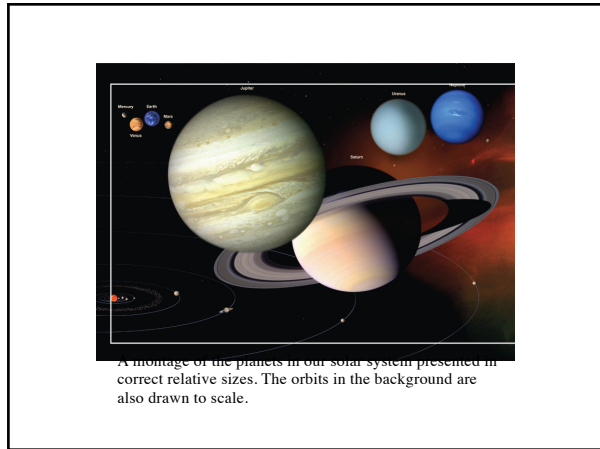


1

Orbital Characteristics of the Planets

	Average distance from Sun		Orbital period (year)	Orbital eccentricity (e)	Orbital inclination
	(AU)	(10 ⁸ km)			
Mercury	0.39	58	0.24	0.206	7.01°
Venus	0.72	108	0.62	0.007	3.39°
Earth	1.00	150	1.00	0.017	0°
Mars	1.52	228	1.88	0.093	1.85°
Jupiter	5.20	778	11.86	0.048	1.30°
Saturn	9.54	1427	29.46	0.054	2.48°
Uranus	19.19	2871	84.01	0.047	0.77°
Neptune	30.06	4497	164.79	0.009	1.77°

2

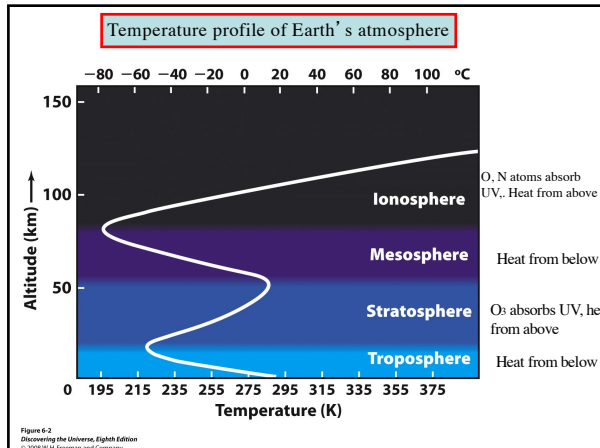


3

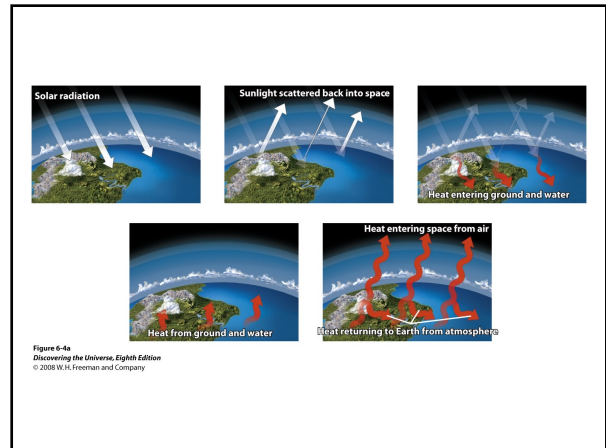
table 9-1 Earth Data

Average distance from the Sun:	1.000 AU = 1.496×10^8 km
Maximum distance from the Sun:	1.017 AU = 1.521×10^8 km
Minimum distance from the Sun:	0.983 AU = 1.471×10^8 km
Eccentricity of orbit:	0.017
Average orbital speed:	29.79 km/s
Orbital period:	365.256 days
Rotation period:	23.9345 hours
Inclination of equator to orbit:	23.46°
Diameter (equatorial):	12,756 km
Mass:	5.974×10^{24} kg
Average density:	5515 kg/m ³
Escape speed:	11.2 km/s
Albedo:	0.39
Surface temperature range:	Maximum: 60°C = 140°F = 333 K Mean: 14°C = 57°F = 287 K Minimum: -90°C = -130°F = 183 K
Atmospheric composition (by number of molecules):	78.08% nitrogen (N ₂) 20.99% oxygen (O ₂) 0.035% carbon dioxide (CO ₂) about 1% water vapor

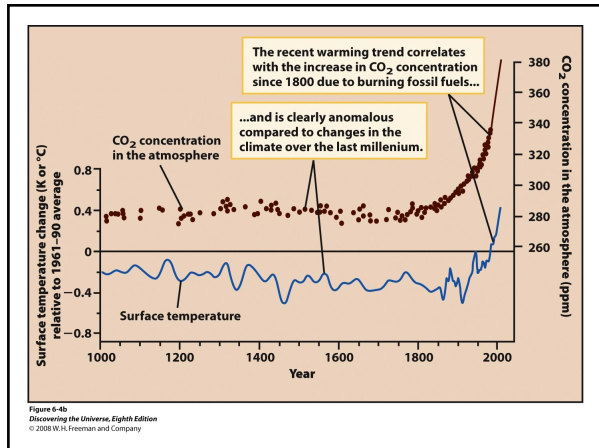
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7

Average surface temperature of planet

$$P_{abs} = (L/4\pi d^2) \times \pi r_p^2 (1 - \text{albedo})$$

$$P_{em} = 4\pi r_p^2 \sigma T_p^4$$

If no atmosphere then for thermal equilibrium:
 $P_{abs} = P_{em}$

$$T_p = [L/(4\pi d^2) \times (1 - \text{albedo}) / (4\sigma)]^{1/4}$$

Example for Earth:
 $L = 3.86 \times 10^{26} \text{ W}$, $d = 1.5 \times 10^{11} \text{ m}$, $\text{albedo} = 0.37$,
 $\sigma = 5.67 \times 10^{-8} \text{ J m}^{-2} \text{ K}^{-4} \text{ s}^{-1}$
 $T_p = 247 \text{ K}$

➔ With average $T = 290 \text{ K} \rightarrow 43 \text{ K}$ due to greenhouse effect

8

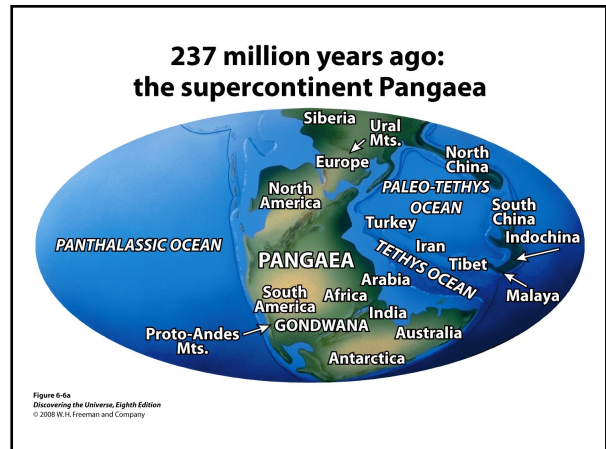
Surface of Earth (crust),
Floating on a layer
of denser material.

Alfred Wegener
1912-1915 observations
Africa and South America fit

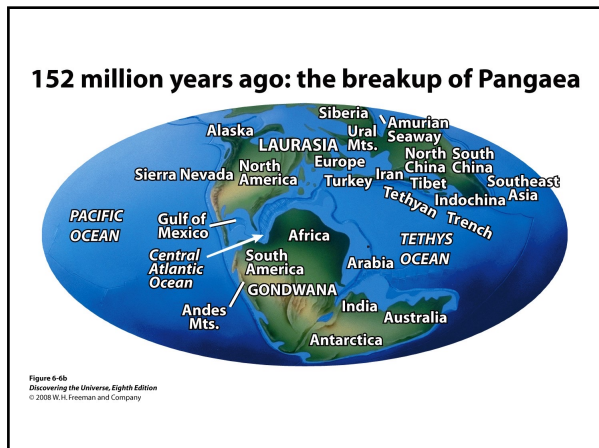
Hypothesis:
Continental drift

Figure 6-5
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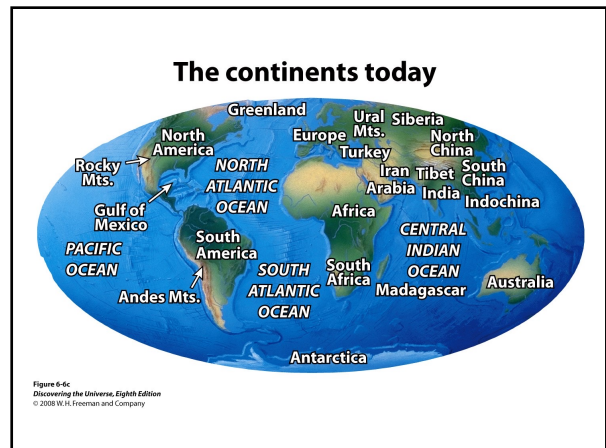
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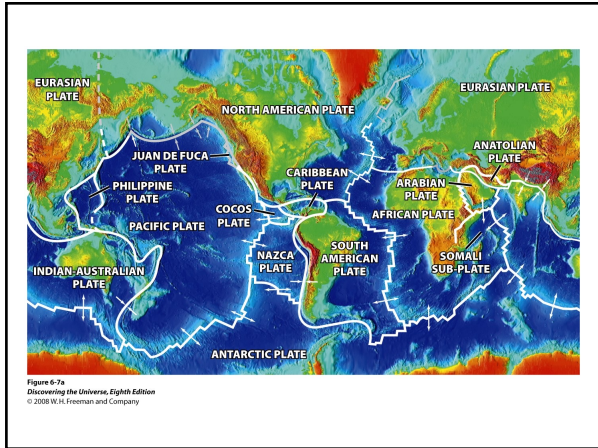
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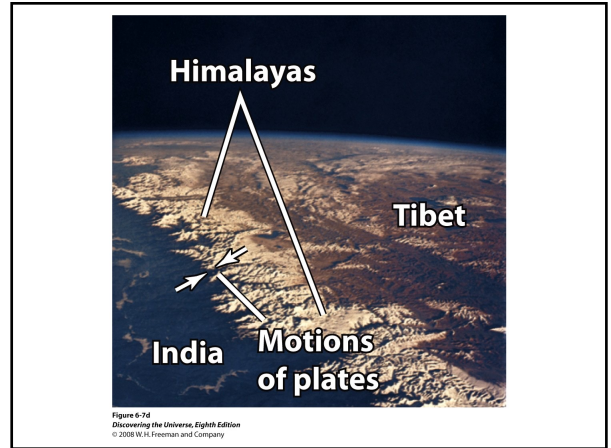
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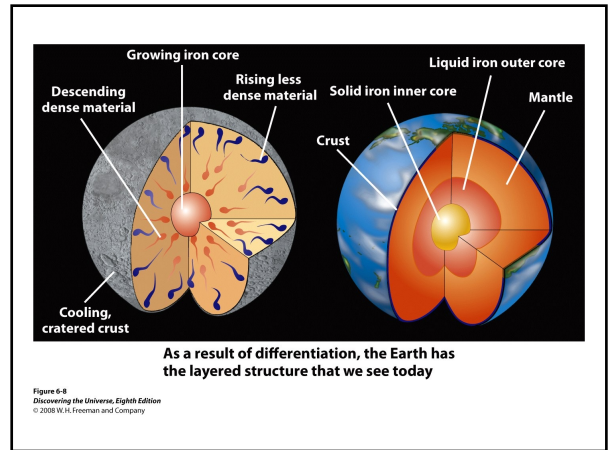
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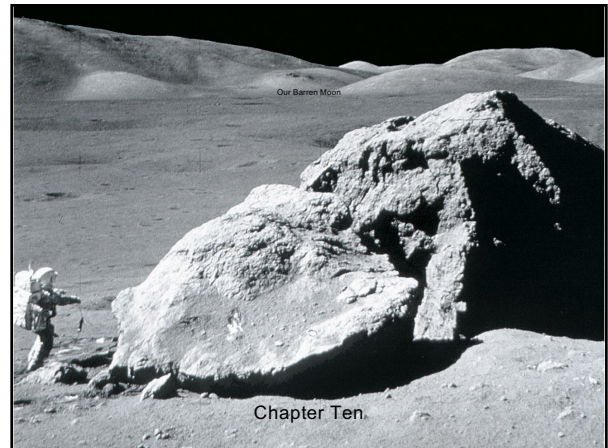
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18



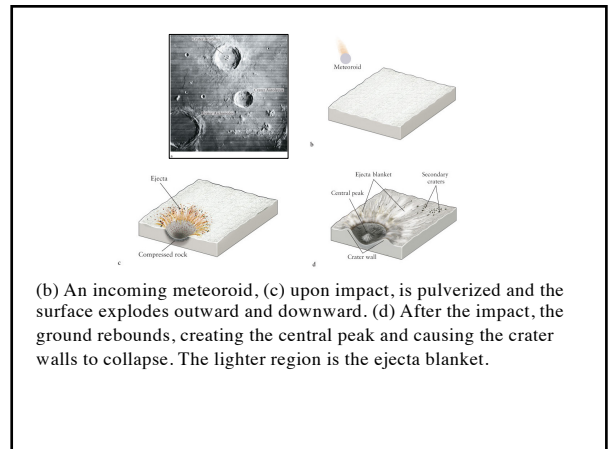
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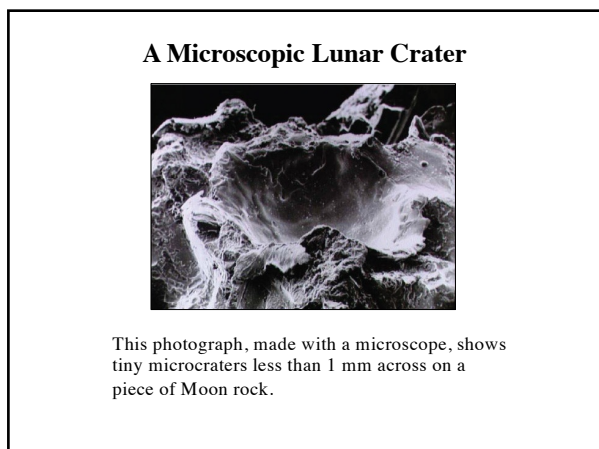
26

table 10-1 Moon Data	
Distance from Earth (center to center):	Average: 384,400 km – 238,900 mi Maximum (apogee): 405,500 km Minimum (perigee): 363,300 km
Eccentricity of orbit:	0.0549
Average orbital speed:	3680 km/h
Sidereal period (relative to fixed stars):	27.322 days
Synodic period (new moon to new moon):	29.531 days
Inclination of lunar equator to orbit:	6.68°
Inclination of orbit to ecliptic:	5.10°
Diameter (equatorial):	3476 km – 2160 mi = 0.272 Earth diameter
Mass:	7.349 × 10 ²² kg = 0.0123 Earth mass
Average density:	3344 kg/m ³
Escape speed:	2.4 km/s
Surface gravity (Earth = 1):	0.17
Albedo:	0.11
Average surface temperatures:	Day: 130°C = 266°F = 403 K Night: -180°C = -292°F = 93 K
Atmosphere:	Essentially none

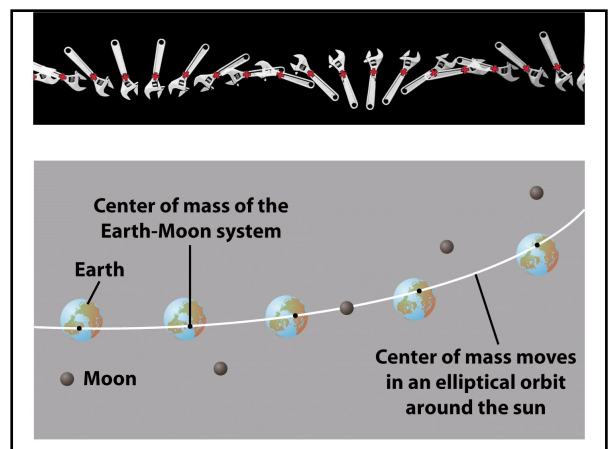
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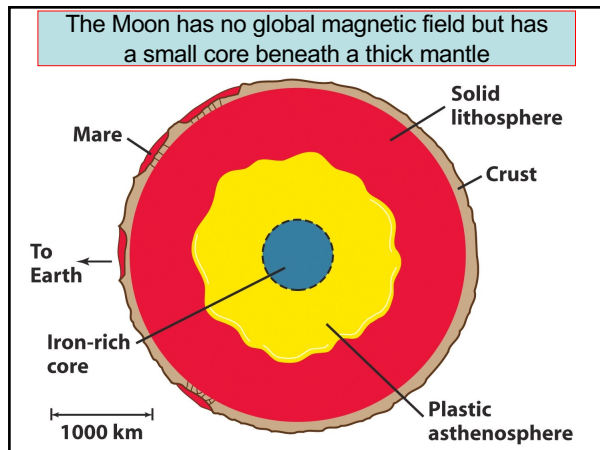
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Seismic experiments revealed that the main regions of the Moon's interior mimic those of Earth, but in different proportions.

Water ice may exist in the polar craters, where the energy received from the Sun is insufficient to melt it.

View of Moon's north polar region

Solid outer mantle

Plastic inner mantle

Iron-rich core

View of Moon's south polar region

Crater

Mare

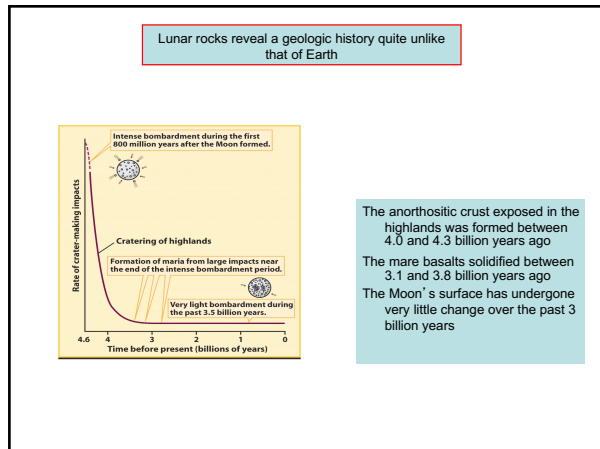
To Earth

1000 km

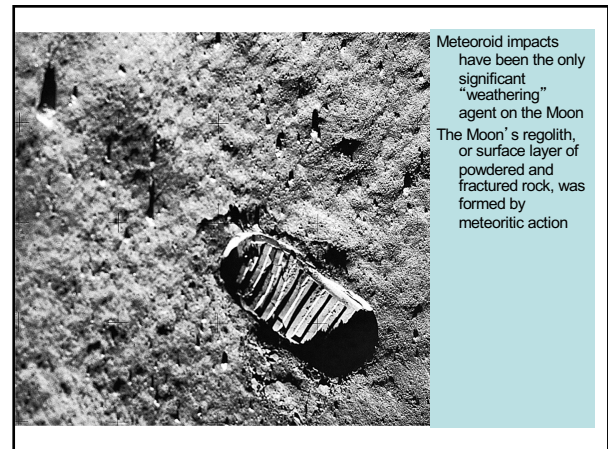
Continuity of Moon's interior

b

38



39



40

All of the lunar rock samples are rocks formed largely of minerals found in terrestrial rocks

The lunar rocks contain no water

They differ from terrestrial rocks in being relatively enriched in the refractory elements and depleted in the volatile elements

41

The Moon probably formed from debris cast into space when a huge planetesimal struck the proto-Earth

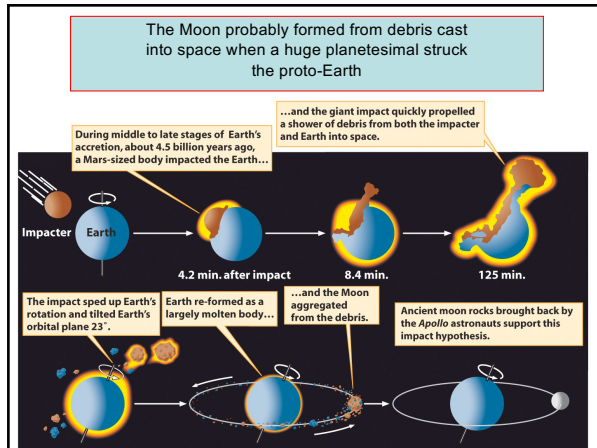
The collisional-ejection theory holds that the proto-Earth was struck by a Mars-sized protoplanet and that debris from this collision coalesced to form the Moon

This theory successfully explains most properties of the Moon

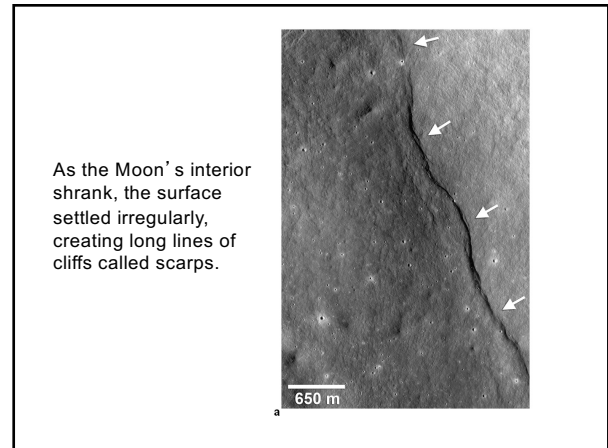
The Moon was molten in its early stages, and the anorthositic crust solidified from low-density magma that floated to the lunar surface

The mare basins were created later by the impact of planetesimals and filled with lava from the lunar interior

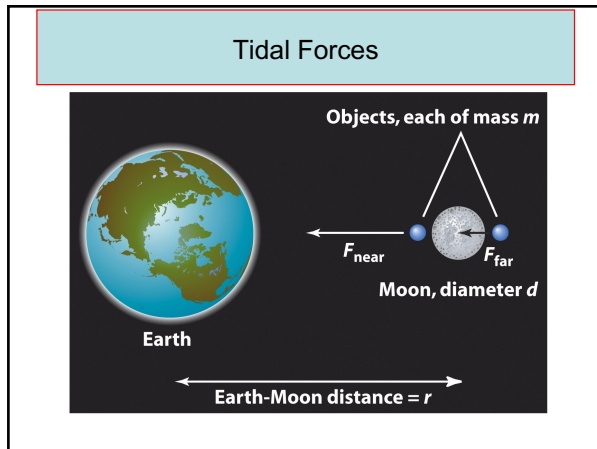
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Tidal forces depend very strongly on the distance between two celestial bodies. They are very strong for the Earth-Moon system. Here is the math:

$$F_{\text{near}} - F_{\text{far}} = F_{\text{tidal}}$$

$$F_{\text{tidal}} = \frac{dF}{dr} \Delta r = \frac{d}{dr} \frac{GM_{\text{Earth}} m_{\text{bulge}}}{r_{\text{Earth}}^2} \Delta r$$

$$F_{\text{tidal}} = - \frac{2GM_{\text{Earth}} m_{\text{bulge}}}{r^3} \Delta r$$

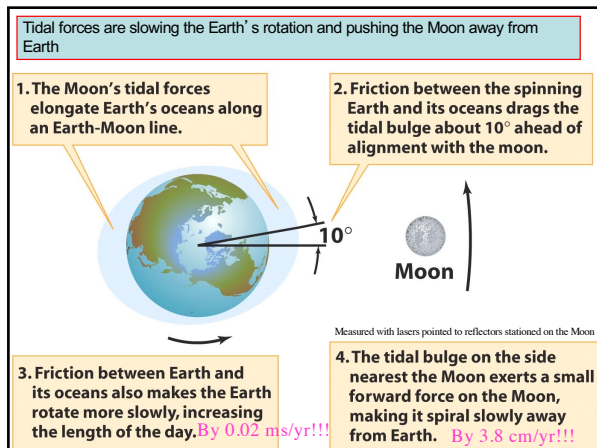
$$m_{\text{bulge}} = \frac{A}{r^3}$$

$$\Delta r = -d$$

$$F_{\text{tidal-net}} = A \frac{2GM_{\text{Earth}}}{r^6} d$$

$$\frac{F_{\text{tidal-net-perigee}}}{F_{\text{tidal-net-apogee}}} = \left(\frac{r_{\text{perigee}}}{r_{\text{apogee}}} \right)^6 = \left(\frac{363,300}{405,500} \right)^6 = 1.93$$

46

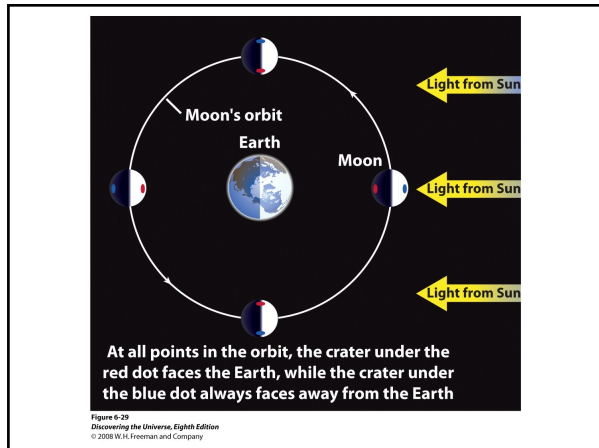


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Why do we see only one side of the moon from earth?

→ Tidal forces cause the moon to be in synchronous rotation.

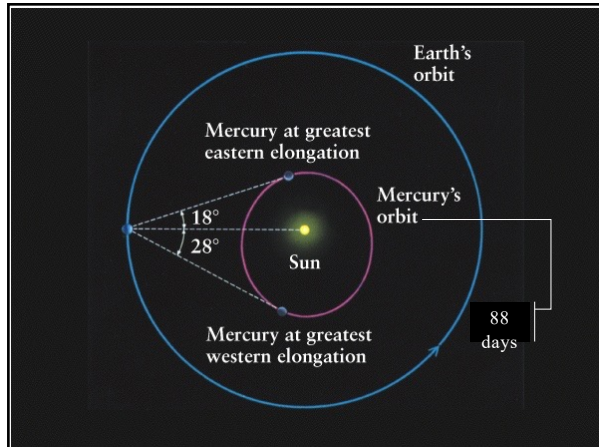
48



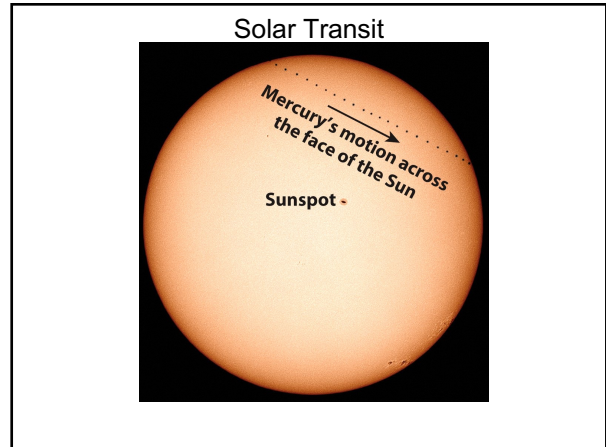
49

table n-1 Mercury Data	
Average distance from Sun:	0.387 AU = 5.79×10^7 km
Maximum distance from Sun:	0.467 AU = 6.98×10^7 km
Minimum distance from Sun:	0.307 AU = 4.60×10^7 km
Eccentricity of orbit:	0.206
Average orbital speed:	47.9 km/s
Orbital period:	87.969 days
Rotation period:	58.646 days
Inclination of equator to orbit:	0.5°
Inclination of orbit to ecliptic:	7° 00' 16"
Diameter (equatorial):	4880 km = 0.383 Earth diameter
Mass:	3.302×10^{22} kg = 0.0553 Earth mass
Average density:	5430 kg/m ³
Escape speed:	4.3 km/s
Surface gravity (Earth = 1):	0.38
Albedo:	0.12
Average surface temperatures:	Day: 350°C = 662°F = 623 K Night: -170°C = -274°F = 103 K
Atmosphere:	Essentially none

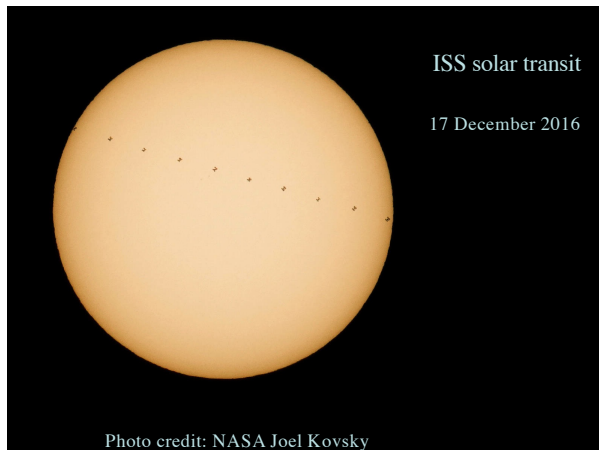
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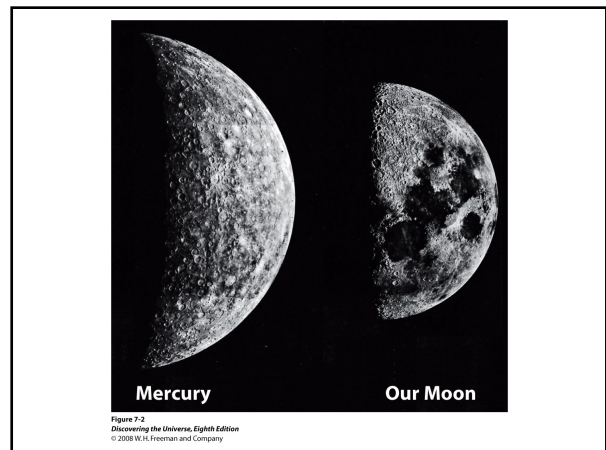
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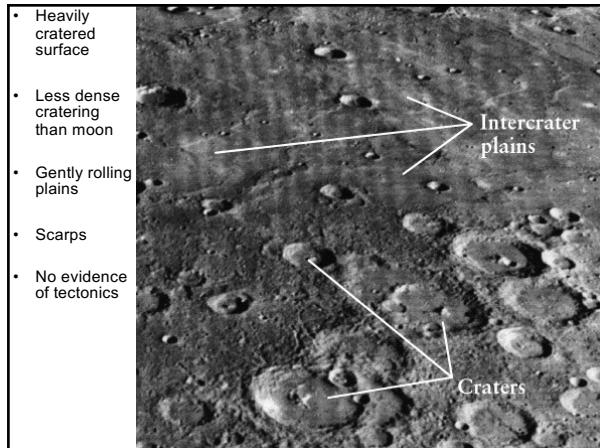
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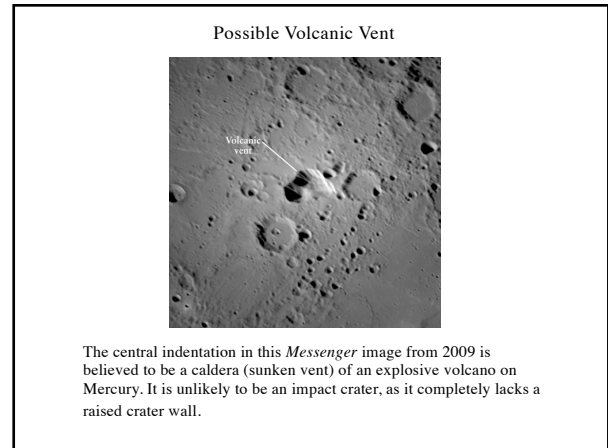
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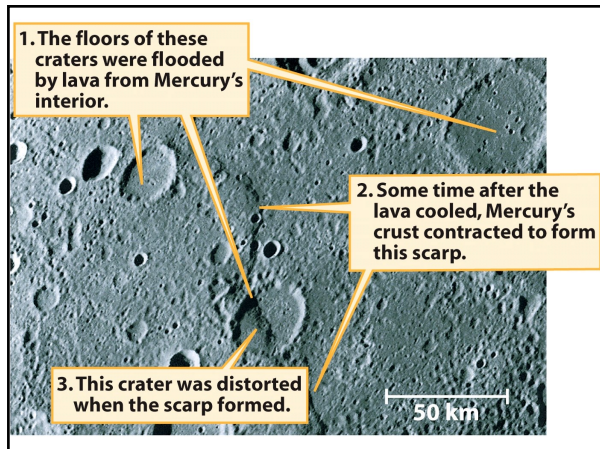
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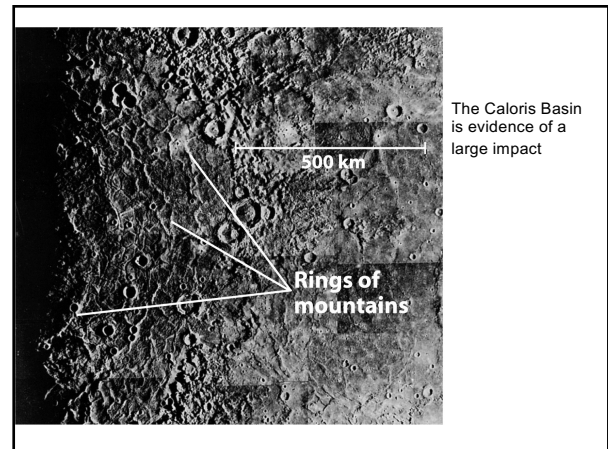
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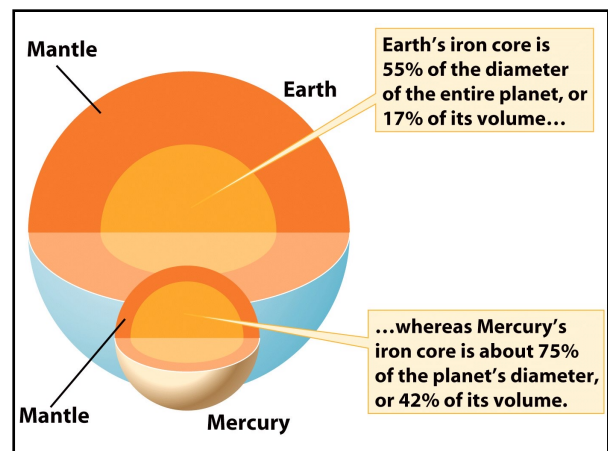


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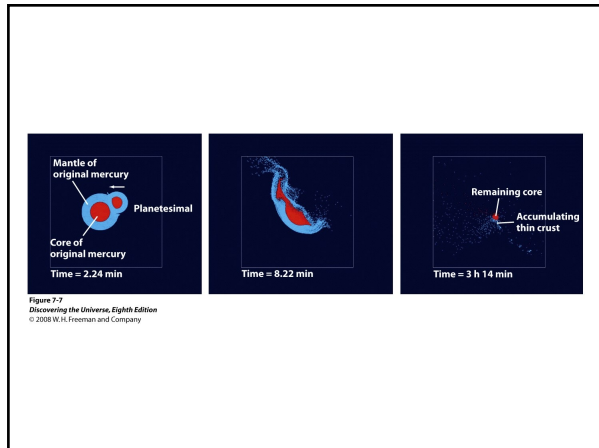
Mercury has an iron core and a surprising magnetic field

- Most iron-rich (relative to mass) planet in the solar system with a core that is 75% of the diameter
- The earth's core is 55% of its diameter and the moon's core is 20% of its diameter
- Among highest density for the planets
- Weak magnetic field indicating part of the core is liquid
- Magnetic field causes a magnetosphere similar to Earth's but weaker

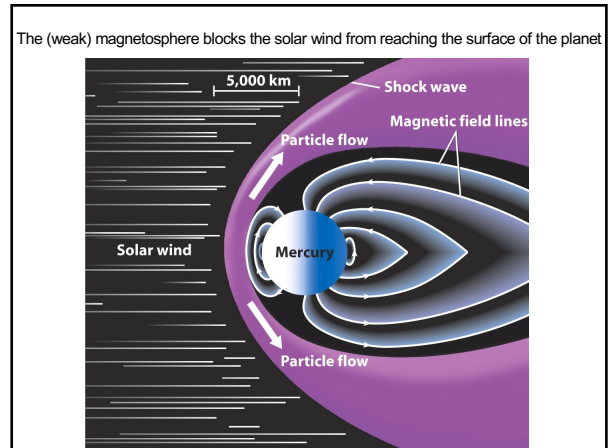
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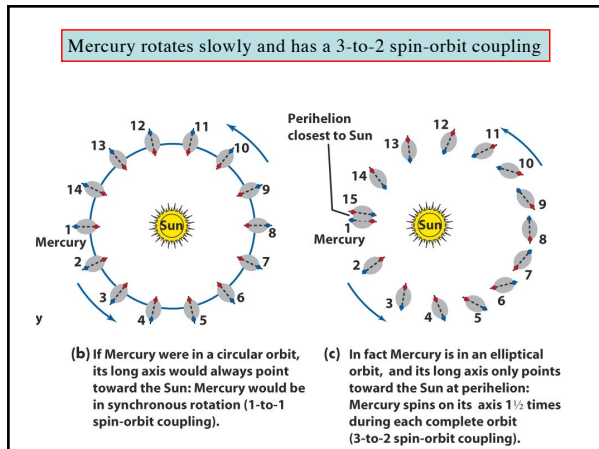
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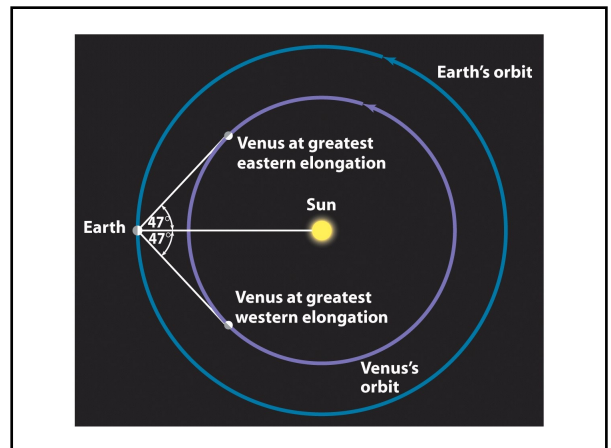
63

table 12-1 Venus Data	
Average distance from Sun:	0.723 AU = 1.082×10^8 km
Maximum distance from Sun:	0.728 AU = 1.089×10^8 km
Minimum distance from Sun:	0.718 AU = 1.075×10^8 km
Eccentricity of orbit:	0.0068
Average orbital speed:	35.0 km/s
Orbital period:	224.70 days
Rotation period:	243.01 days (retrograde)
Inclination of equator to orbit:	177.4°
Inclination of orbit to ecliptic:	3.39°
Diameter (equatorial):	12,104 km = 0.949 Earth diameter
Mass:	4.868×10^{24} kg = 0.815 Earth mass
Average density:	5243 kg/m ³
Escape speed:	10.4 km/s
Surface gravity (Earth = 1):	0.91
Albedo:	0.59
Average surface temperature:	480°C = 890°F = 733 K
Atmospheric composition (by number of molecules):	96.5% carbon dioxide (CO ₂) 3.5% nitrogen (N ₂), 0.003% water vapor (H ₂ O)

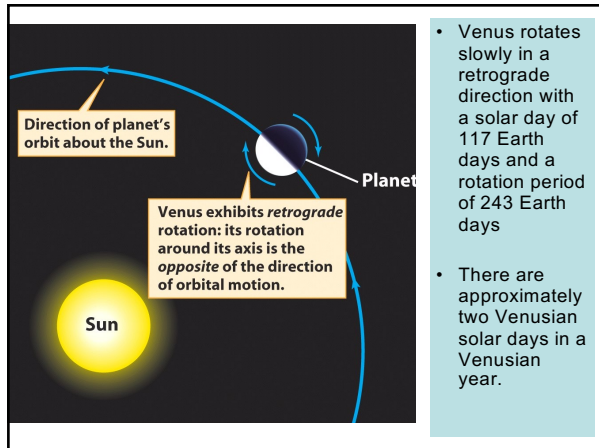
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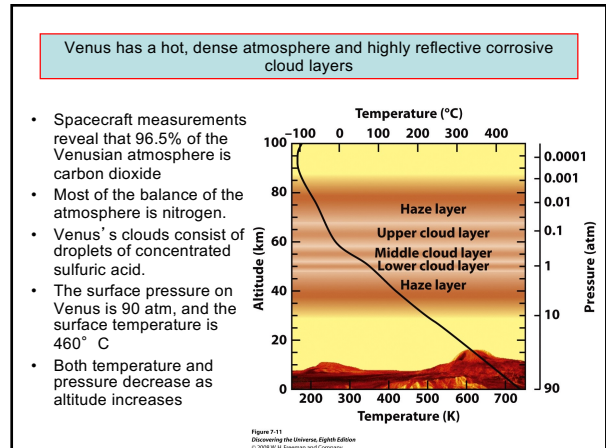


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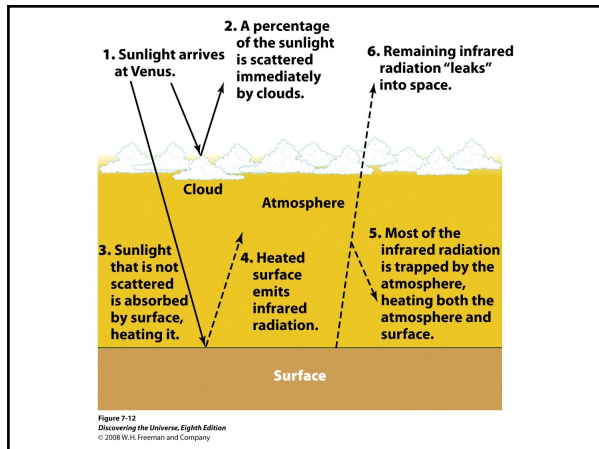


- Venus rotates slowly in a retrograde direction with a solar day of 117 Earth days and a rotation period of 243 Earth days
- There are approximately two Venusian solar days in a Venusian year.

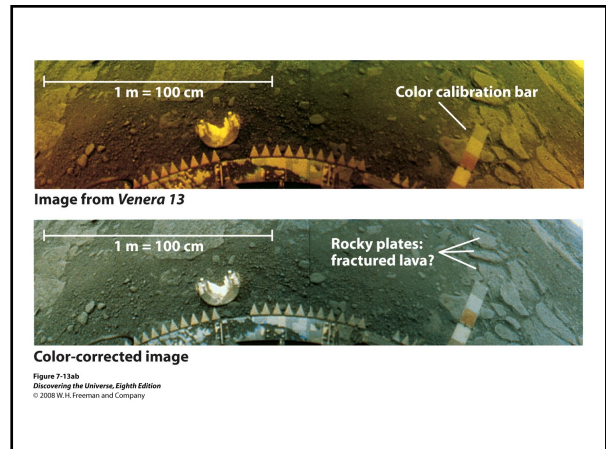
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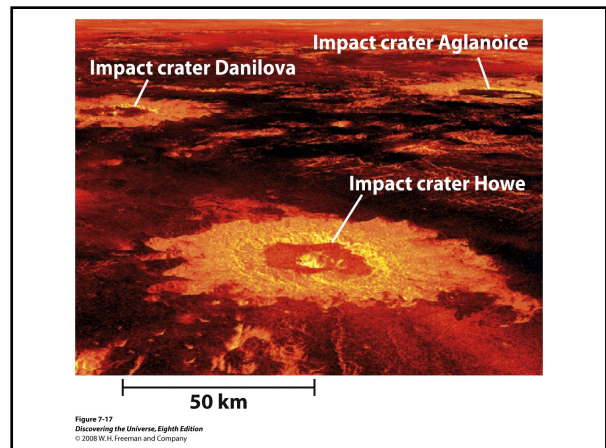
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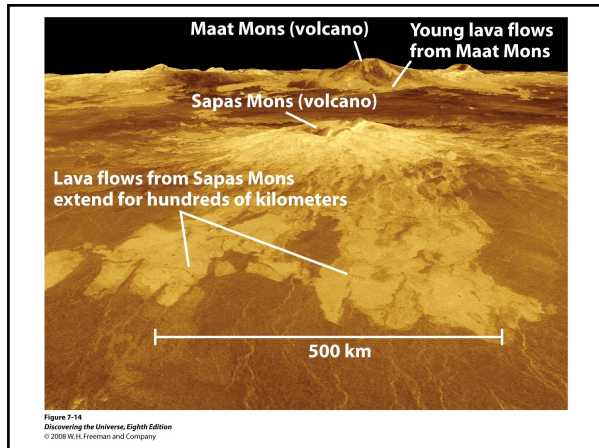


Figure 7-14
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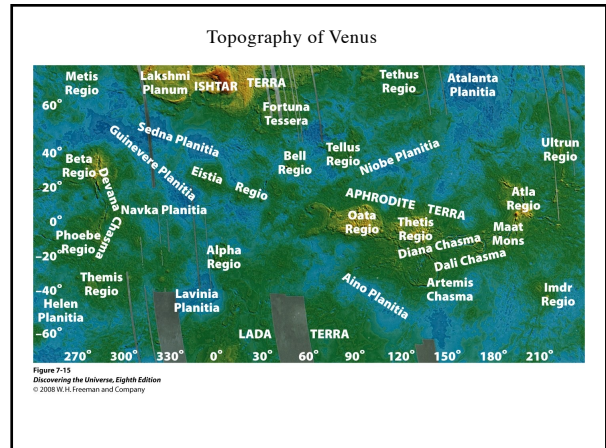


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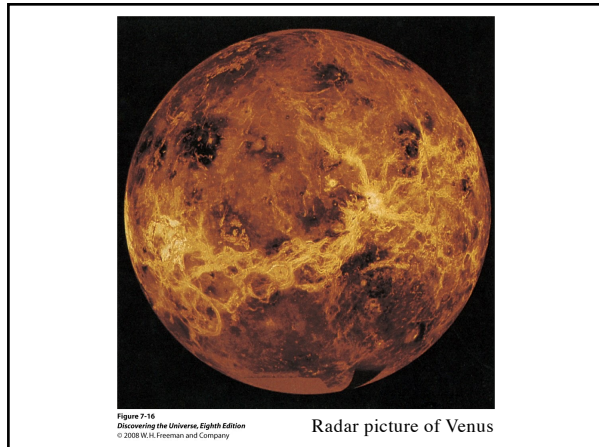


Figure 7-16
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table 13-1 Mars Data	
Average distance from Sun:	1.524 AU = 2.279×10^8 km
Maximum distance from Sun:	1.666 AU = 2.492×10^8 km
Minimum distance from Sun:	1.381 AU = 2.067×10^8 km
Eccentricity of orbit:	0.093
Average orbital speed:	24.1 km/s
Orbital period:	686.98 days = 1.88 years
Rotation period:	$24^h 37^m 22^s$
Inclination of equator to orbit:	25.19°
Inclination of orbit to ecliptic:	1.85°
Diameter (equatorial):	6794 km = 0.533 Earth diameter
Mass:	6.418×10^{23} kg = 0.107 Earth mass
Average density:	3934 kg/m ³
Escape speed:	5.0 km/s
Surface gravity (Earth = 1):	0.38
Albedo:	0.15
Surface temperatures:	Maximum: $20^\circ\text{C} = 70^\circ\text{F} = 293$ K Mean: $-53^\circ\text{C} = -63^\circ\text{F} = 220$ K Minimum: $-140^\circ\text{C} = -220^\circ\text{F} = 133$ K
Atmospheric composition (by number of molecules):	95.3% carbon dioxide (CO ₂) 2.7% nitrogen (N ₂) 0.036% water vapor (H ₂ O) 2% other gases

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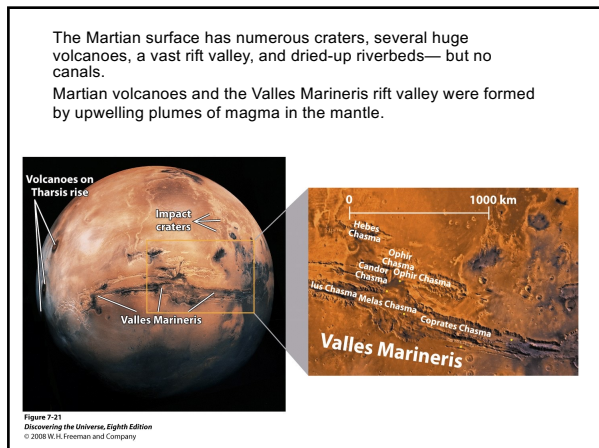


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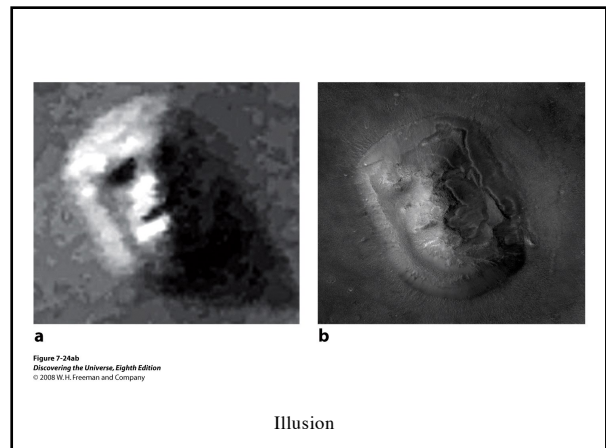
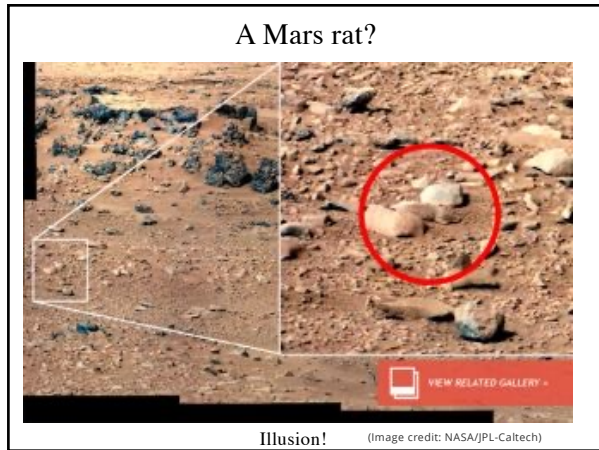


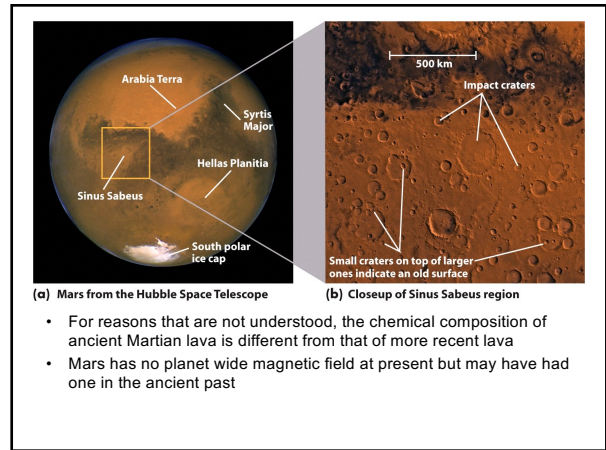
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Illusion

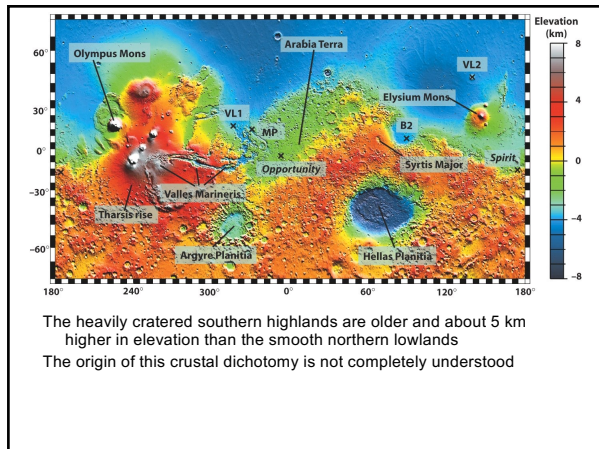
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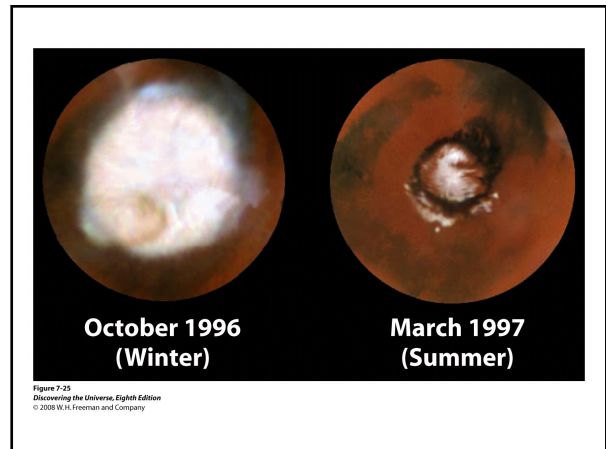
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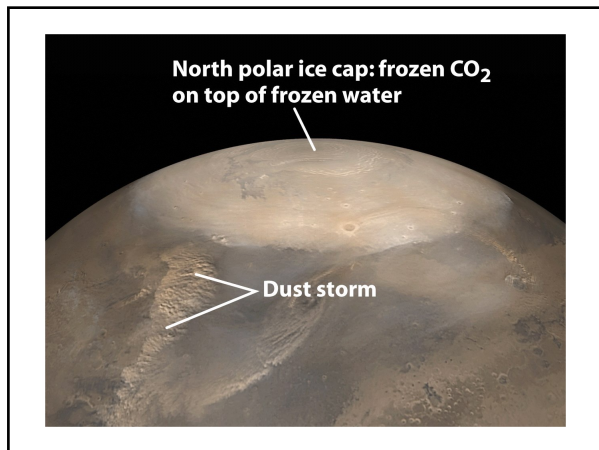
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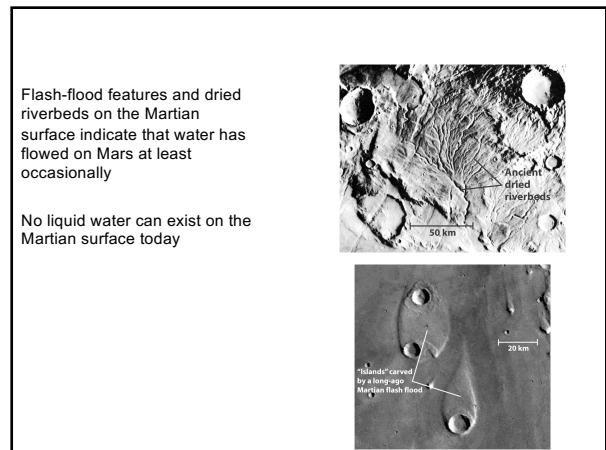
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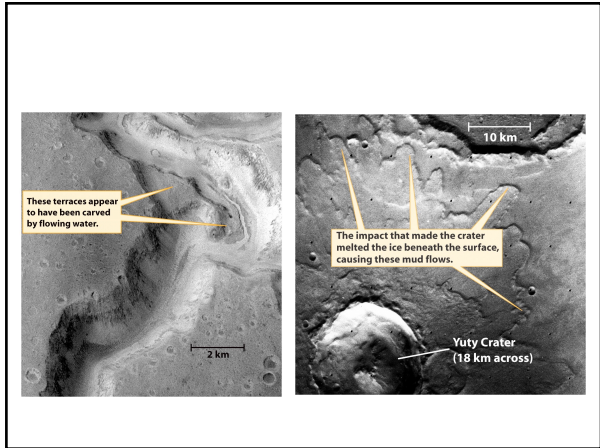
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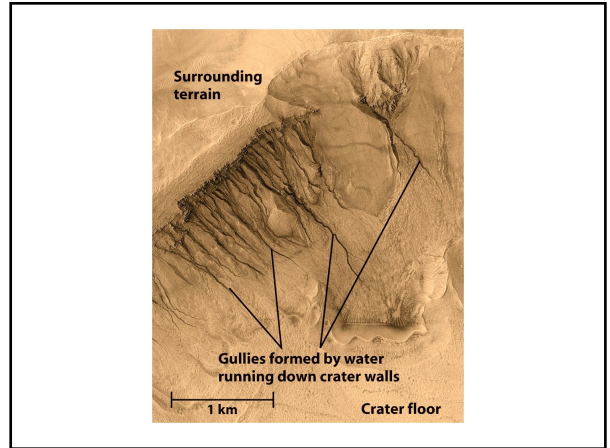
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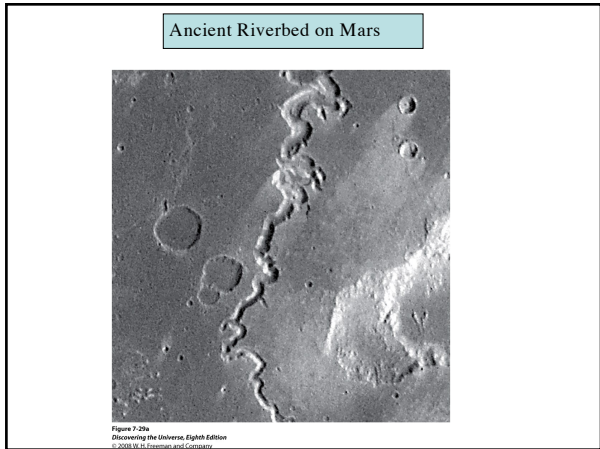
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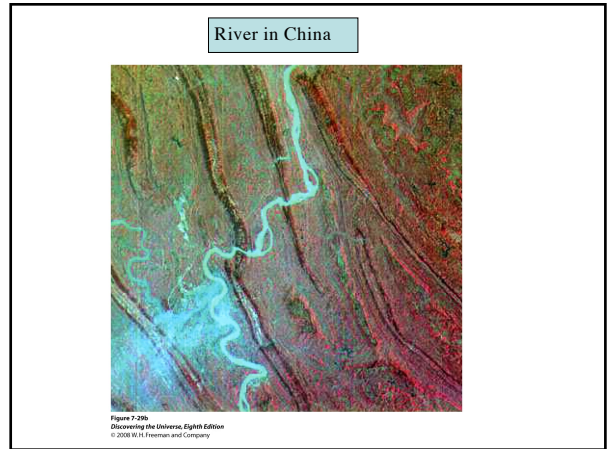
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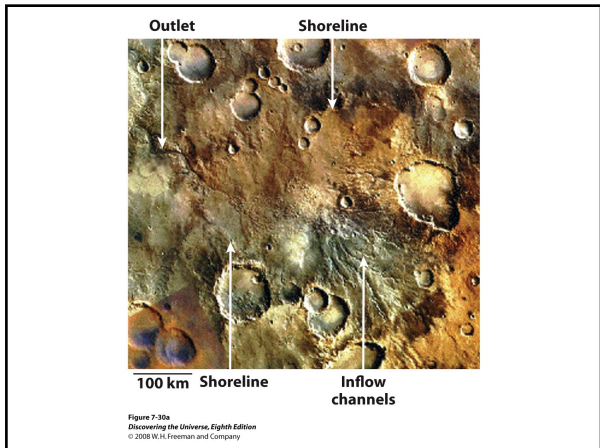
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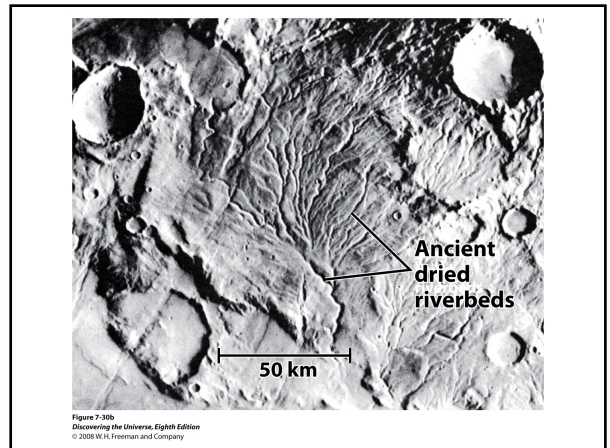
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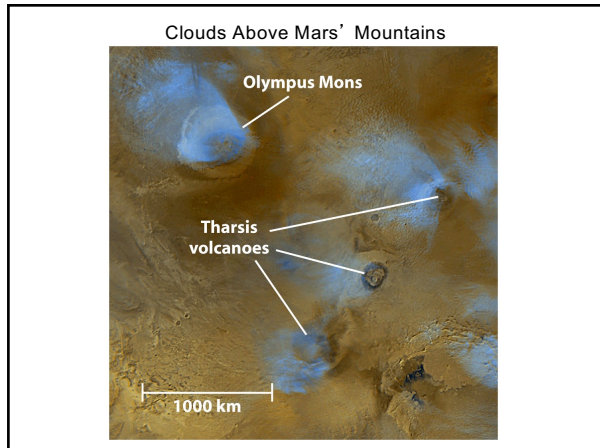
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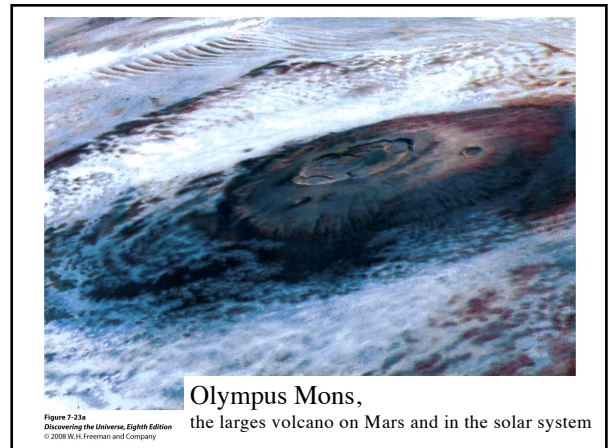
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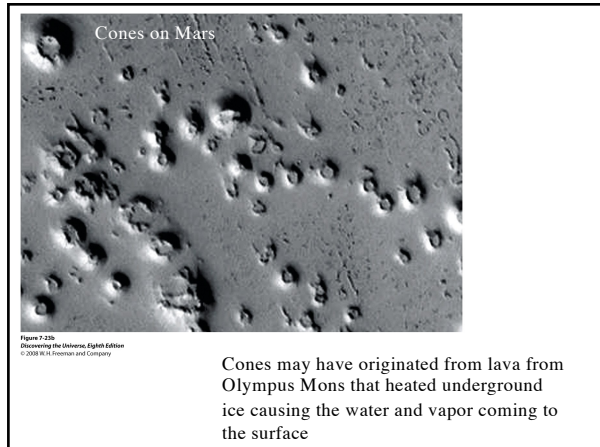
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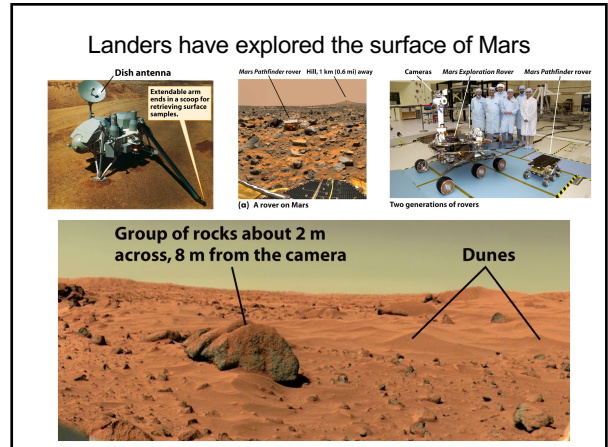
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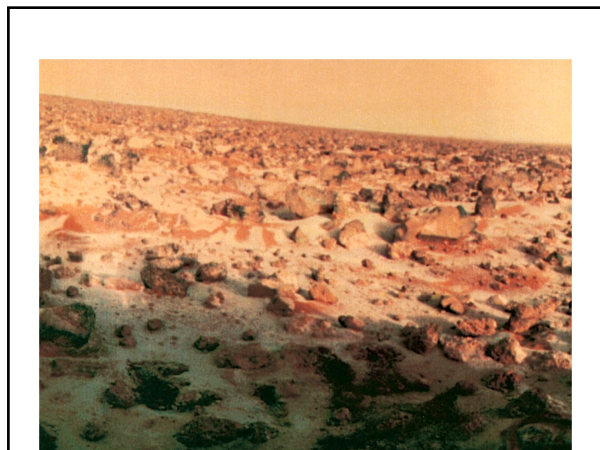
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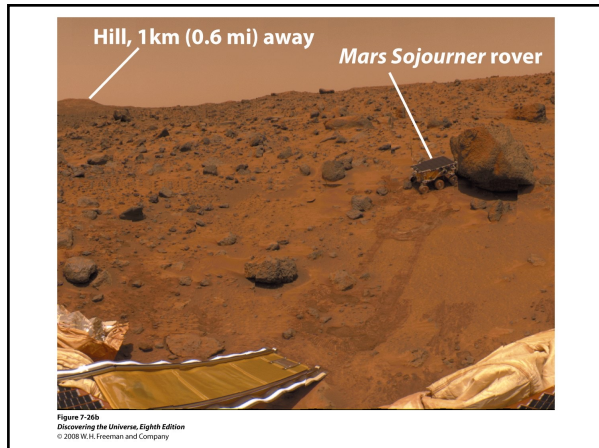
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97



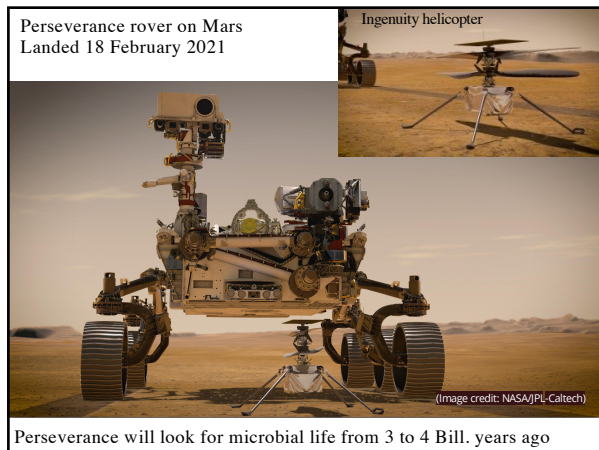
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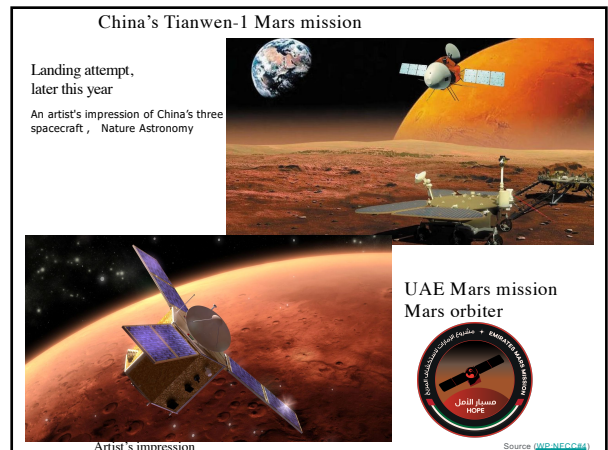
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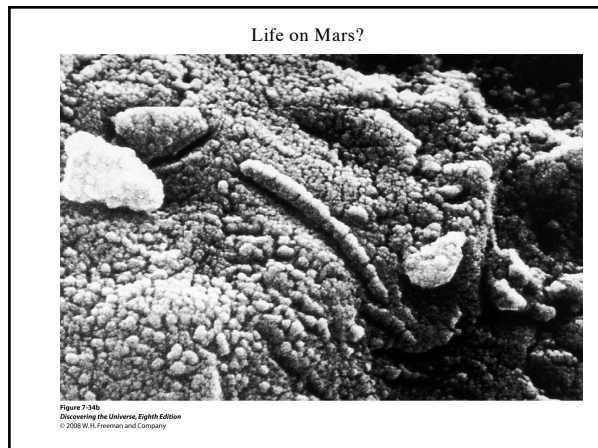
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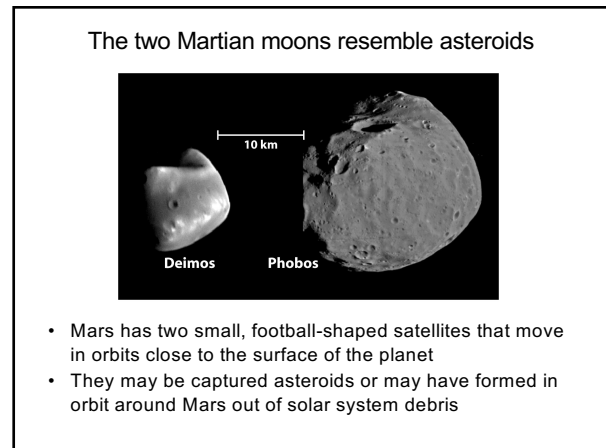
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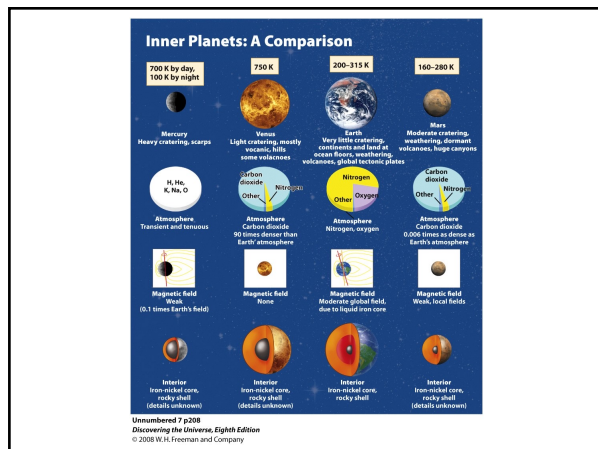
102



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105

Why is there no H₂ in the atmosphere of the inner planets?

$E_k = 1/2mv^2$	J	Kinetic energy due to motion with velocity, v
$E_k = 3/2kT$	J	Thermal kinetic energy of gas, atoms or molecules
$v = (3kT/m)^{1/2}$	m/s	Average speed of a gas, atom or molecule
$k = 1.38 \times 10^{-23}$	J/K	Boltzmann's constant
$m = \mathcal{M} \times \text{amu}$	kg	mass of atom or molecule
\mathcal{M}		mass number
$\text{amu} = 1.66 \times 10^{-27} \text{ kg}$		atomic mass unit

Example for Mars: $T=220\text{K}$, $\text{H}_2 : \mathcal{M}=2$, $m = 2 \times 1.66 \times 10^{-27} \text{ kg}$
 $v = [(3 \times 1.38 \times 10^{-23} \times 220) / (2 \times 1.66 \times 10^{-27})]^{1/2} = 1656 \text{ m/s}$
 A planet or moon can retain a gas if the escape speed is at least 6 times greater than the average velocity of the gas.

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What is the escape velocity for Mars?

$v^2_{\text{escape}} = 2GM/r$
 $M = 6.418 \times 10^{23} \text{ kg}$ (mass of Mars)
 $r = 3397 \text{ km}$ (radius of Mars)

$v^2_{\text{escape}} = 2 \times 6.673 \times 10^{-11} \times 6.418 \times 10^{23} / (3.397 \times 10^6) = 25.214 \times 10^6 \text{ (m/s)}^2$
 $v_{\text{escape}} = 5021 \text{ m/s} = 5.021 \text{ km/s}$

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 A planet or moon can retain a gas if the escape speed is at least 6 times greater than the average velocity of the gas.
 $v_{\text{esc}} = 5.02 \text{ km/s} = 3.0 \times v \rightarrow \text{H}_2 \text{ cannot be retained by Mars.}$

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