Molly wants to know how long it will take us to get to Mars. She has to decide what to pack, after all. When I ask her how far she thinks it is to Mars, Molly says, ‘We learned at school that the Earth is 150 million km from the Sun and that Mars is, on average, 228 million km from the Sun.’

‘It’s not quite that simple,’ I caution. ‘This does not mean that the Earth and Mars are, at any given moment, 78 million km apart. The Earth and Mars move around the Sun in their orbits at different speeds from one another and their orbits are not the same shape. The shape of the Earth’s orbit is closer to a circle than Mars’ orbit. The distance between the Earth and Mars varies quite a bit, from 55 million km to 250 million km. Owing to the fact that the planets are moving relative to each other, the trip must be planned so that the trajectory of the spaceship and the orbit of Mars intersect. This opportunity, called a ‘launch window,’ arises only every 26 months, so when planning to travel to Mars, or the journey home for that matter, timing is essential. Scientists and engineers study celestial mechanics, also called orbital mechanics, to decide the best time for a launch.

If your brother or sister wants to be this kind of mechanic, Molly, they had better pay attention in their mathematics class at school!

Getting to Mars

The trip to Mars could take anything from six to nine months, depending on the orbital configuration and fuel budget for the mission. The cost of flying to Mars is ‘astronomical,’ so to speak, so the space agencies collaborating on the mission would minimize costs by reducing speed to economize fuel and by waiting for a launch window in both directions. Nine months? That’s a long time to travel in space. It only took three days to get to the Moon.

People have actually sojourned in space for much longer than nine months. The record goes to Valeri Polyakov, who worked aboard the Russian space station Mir for 437 days. Just like life aboard Mir, during the trip to Mars, the crew would be living in a weightless environment. Everyday activities could become an adventure in a world without gravity. What does it mean to be upside down when there is no gravity to point to where ‘down’ is?

Molly recently heard former NASA astronaut Don Thomas say that he was 39 years old when he made his first trip into space. If humans head for Mars in the next 30 years or so, as NASA has suggested, Molly will be just about that age. Nowadays, it makes sense for children all over the world to include Mars in their list of potential career postings. Space agencies from various countries are working together to plan science missions to the Moon, Mars and beyond. Before placing Mars on her list of the Top 10 Places to Live and Work, however, I convince Molly that we should spend some time learning a bit more about the Red Planet. We may end up needing more than warm boots.
The human body did not evolve in a weightless environment. Studies show that spending a long time without gravity can waste a person’s muscles and bones: humans lose 1–2% of their bone mass every month in space. While lower gravity makes it easier to move around, muscles and bones need to work to stay strong. So during the long trip to Mars, the crew would concentrate on staying in shape by exercising regularly and often. Add physical trainer to the crew of the Mars mission.

Of course, weightlessness is not all bad. Just imagine spilling a glass of milk while in a zero-gravity environment. Would it make a mess? Of course not! It would form drops that hung in the air! Actually, you’d never put your drink in a glass or any open container, to begin with. With no gravity to pull it ‘down,’ the liquid would have no reason to stay in the glass. Onboard the Space Shuttle, drinks are typically stored in a dehydrated fashion and hydrated as needed into a pouch. NASA maintains the Space Food Systems Laboratory at the Johnson Space Center to conduct research on engineering space food and its packaging. Add nutritionist to the list of crew preparing for the trip to Mars.

In addition to learning to eat in a low gravity environment and exercising to keep their bodies healthy, crew members would be constantly training for life on Mars during their trip. Mars will be a new and exciting world, very different from Earth. Let’s investigate what the physical conditions on Mars are like, so that we have an idea of what would lie in store for Molly and her friends on their journey to Mars.

Finding water on Mars

When I ask Molly what she knows about Mars, the first thing she says is, ‘Well, it’s red.’ Correct, Molly, in fact, it is often called the ‘Red Planet.’ When I ask her why, she isn’t so sure. In fact, the red colour is rust! It is the iron oxides in the soil which give the planet its reddish hue. This reddish hue is one of the first things you would notice on approaching Mars.

On landing, you would quickly suspect that there is no liquid water on Mars. It is too cold. We have known for a long time that the polar ice caps contain frozen water and frozen carbon dioxide (dry ice). ‘So there is no water on Mars? What will we drink and bathe with?’ Molly asks. Good question.

Last year, the Phoenix spacecraft landed on the Martian surface to study the ice near the north pole and search for organic molecules in the soil. The Phoenix mission found a significant amount of water ice in the soil which appears as frost. So there is water on Mars but it is frozen. Figuring out a way to use it to sustain a human presence is a challenging project for space engineers to work on. Add hydrogeologist to the list of jobs on Mars.

In the meantime, scientists have worked out ways to recycle wastewater, a technique which might come in very handy on the mission to Mars. In November 2008, the Water Recovery System devised by MichiganTech in the USA was sent up to the International Space Station in orbit 350 km above the Earth. Astronauts at the space station are accustomed to recycling every last drop of water: evaporated water from the shower, water from...
Setting up home on Mars

We have known for a long time that it is colder on Mars than on Earth. ‘We didn’t need to send spacecraft to Mars to figure that out,’ quips Molly, ‘since Mars is farther from the Sun than Earth.’ True but how cold? Reported temperatures vary somewhat but it is clear that, at its coldest, Mars is colder than anywhere on Earth, with temperatures plummeting to about -128°C at night in winter.

In order for humans to survive long in such cold temperatures, it will be essential to improve space-suit technology and the heating and insulation of living quarters on Mars. There’s plenty of work for innovative engineers and architects in this area, so add them to the list of essential jobs for the mission to Mars!

tailoring space suits to life on Mars

The space suit is a complicated habitat of its own. It must adjust pressure and temperature, while providing breathable air. A space suit must provide protection from harmful radiation and micrometeorites, while at the same time being flexible enough to permit easy movement.

Furthermore, the space suits worn by astronauts on the Moon will not be adequate for Mars because the gravity on Mars is greater than on the Moon. As a result, much more attention will be paid to making the space suits light enough so that they do not exhaust the astronaut, yet strong enough to resist the wear and tear in an extremely dusty environment.

See also: www.astronautix.com/craftfam/spasuits.htm

Teeth-brushing, hand-washing and shaving – even their own perspiration!

The new Water Recovery System goes a step further: it recycles urine into drinking water! The urine is first distilled before it joins the other recovered fluids in a water processor to filter solids like hair strands. In the next stage, the wastewater trickles through a series of filtration beds to extract contaminants like microbes. The last step is a reactor which breaks down any remaining contaminants into carbon dioxide, water and a few ions.

Drawing of a rover like Spirit and Opportunity, which have been exploring Mars since 2004

Bluish-white water frost on Martian soil in the northern arctic, photographed last year by the Phoenix Lander
Exploring Mars

Once we have set up a home base, the next step will be to explore the Red Planet. To get around, we shall need to use rovers like the one being tested in the Arizona desert (see photo).

As a tourist attraction, Mars has a lot to offer. It has the biggest canyon in the Solar System, for instance (see photo). It also boasts the Solar System’s tallest mountain, *Olympus Mons*, which rises about 27 km high and extends 600 km at its base. *Olympus Mons* is a shield volcano like *Mauna Loa* in Hawaii, the largest volcano on Earth. Both have calderas and have been built up over time by effusive eruptions that produced long lava flows. Some volcanoes on Mars may have experienced explosive eruptions. These would probably have deposited ash on the Martian landscape.

The gigantic size of *Olympus Mons* may be due to the absence of tectonic plates on Mars. As the crust was immobile, the hot spot would not have moved and the volcano would have kept spewing lava in effusive eruptions until it grew to its present size. Martian volcanoes are thought to be extinct today but, if they were once active for a long time, they would have released large quantities of gas which would have warmed the atmosphere and thickened it.

Mars may even have been warm enough for water to flow there,
Dangers to look out for on Mars

What will the weather be like? As the rotation axis of Mars is tilted, it has seasons, much like on Earth (see overleaf Weather Report for the Solar System). So there are warmer periods, particularly at the Martian equator. The temperature can reach about 20°C but, even so, we won’t be running around outside on Mars in swim suits, for a number of reasons. Two that immediately spring to mind are our need for breathable air and for protection from harmful solar radiation!

The harsh radiation environment is one of the arguments against there being life currently on the Martian surface. Before humans can set up a sustained presence on Mars, the living quarters, space suits and transportation systems designed for use on Mars will have to provide protection from cosmic radiation.

The composition and density of the Martian atmosphere are quite different from those of Earth. The Earth’s atmosphere is composed mainly of nitrogen, which we breathe in and out without using. It is this nitrogen that scatters sunlight around and makes the Earth’s sky appear blue to us. On Mars, the sky would appear pink because sunlight is scattered by dust particles, which are larger than nitrogen molecules and tend to scatter red light more than blue light – red light has a longer wavelength than blue light.

Molly interjects at this point, ‘We learned in school that carbon dioxide is a greenhouse gas that may be contributing to global warming on Earth. So if the Martian atmosphere is mostly carbon dioxide, why isn’t there global warming on Mars?’

IN FOCUS

The search for Martians

The idea of there being life on Mars has tantalized Earthlings for a very long time. NASA’s Viking 1 and Viking 2 spacecraft journeyed to Mars in 1976 to study the surface and search for evidence of life. These missions determined that the soil was composed of iron-rich clay but their biological experiments detected no evidence of life.

Scientists look for evidence of water on Mars because it is thought that life on Earth originated in the oceans. The combination of temperature and surface pressure simply do not permit liquid water on the surface of Mars.

Recently, scientists were able to take measurements of methane (CH₄) in the Martian atmosphere. Methane is what is known as an organic molecule. The term ‘organic’ here describes the chemistry of carbon chain molecules. Carbon is found in all living things. Methane is the simplest organic molecule, since there is only one link in the carbon chain (and four hydrogen atoms). The recent discoveries of methane on Mars are important to scientists studying the atmosphere on Mars but they do not indicate that life has been discovered there. Methane could also be a sign of geological activity underground.

NASA’s Mars Science Laboratory and the European Space Agency’s ExoMars missions will be using rovers to study the geology, atmosphere, environment and, once again, search for signs of life on Mars when they are deployed in 2014 and 2016 respectively, the latest launch dates. Looks like we shall need an exobiologist on the Mars mission team.

In December last year, NASA announced that its Mars Reconnaissance Orbiter had found long-sought-after carbonate minerals on the Martian surface, indicating that Mars had neutral to alkaline water when the carbonate minerals formed at these locations more than 3.6 billion years ago. Carbonates (shown here artificially in green in an image about 20 km wide), which on Earth include limestone and chalk, dissolve quickly in acid. Therefore, their survival until today on Mars challenges suggestions that an exclusively acidic environment later dominated the planet. Instead, it indicates that different types of watery environments existed. The greater the variety of wet environments, the greater the chances that one or more of them may have supported life.
In this map showing the height of landmarks on Mars, we can see that the northern plains have been flattened by lava flows, whereas the south is made up of highlands pitted by ancient impacts of asteroids and comets. The biggest crater on Mars is the Hellas Impact Basin, some 2200 km in diameter, also known as Hellas Planitia – planitia(e) meaning plain. It was once thought that the paler plains of Mars were Martian continents separated by seas, which is why they were given names like Amazonis Planitia and Arabia Terra.

Comparing the atmosphere on Mars and Earth

<table>
<thead>
<tr>
<th></th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average surface temperature</td>
<td>15 ºC</td>
<td>-55 ºC</td>
</tr>
<tr>
<td>Surface pressure</td>
<td>1013 mbar (=1 atmosphere)</td>
<td>6.35 mbar</td>
</tr>
<tr>
<td>Composition of the atmosphere</td>
<td>78.07% nitrogen, 21.0% oxygen, 0.9% argon, 0.03% carbon dioxide</td>
<td>95.49% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen, 0.08% carbon monoxide</td>
</tr>
<tr>
<td>Atmospheric density* at the surface</td>
<td>1.22 kg/m³</td>
<td>0.015 kg/m³</td>
</tr>
</tbody>
</table>

*The atmospheric density on Mars is approximately 80 times lower than on Earth. The atmospheric density of a planet varies, in fact, decreasing with increasing altitude, temperature and humidity. Here, it has been calculated for the average temperature on both planets.

Source: www.esa.int

If you would like to calculate the atmospheric density on Mars yourself, go to: http://esamultimedia.esa.int/docs/edu/Exercises/Preparing_%20a_%20mission_%20to_%20Mars.pdf

Not only does the Earth’s atmosphere act like a blanket to keep the terrestrial surface warm, unlike the Martian atmosphere; the Earth’s atmosphere and magnetic field also act as a shield protecting humans from harmful radiation from space. Potential sources of damaging radiation are the solar wind (charged particles from the Sun), ultraviolet solar radiation (the part of the electromagnetic spectrum that is largely absorbed by ozone in the Earth’s atmosphere but is responsible for sunburn) and Galactic Cosmic Rays (high-energy particles that come from beyond the Solar System).

It isn’t just the composition of the atmosphere on Mars that is different from Earth. Since Mars is such a small planet, with a mass only one-tenth that of Earth, Martian gravity is too weak to hold on to a big atmosphere. The carbon dioxide in the Martian atmosphere does contribute to warming but only by a few degrees. The amount of carbon dioxide in the atmosphere is even less when some of it freezes and falls to the surface as carbon dioxide snow. So you cannot count on the greenhouse effect to warm up the surface of Mars much.
Rain
Ours is not the only planet to experience rain. It suffices for the right conditions to exist for liquid rain to form in the atmosphere, based on the melting point of each chemical. On Venus, it rains sulfuric acid but this rain never reaches the planet’s surface owing to the planet’s intense heat. On Saturn’s moon Titan, methane rains form lakes and rivers in the northern latitudes. Titan is shrouded in a nitrogen-rich atmosphere which might be similar to that of Earth long ago.

Rain also occurs on the giant gas planets of Jupiter, Saturn, Uranus and Neptune, the atmospheres of which are composed mainly of hydrogen and helium. The additional presence of methane on Uranus and Neptune accounts for their blue hue. Jupiter’s clouds are made of ammonia, hydrogen sulfide and water. The planet’s fast rotation generates eastward winds of 480 km per hour. Deep in the atmosphere, the pressure and temperature rise, compressing the hydrogen into a liquid. It is thought that Jupiter’s Great Red Spot may actually be a hurricane that has been raging for more than 400 years.

Extreme temperatures
Temperature swings on Mercury are the most extreme in the Solar System: up to 430°C during the day and as low as -170°C at night, Mercury having too thin an atmosphere to retain the heat. Its extremely slow rotation results in a long day that leaves plenty of time for the surface to heat up. With the tilt of its axis being zero, there are no seasons.

Venus is covered by thick, rapidly spinning clouds composed primarily of CO₂ (96%) that trap surface heat, creating a scorching greenhouse-like world hot enough (700°C) to melt lead and pressure so intense that standing on Venus would feel like standing at a depth of 900 m in the Earth’s oceans.

Jupiter has temperatures of about -148 °C in the highest clouds. However, the temperature varies widely because of the different chemical compositions that make up Jupiter’s atmosphere. As you travel farther into the interior, the temperature rises: at Jupiter’s core, it is hotter even than the surface of the Sun!

On Saturn, the temperature oscillates around -178 °C. Saturn’s rings are made mostly of water ice.

Near the cloud tops on Uranus, the temperature is -216 °C. The bulk of the planet’s mass is contained in an extended liquid core consisting primarily of icy materials: water, methane and ammonia. The planet experiences seasons which last more than 20 years but the temperature differs little on the summer and winter sides because the planet is so far from the Sun.

On Triton, one of Neptune’s 13 moons, the surface temperature is as low as -235°C. Despite this, the Voyager 2 spacecraft discovered geysers spewing icy material upward more than 8 km. Triton’s thin nitrogen atmosphere is warming for an unknown reason.

Lightning
Anywhere there is an atmosphere, potentially there is lightning, a build-up of an electrostatic charge which generates a flash of light. Lightning has been observed throughout the Solar System. The European Space Agency’s Venus Express spacecraft has revealed visible flashes in the atmosphere of Venus’s sulfuric acid clouds and localized emissions of radio waves. The vast dust storms on Mars are potential sources of lightning.

Lightning has been directly observed on Jupiter, Saturn and Neptune, and static charges were detected by Voyager 2 as it cruised past Uranus two decades ago. Even Titan has the potential for lightning, although none has been observed yet. One interesting result of lightning may be the formation of biomolecules, the precursors of life.
Mars has no magnetic field to deflect the solar wind or Galactic Cosmic Rays away from the planet and the thin Martian atmosphere does not do a good job of stopping the ultraviolet radiation headed for the surface.

Such cosmic radiation will be a great danger to humans because it may damage DNA molecules in living cells, potentially leading to cancer if damaged cells begin to reproduce. Clearly, doctors and nurses will be among the essential occupations at the Martian base.

“So it is cold, we have to worry about getting hurt by radiation and there’s less gravity than our bodies are used to. Does Mars have anything normal, like weather?” Molly asks. Well, NASA’s Phoenix Lander has discovered falling snow on Mars! But I wouldn’t pack your skis just yet because the snow sublimates before it hits the ground. ‘Sublimates?’ Yes, it goes from being frozen water to a gas in the form of water vapour, without passing through the liquid phase. If you want to see an example of sublimation, dry ice (carbon dioxide) sublimates on Earth; it is often used in food storage to keep things cold and can be purchased at some grocery stores.

In 1971, the first satellite to orbit the Red Planet, Mariner 9, arrived on Mars during a massive dust storm that engulfed the entire planet. Mariner 9 was the first to discover dust storms on Mars but, nowadays, these are common knowledge. They have plagued subsequent spacecraft that have landed on Mars by clogging their electronics and moving parts, as well as blanketing the solar energy collectors with dust. Spirit, one of the two Mars Exploration Rovers that landed on Mars in 2004, suffered a nearly fatal blanketing with fine Martian dust in November 2008.
But dust has not been all bad on Mars. For several years now, we have known about little twisters full of dust on the Martian surface, called 'dust devils.' We have them on Earth, too. In March 2005, such a dust devil swept across Spirit, cleaning the dust off its solar panels so that it could receive energy again. Although the little dust devil helped the rover, a human probably wouldn't want to get caught in one, since NASA’s Phoenix Lander recently clocked the wind speed in a dust devil at about 40 km per hour!

Let's recap. We have talked about the need for food, air, water, shelter and transport. Add the need for a stable power supply to the list of challenges to overcome. Without fossil fuels on Mars, harnessing solar and potentially wind power may be options for the Martian base. However, the solar flux that reaches Mars is, on average, less than half that on Earth and the atmospheric density is much lower, so technologies developed on Earth may not be directly transferable to Mars.

I ask Molly if she still wishes to explore Mars after learning more about it. ‘I think we need to explore space,’ she replies, ‘especially planets other than Earth.’ When I ask her why, a funny look comes over her face and she adds, ‘What if we don’t do such a good job of taking care of this planet?’ That’s a very good question, Molly.

Susan Hoban

SOLUTION: The apparent size of any object varies inversely and linearly with distance. You can prove this yourself using a ruler and a pen: set a cup on a table a known distance away (say, 1 m). Hold out your index finger and mark the apparent size of the cup on your finger. Now, move twice as far away (2 m) and repeat the measurement. How has the apparent size of the cup changed? Using this principle and bearing in mind that 60 arcminutes = 1 degree, we can calculate that the angular size of the Sun seen from Mars = the angular size of the Sun seen from Earth times (the average distance of Earth from the Sun divided by the average distance of Mars from the Sun), or x = 30 arcminutes times (1 AU/1.5 AU). Answer: x = 20 arcminutes, equivalent to one-third of a degree

Would you like to know more?
To read about some of the past, present and future missions to Mars, how to design a space colony, or to find the Martian weather report, follow these links:

on the Viking spacecraft: http://nssdc.gsfc.nasa.gov/planetary/viking.html
on the Phoenix Lander: http://ophoenix.lpl.arizona.edu/

for a Martian weather report: www.asc-csa.gc.ca/eng/astronomy/ophoenix/weather1.asp

on the Mars Science Laboratory: http://marsprogram.jpl.nasa.gov/ms

on the European ExoMars mission: www.esa.int/SPECIALS/ExoMars/SEM10VLPO5F_0.html

on Martian volcanoes: www.solarviews.com/eng/marsviolc.htm
on designing a space colony: www.lpi.usra.edu/education/explore/colonies/
see also Mars for Kids: http://mars.jpl.nasa.gov

This is what the sunset would look like if you were standing on Mars. The Sun appears much smaller than on Earth because of the greater distance. From what you have learned in this article, if the angular size of the Sun on Earth is half a degree (30 arcminutes), what would it be on Mars on average? (See below for the solution)

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