first day of February, Orion will already be in that position at 10 p.m. and at midnight it will be approximately 30 degrees further to the west (figure 3a). A few months later Orion will have disappeared below the horizon and other constellations will have taken its place in the southern sky. So the appearance of the night sky changes slowly, until exactly one year later the Earth has reached the same point in its orbit again and on the first day of January Orion will be back in its original position at midnight.

The points where the extension of the Earth's axis cuts the celestial sphere are called the celestial Poles (see figure 4). Very close to the celestial North Pole is a star of average brightness, *Polaris*, or the Pole Star. It always appears in the same place in the sky, above the north point of the horizon, and the whole sky appears to be rotating around it. Looking at north in January at midnight, the Big Dipper appears east (to the right) of Polaris (figure 3b). Three months later, at the same time, it will be 'above' Polaris. You have to look way up high to see it. In another three months it will be west of Polaris and in October it will be close to the horizon. At least, this is the case if you are living north of latitude 40°N. The angle between the horizon plane and Polaris equals your latitude on earth. If you are living at 40° northern latitude, Polaris is 40 degrees above the northern horizon. When you are living closer to the Earth's equator Polaris will be closer to the horizon and the Big Dipper will, at its lowest position, disappear below the horizon. Looking south again, it will be the other way around. The closer to the equator you are, the higher the southern constellations rise above the horizon. Standing on the North Pole, you would see Polaris at 90 degrees above the horizon, actually in

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Figure 3a

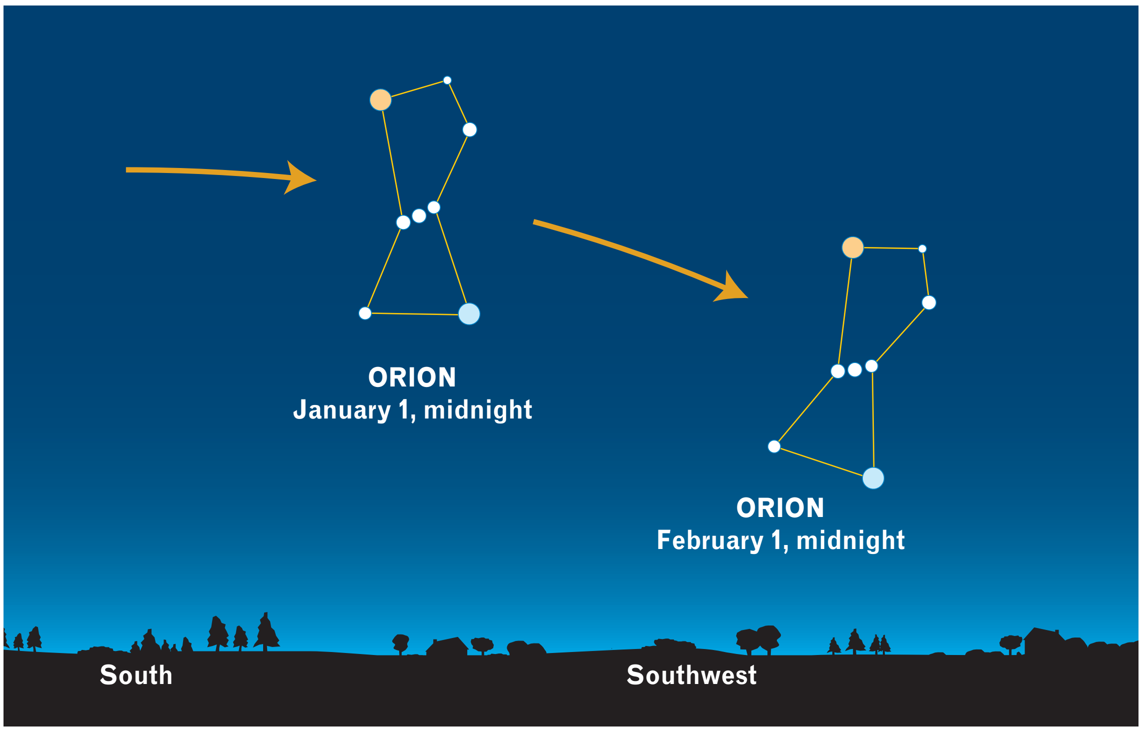
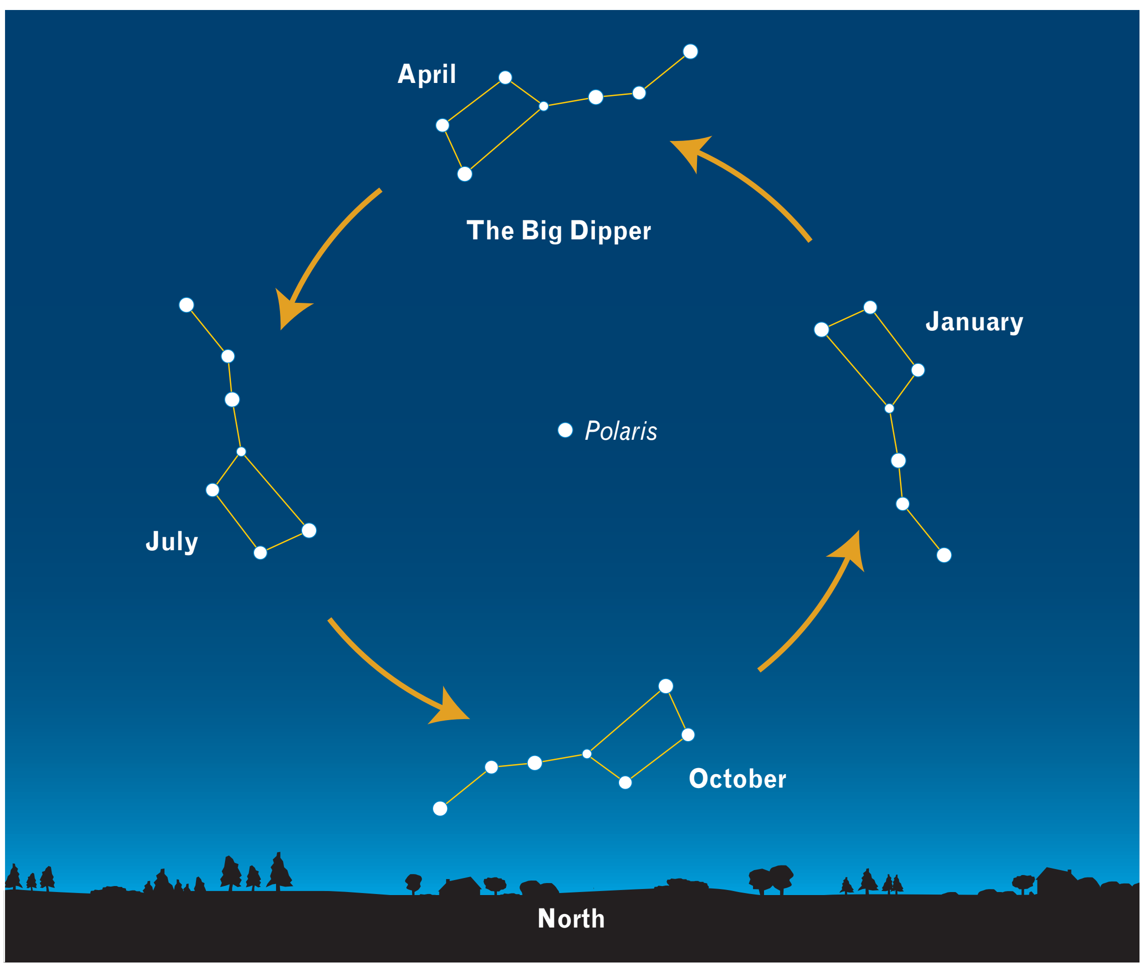


Figure 3b



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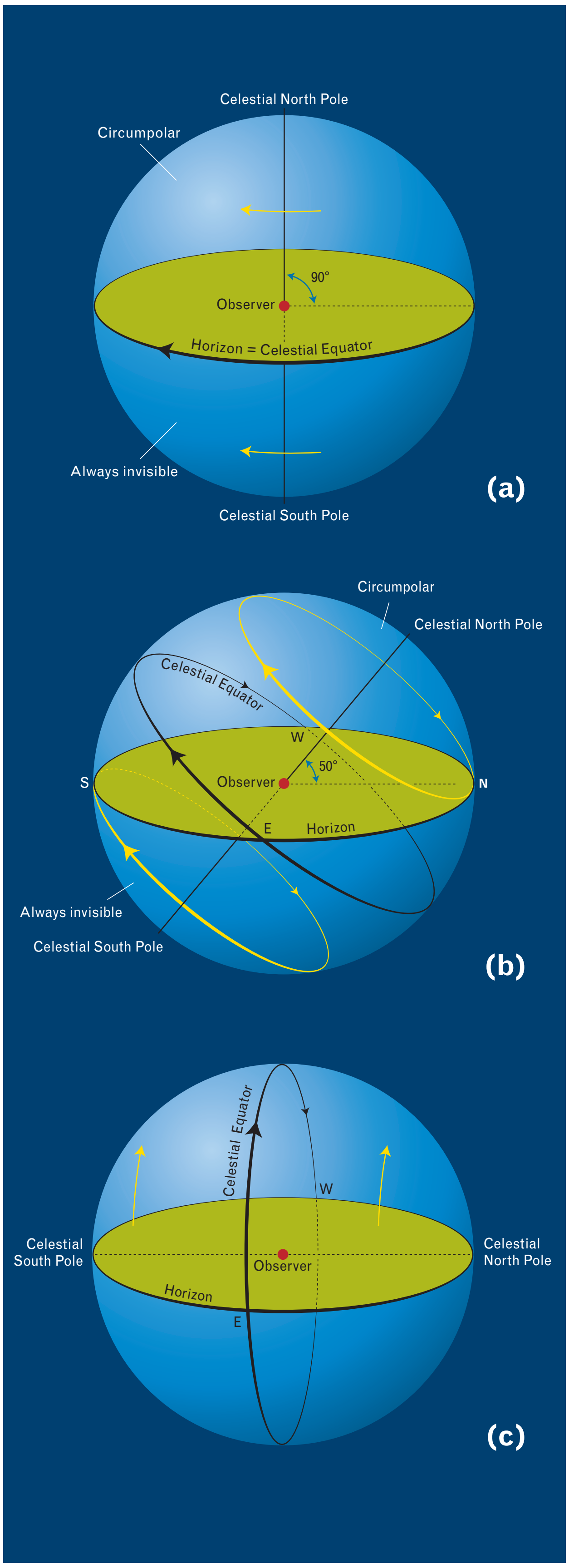

the *zenith*, the point straight above your head. From that cold location you would always see the same part of the sky, the northern half of the celestial sphere. Seen from there the whole sky rotates around the zenith, and stars move only parallel to the horizon – they do not rise or set (figure 4a). At the South Pole you have a similar situation, but with only the southern part of the sky visible. Since the axis of our planet does not change its position relative to the stars when it moves around the Sun, the sky visible from the poles of the Earth remains the same all year long or, better, during about six months of darkness. The rest of the year the poles have continuous daylight.

On the other hand, on the Equator things are quite different. The *celestial Equator*, the line where the plane of the Earth's Equator cuts the celestial sphere, runs from the east, passing directly overhead, to the west (figure 4c). All the stars and other objects in the sky rise and set, and during the course of a year it is possible to view the entire celestial sphere. Finally, in the intermediate areas the situation is more complicated, as you can see in the figure 4b. There is an area of the sky that is called *circumpolar*. Stars in this part of the sky are so close to the pole that they never rise or set, but remain above the horizon. In the opposite part of the celestial sphere, there is an equally sized part that never becomes visible.

In the star maps you can see a band of a slightly lighter blue, representing the brightest parts of the Milky Way. All the stars, nebulae and clusters that we see in the sky (except the galaxies; see pages 36–37, where nebulae and clusters are also explained in more detail) belong to a huge formation called the

Figure 4

(a) The way the sky moves for an observer at the North Pole. Half of the sky is always visible (circumpolar), and the other half is always invisible. Stars do not rise or set.

(b) The way the sky moves for an observer at a latitude of 50° north. A smaller part of the northern sky is always visible (circumpolar), and a similar area of the southern sky is always invisible. Most stars rise and set.

(c) The way the sky moves for an observer at the Equator. There are no circumpolar stars, and no stars that are always invisible. All stars rise and set.