Mars
The Last Terrestrial
### Vital Statistics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Distance from Sun</td>
<td>1.524 AU ( (2.279 \times 10^8 \text{ km}) )</td>
</tr>
<tr>
<td>Mean Orbital Speed</td>
<td>24.1 km/sec</td>
</tr>
<tr>
<td>Sidereal Period</td>
<td>686.98 days</td>
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<tr>
<td>Rotation Period</td>
<td>24 hrs, 37 min</td>
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<tr>
<td>Inclination of Axis</td>
<td>23 deg, 59 min</td>
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<tr>
<td>Inclination of Orbit</td>
<td>1 deg, 51 minutes</td>
</tr>
<tr>
<td>Mass</td>
<td>0.107 ME ( (6.42 \times 10^{23} \text{ kg}) )</td>
</tr>
<tr>
<td>Mean Density</td>
<td>3.94 g/cm(^3)</td>
</tr>
<tr>
<td>Albedo</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Mars - Basics

About half the size of the Earth
Total surface area is about the same as Earth's land surface area
(not including the area covered by water)

About 1/10 the mass of the Earth

Takes almost twice as long as the Earth to go around the Sun

Martian day is only slightly longer than Earth's day

Mars is also cratered
Though the bottoms have been filled in

Surface temperatures range from $-87^0\ C$ to $-5^0\ C$

Low winter temperatures can be $-140^0\ C$ to high summer temperatures of $20^0\ C$
Mars is Earth-like

Mars has seasons, which last ~ twice as long as those as on Earth

Mars has polar ice caps, that vary in size according to the seasons

These are primarily carbon dioxide ices with some water ices

Mars has an atmosphere, though its composition is different than Earth's atmosphere

Movie Comparison
Martian Seasons

Seasons are of unequal strength in the two hemispheres

Due to the eccentricity of its orbit

9% eccentricity

Summer in the southern hemisphere is hotter than summer in the northern hemisphere

Mars is closest to the Sun for summer in the southern hemisphere

Winter in the southern hemisphere is colder than winter in the northern hemisphere

Mars is furthest from the Sun for winter in the southern hemisphere
The Martian Atmosphere

Martian atmosphere consists of
  Carbon dioxide - 95.3%
  Nitrogen - 2.7%

Atmospheric pressure at the surface is 1/160th of the Earth's atmospheric pressure

Very little water vapor in the Martian atmosphere

No ozone layer to shield Martian surface from deadly ultraviolet radiation
The Martian Atmosphere

Atmosphere is too thin to retain much heat

Temperature drops sharply at night
The Martian Atmosphere

Fog can form in low-lying areas, as sunlight strikes...
The Martian Atmosphere

Mars may be victim of runaway greenhouse effect in the opposite sense of Venus’s:

As water ice froze, Mars became more and more reflective and its atmosphere thinner and thinner, freezing more and more water and eventually carbon dioxide as well.
The Martian Atmosphere

As a result, Mars may have had a thicker atmosphere and liquid water in the past, but they are now gone.
Variation of Polar Ice Caps

As temperature in a hemisphere increases, the polar ice cap shrinks.

The carbon dioxide ices sublimate into the atmosphere.

This leaves a much smaller ice cap, probably consisting of water ices.

During the winter months, the ice cap could occupy about 30% of the hemispheric surface.

During the summer months, ice cap could shrink to ~1% of the hemispheric surface.

The changing amounts of gaseous carbon dioxide can cause ~20% variation in the atmospheric pressure.

Can cause strong winds.
Martian Dust Storms

The winds on Mars show seasonal effects, just as the winds on Earth.

Winds strong enough to move the fine grained particles.

Dust particles

Fill in the bottom of the craters.

Cause additional erosion of the surface features.
Martian Dust Storms

Periodically local dust storms coalesce into a much larger storm
This much larger storm then throws large quantities of dust into the atmosphere
The storm then further increases in intensity by utilizing the Sun's energy
The larger storm increases the amount of dust in the atmosphere obscuring the whole surface of Mars
The storm eventually dies out, due to cooling of the surface below
Because there is no rain the dust takes a long time to settle down to the surface
Martian Clouds

Dust storms kick up fine dust particles.
Droplets can form around these dust particles.

Clouds
These clouds made up of CO₂.
The Martian Surface

Major Feature - Tharsis Bulge

Size of North America and 10 km above surroundings

Minimal cratering

Youngest surface on Mars
The Martian Surface

Topologies of the northern and southern hemispheres are different from each other

No evidence for plate tectonics
The Martian Surface

Northern hemisphere (left) is rolling volcanic terrain

Southern hemisphere (right) is heavily cratered highlands; average altitude 5 km above northern

Assumption is that northern surface is younger than southern

Means that northern hemisphere must have been lowered in elevation and then flooded with lava
The Martian Surface

Northern hemisphere has flattened plains with volcanoes

The northern hemisphere is the younger of the two hemispheres

Southern hemisphere has highlands with extensive cratering

The southern hemisphere is the more ancient
The Martian Surface

Various topologies on Mars:

Canyons,
Volcanoes, and
Craters
The Martian Surface - Canyons

One canyon system, Valles Marineris, effectively separates the northern hemisphere from the southern hemisphere.

- It is over 4000 km long, 120 km wide, and as deep as 7 km.
- It is 1/5 of the circumference of Mars.
- The Grand Canyon could easily fit into the Valles Marineris.
The Martian Surface - Volcanoes

The large shield volcanoes on Mars resemble Hawaiian shield volcanoes.

Largest volcano in the solar system is located on Mars:

- **Olympus Mons**
  - Rises 25 km above the plains and has a diameter of about 700 km.
  - A fairly young volcano, in that very few impact craters are seen on its flanks.
  - Three times the height of Mt. Everest.

Three other Martian volcanoes are only slightly smaller.
Martian Surface - Craters

43,000 craters with diameter > 5 km

Crater densities in excess of typical lunar mare surfaces

Suggests that most of the Martian surface is probably billions of years old

Resurfacing is extremely slow in most places compared
Martian Internal Structure

No seismic studies have been done

From behavior of crust, it is estimated to be 100 km thick

No magnetic field, so core is probably not metallic, not liquid, or both
Water on Mars

Was there running water on Mars?

Runoff channels resemble those on Earth

Left: Mars
Right: Louisiana
Water on Mars

Current thinking

Open water (rivers, lakes) once existed on Mars
Water on Mars

This may be an ancient Martian river delta

(Or it may not)
Water on Mars

Much of northern hemisphere may have been ocean
Water on Mars

Impact craters less than 5 km across have mostly been eroded away.

Analysis of craters allows estimation of age of surface.

Crater on right was made when surface was liquid:
Water on Mars

Recently, gullies have been seen that seem to indicate the presence of liquid water. Interpretation is still in doubt.
Water on Mars

More intriguing, this pair of images appears to show that gully formation is ongoing:

![Images of gullies on Mars, labeled 1999 and 2005]
Water on Mars

Some water may now be permafrost under polar ice caps
Left: Southern polar cap, mostly carbon dioxide
Right: Northern polar cap, mostly water
Both images taken during local summer
Water on Mars

*Viking* landers both landed in low-latitude northern plains

Rocky surface, red due to iron content

*Viking 1*
Water on Mars

Viking 2
Water on Mars

The landing site for *Opportunity* was chosen to maximize the chances of finding water, or evidence for water.
Life on Mars?

*Viking* landers looked for evidence of living organisms. The experiments did not find anything conclusive.
Search for Life on Mars

Three experiments done by the Viking landers

Gas Exchange Experiment
Labeled Release Experiment
Pyrolitic Release Experiment

Meteorites
Viking - Gas Exchange Experiment

Soil mixed with nutrient medium
Look for release of carbon dioxide and oxygen
Initially both gases were rapidly released
Then the amount of oxygen being released decreased with time
Gas release could be accounted for by chemical interaction of soil with medium
Viking - Labeled Release Experiment

Soil mixed with simpler nutrient medium containing radioactive carbon

Look for release of carbon dioxide

Again carbon dioxide was released, but then ceased

No further carbon dioxide was released when additional medium was added

As before, the carbon dioxide release could be accounted for by chemical reactions
Viking - Pyrolitic Release Experiment

Soil sealed in chamber with Martian atmosphere and simulated Martian sunlight along with some radioactive carbon compounds.

Soil then pyrolized and searched for radioactive carbon within the soil.

Initial results seemed to be positive.

However, subsequent repeats did not yield the same results.

Again chemical reactions within the soil.
Viking Experiments on Life on Mars

The Viking lander experiments indicate that life as is known on Earth does not exist on Mars.
Life on Mars?

Two Martian meteorites found in Antarctica show possible signs of microbial life, but evidence is disputed.
Meteorites

Studies of meteorites from Mars indicate the presence of fossilized life forms as interpreted by some. Others suggest chemical processes on Mars produced these.
Moons of Mars

Two moons
   Phobos
   Deimos

Both moons
   Probably about 2 billion years old
   Have a density of about 2 g/cm³
   Are tidally locked

Both probably captured from the asteroid belt
Phobos

Oblong shaped - 27 X 21 X 19 km
Orbital period of 7.3 hours
Heavily cratered
Interesting parallel grooves about 150 m long and 25m deep

Since Phobos orbits Mars faster than the planet itself rotates, tidal forces are slowly but steadily decreasing its orbital radius. When it approaches Mars closely enough Phobos will be broken up by these tidal forces.
Deimos

Covered with a thick layer of dust
Dust fills in craters
Oblong shaped, 15 X 12 X 11 km
Orbital period of 30.3 hours

Deimos’ orbit is being slowly being boosted as in the case of our own Moon