Exploring Life on Mars

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Is there life on Mars?

Someday there could be a human outpost on Mars.

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- Earth is the only place that we know for certain supports life.
- Many claims have been made by observers who thought they saw evidence of life on Mars, but we now know they were tricked by the very difficult measurements.
- From Earth, even with our most powerful telescopes, we just cannot see enough detail on Mars to answer this question. We need a close-up look at the planet

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- While robotic spacecraft have given us wonderful views, no humans have ever tried to journey to Mars, and no such missions will be attempted for many years.
- NASA is working hard now to discover whether there is life on Mars.
- [Planned Mars 2020]

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- The United States and other countries have been sending spacecraft to orbit or land there since the 1960s, and each mission teaches us more about this fascinating planet.
- We have learned that even though Mars is more similar to Earth than anywhere else in the solar system, and therefore is a good place to look for life, it is still different from Earth in many ways.
- A compass points to the north pole on Earth because our whole planet acts like a giant magnet, but Mars does not act this way.

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- Besides turning a compass needle, Earth's magnetic field turns away dangerous particles of space radiation. Without a magnetic field on Mars and with much, much less air than on Earth, more harmful space radiation reaches its surface.
- Although some measurements tell us there probably is water on Mars, there is far less than on Earth.
- And it is so cold there that most of the water is probably not liquid but rather is ice.
- Overall, Mars would be a pretty uncomfortable place to try to live!

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- In 1976, NASA landed robotic spacecraft named Viking 1 and Viking 2 on Mars.
- One of these landers worked there for nearly 4 years and the other lasted more than 6 years. Think of spending that much of your life studying another world!
- Among their scientific experiments were the only ones so far specifically designed to discover whether there was something tiny (like bacteria) living in the soil. Most scientists agree that the results do not reveal any signs of life

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- The spacecraft had cameras that returned thousands of images of the surface, showing the changing seasons and details of the rocks and dirt near the stationary landers.
- While not officially part of the life experiments, the cameras did show us that there weren't any large creatures wandering around! Future landers will probe underneath the surface to try to find out if there is anything living below ground.

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- But where is the best place to look for life?
- Although Mars is smaller than Earth, it is still a very, very big place, so where should scientists aim landers to give them the best chance of finding evidence of life?
- All life on Earth depends upon water, so spacecraft in orbit and the next few landers will search for more signs of water to help guide later missions to promising locations.

Many features on Mars seem to have been formed by running water.

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- Even if there were no life on Mars, it would be exciting to know whether there used to be life there.
- So in addition to looking for living bacteria, NASA will be searching for tiny fossils that might indicate life got a start early in Mars' history but, unlike on our home planet, it did not survive and evolve into larger life forms.
- Many of the studies of Mars will involve robots, like the ones that have gone there before, but getting more advanced with each flight.

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- Someday a spacecraft may pick up samples from Mars and bring them back to Earth where they can be studied in our best laboratories.
- Eventually, humans may make the daring journey, but many important problems have to be solved before trying such an expensive, difficult, and exciting voyage.

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Determine if Life Ever Arose On Mars

- During the next two decades, NASA will conduct several missions to address whether life ever arose on Mars. The search begins with determining whether the Martian environment was ever suitable for life.

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Conditions Needed for Life to Thrive

- On Earth, all forms of life need water to survive. It is likely, though not certain, that if life ever evolved on Mars, it did so in the presence of a long-standing supply of water.
- On Mars, we will therefore search for evidence of life in areas where liquid water was once stable, and below the surface where it still might exist today.
- Perhaps there might also be some current "hot spots" on Mars where hydrothermal pools (like those at Yellowstone) provide places for life.

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- Data from Mars Global Surveyor suggest that liquid water may exist just below the surface in rare places on the planet, and the 2001 Mars Odyssey has mapped subsurface water reservoirs on a global scale.
- We know that water ice is present at the Martian poles, and these areas will be good places to search for evidence of life as well.
- In addition to liquid water, life also needs energy.

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- Therefore, future missions will also be on the lookout for energy sources other than sunlight, since life on the surface of Mars is unlikely given the presence of "superoxides" that break down organic (carbon-based) molecules on which life is based.
- Here on Earth, we find life in many places where sunlight never reaches--at dark ocean depths, inside rocks, and deep below the surface.
- Chemical and geothermal energy, for example, are also energy sources used by life forms on Earth. Perhaps tiny, subsurface microbes on Mars could use such energy sources too.

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Looking for Life Signs

- NASA will also look for life on Mars by searching for telltale markers, or biosignatures, of current and past life.
- The element carbon, for instance, is a fundamental building block of life.
- Knowing where carbon is present and in what form would tell us a lot about where life might have developed.

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- We know that most of the current Martian atmosphere consists of carbon dioxide.
- If carbonate minerals were formed on the Martian surface by chemical reactions between water and the atmosphere, the presence of these minerals would be a clue that water had been present for a long time--perhaps long enough for life to have developed.
- On Earth, fossils in sedimentary rock leave a record of past life. Based on studies of the fossil record on Earth, we know that only certain environments and types of deposits provide good places for fossil preservation.

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- On Mars, searches are already underway to locate lakes or streams that may have left behind similar deposits.
- So far, however, the kinds of bio-signatures we know how to identify are those found on Earth.
- It's possible that life on another planet might be very different.
- The challenge is to be able to differentiate life from nonlife no matter where one finds it, no matter what its varying chemistry, structure, and other characteristics might be.
- Life detection technologies under development will help us define life in non-Earth-centric terms so that we are able to detect it in all the forms it might take.

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The Mars Exploration Program

- Since our first close-up picture of Mars in 1965, spacecraft voyages to the Red Planet have revealed a world strangely familiar, yet different enough to challenge our perceptions of what makes a planet work.
- Every time we feel close to understanding Mars, new discoveries send us straight back to the drawing board to revise existing theories.
- You'd think Mars would be easier to understand. Like Earth, Mars has polar ice caps and clouds in its atmosphere, seasonal weather patterns, volcanoes, canyons and other recognizable features.

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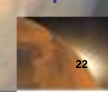
- However, conditions on Mars vary wildly from what we know on our own planet.
- Over the past three decades, spacecraft have shown us that Mars is rocky, cold, and dry beneath its hazy, pink sky.
- We've discovered that today's Martian wasteland hints at a formerly volatile world where volcanoes once raged, meteors plowed deep craters, and flash floods rushed over the land.
- And Mars continues to throw out new enticements with each landing or orbital pass made by our spacecraft.



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The Defining Question for Mars Exploration: Life on Mars?

- Among our discoveries about Mars, one stands out above all others: the possible presence of liquid water on Mars, either in its ancient past or preserved in the subsurface today.
- Water is key because almost everywhere we find water on Earth, we find life. If Mars once had liquid water, or still does today, it's compelling to ask whether any microscopic life forms could have developed on its surface.

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- Is there any evidence of life in the planet's past?
- If so, could any of these tiny living creatures still exist today? Imagine how exciting it would be to answer, "Yes!!"
- Even if Mars is devoid of past or present life, however, there's still much excitement on the horizon.
- We ourselves might become the "life on Mars" should humans choose to travel there one day. Meanwhile, we still have a lot to learn about this amazing planet and its extreme environments.

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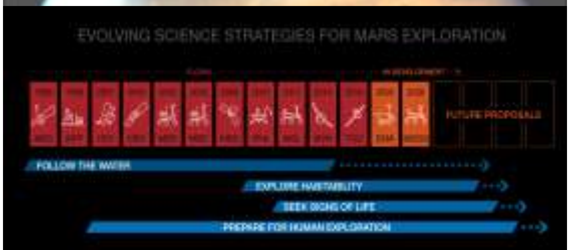
Our Exploration Strategy: Seek Signs of Life



Mars Global Surveyor- MGS
Mars Odyssey-ODY
Mars Reconnaissance Orbiter –MRO
MAVEN
ExoMars Trace Gas Orbitor

Mars Path Finder-MPF
Mars Express-MEX
Mars Science Laboratory –MSL (Curiosity)

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- To discover the possibilities for past or present life on Mars, NASA's Mars Exploration Program is currently following an exploration strategy known as "Seek Signs of Life.“
- This science theme marks a transition in Mars exploration. It reflects a long-term process of discovery on the red planet, built on strategies to understand Mars' potential as a habitat for past or present microbial life.
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- Searching for this answer means delve/(lookinto) into the planet's geologic and climate history to find out how, when and why Mars underwent dramatic changes to become the forbidding, yet promising, planet we observe today.
- About 3.8-3.5 billion years ago, Mars and Earth were much more similar.
- Evidence from Mars missions suggest Mars may have been much warmer and wetter than we observe it to be today.
- In this ancient timeframe, scientists find the first evidence of microbial life on Earth.

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- Did Mars provide similar environmental conditions for life long ago?
- If microbes were present on Mars in the planet's ancient past, could it exist in special regions today?
- And, even if microbial life never existed, might Mars provide a future habitat for human explorers someday in the future?
- Because water is key to life as we know it, earlier Mars missions (2001 Mars Odyssey, Mars Exploration Rovers, Mars Reconnaissance Orbiter, Mars Phoenix Lander) were designed to make discoveries under the previous Mars Exploration Program science theme of "Follow the Water."

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- Progressive discoveries related to evidence of past and present water in the geologic record make it possible to take the next steps toward finding evidence of life itself.
- The Mars Science Laboratory mission and its Curiosity rover mark a transition between the themes of "Follow the Water" and "Seek Signs of Life."
- In addition to landing in a place with past evidence of water, Curiosity is seeking evidence of organics, the chemical building blocks of life.
- Places with water and the chemistry needed for life potentially provide habitable conditions.

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- Future Mars missions would likely be designed to search for life itself in places identified as potential past or present habitats.
- Like all Mars Exploration Program missions, future missions will be driven by rigorous/precise scientific questions that continually evolve from discoveries by prior missions.
- New and previously developed technologies will enable us to explore Mars in ways we never have before, resulting in higher-resolution images, precision landings, longer-ranging surface mobility and even the return of Martian soil and rock samples for studies in laboratories here on Earth.

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Mars, The God of War (Red Planet)

The planet was named after Mars, the Roman God of War, who was one of the most worshipped and respected gods in ancient Rome.

The god Mars held a special place in the Roman Pantheon not only for his patronly influence, but because of the importance of military achievement in the republic and the Roman Empire.

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Early concepts

Before space exploration, Mars was considered the best candidate for harboring extraterrestrial life.

Italian astronomer, Giovanni Schiaparelli thought he saw straight lines crisscrossing its surface.

This led to the popular belief that irrigation canals on the planet had been constructed by intelligent beings.

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- Mars is the fourth planet from the Sun.
- Commonly referred to as the Red Planet.
- The rocks and soil have a red iron oxide (rust) they contain.

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NASA Hubble Space Telescope view provides the most detailed complete global coverage of the red planet Mars ever seen from Earth.
This picture was taken on February 25, 1995, at a distance of 65 million miles.

By HST

NASA's Hubble Space Telescope photographed Mars on July 18, near its closest approach to Earth since 2003. The planet was observed near opposition, when the Sun, Earth and Mars are lined up, with Earth sitting in between the Sun and Mars.

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Hubble Space telescope (HST)

The NASA Hubble Space Telescope is a project of international cooperation between NASA and ESA. AURA's Space Telescope Science Institute in Baltimore, Maryland, conducts Hubble science operations.

HUBBLE WORKS WITH THE WIDER ASTRONOMICAL COMMUNITY TO EXPLORE THE UNIVERSE

Hubble Space telescope (HST)

- Launched in 1990, Hubble has been visited by astronauts four times in order to make repairs and add new instruments.
- Each instrument that flies on Hubble has special features that let astronomers study the heavens in different ways.
- Hubble's unique capabilities can also be partnered with other space observatories and those on the ground to enable scientists to explore the universe in ways that no single mission could ever accomplish alone.

Hubble's science instruments, the astronomer's eyes to the universe, work together or individually to provide the observations. Each instrument is designed to examine the universe in a different way. Hubble holds two main varieties of instruments: cameras, which capture Hubble's famed images, and spectrographs, which break light into colors for analysis.

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Atmosphere on Mars

Mars has a rocky, dry terrain with huge volcanoes and deep valleys.

The atmosphere is much thinner than Earth's & is comprised primarily of carbon dioxide and nitrogen.

It's gravity is about one-third of our own.

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Largest Volcano on Mars

The largest volcano in the solar system is Olympus Mons.

It is 624 km in diameter; about the same size as Arizona.

The altitude of Olympus Mons is three times the altitude of the largest peak on Earth, Mt. Everest.

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Gigantic Canyon

Mariner Valley, is a vast canyon (Valley) system that runs along the Martian equator.

Valles Marineris is 2500 miles long and reaches depths of up to 4 miles.

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Gigantic Canyon

For comparison, the Grand Canyon in Arizona is about 500 miles long and 1 mile deep.

In fact, the extent of Valles Marineris is as long as the United States and it spans about 20 percent (1/5) of the entire distance around Mars.

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Seasons on Mars

Like Earth, Mars has seasonal changes but the seasons last much longer.

In Winter, Mars' polar ice cap can reach down to 45 degrees latitude and then rapidly shrink during Spring.

Dust storms are seasonal, also, as witnessed in this Hubble image.

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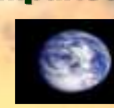
Earth/Mars Comparison

Mars   Earth

	Mars	Earth
Distance from Sun	141.6 Million Miles	93 Million Miles
Diameter	4222 Miles	7926 Miles
Length of Year	687 Earth Days	365.25 Days
Length of Day	24 hours 37 minutes	23 hours 56 minutes
Gravity	.375 that of Earth	2.66 times that of Mars
Temperature	Average -81 F	Average 57 F
Temperature Range	-127 C to 17 C	-88 C to 58 C
Number of Moons	2	1

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Polar CAPS

- Mars's surface features undergo slow seasonal changes over the course of a Martian year—a consequence of Mars's axial tilt and somewhat eccentric orbit.
- The polar caps grow or shrink according to the seasons, almost disappearing during the Martian summer.

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- To fanciful observers around the start of the twentieth century, these changes suggested the annual growth of vegetation but, as with Venus, however, these speculations were not confirmed.
- The changing polar caps are mostly frozen carbon dioxide, not water ice as at Earth's north and south poles (although smaller "residual" caps of water ice also exist), and the dark regions are just highly cratered and eroded areas on the surface.

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- Mars polar caps are composed predominately of <u>Carbon dioxide frost- Dry ice- and shows seasonal variations.</u>
- Each cap consist two distinct parts:
  - <u>Seasonal cap</u>: grows and shrinks each Martian year
  - <u>Residual cap</u>: remains permanently frozen

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Seasonal Caps

- <u>In Sothern Midwinter- </u>Southern seasonal cap is ~4000 km across (1/5th the circumference of the planet)
- After ½ martian year <u>northern cap is at its largest-reaching ~3000 km</u>
- <u>The two polar caps do not have same maximum size- due to its orbit eccentricity.</u>

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- In southern winter, mars is farther from the sun than in northern winter.
- Thus southern winter season is longer and colder than in north and polar caps grows correspondingly larger.
- S. Caps are composed of entirely of CO_2.
- Their temp. never greater than ~150K (120C)- the point where dry ice can form.

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- <u>During Martian summer- </u>intense sunlight striking the cap- CO_2 evaporates into the atmosphere and the cap shrinks.
- In the winter atmospheric CO_2 refreezes and cap forms.
- As the caps grow and shrink-they cause substantial variation (~30%) in Martian atmospheric pressure.
- From atmospheric fluctuations, scientist estimate the amount of CO_2 in seasonal caps.
- <u>Maxm thickness of the seasonal cap is ~1m</u>

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Residual Caps

- Are smaller and brighter than seasonal caps.
- Shows more marked north south asymmetry.
- Southern R.C is ~350 km across.
- Made mostly CO2
- Although contain some water ice.
- Its temp. remains below 150K at all times

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- Northern R. Cap is much larger ~100km across and warmer
- With a temp that can exceed 200K in northern summer time.
- Scientists believe that northern cap is made mostly of water ice.
- Opinion strengthened by observed increase in the concentration of water vapor above the north pole in north summer as some small fraction of its water ice evaporates in the sun's heat.

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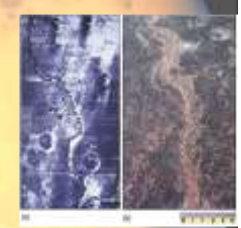
Evidence for Water on Mars

- Although the Valles Marineris was not formed by running water, photographic evidence reveals that liquid water once existed in great quantity on the surface of Mars. **Two types of flow features are seen**: runoff channels & outflow channels.



Martian Channel (a) This runoff channel on Mars is about 400 km long and 5 km wide. (b) The Red River running from Shreveport, Louisiana, to the Mississippi. Martian runoff channels and rivers on Earth differ mainly in that there is currently no liquid water in this, or any other, Martian channel. (NASA)

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Runoff Channels

- The runoff channels are found in the southern highlands.
- They are extensive systems—sometimes hundreds of kilometers in total length—of interconnecting, twisting channels that merge into larger, wider channels.
- They bear a strong resemblance to river systems on Earth.

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- Geologists believe that is just what they are: the dried-up beds of long-gone rivers that once carried rainfall on Mars from the mountains down into the valleys.
- These runoff channels speak of a time four billion years ago (the age of the Martian highlands) when the atmosphere was thicker, the surface warmer, and liquid water widespread.

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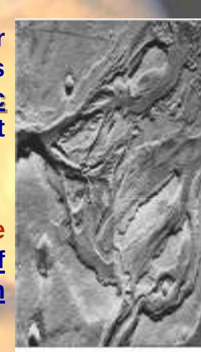
Martian Outflow Channels

- An outflow channel near the Martian equator bears witness to a catastrophic flood that occurred about three billion years ago.
- The outflow channels are probably remnants of catastrophic flooding on Mars long ago.



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- They appear only in equatorial regions and generally do not form the extensive interconnected networks that characterize the runoff channels.
- They are probably the paths taken by huge volumes of water draining from the southern highlands into the northern plains.

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- Judging from the width and depth of the channels, the flow rates must have been truly enormous—perhaps as much as a hundred times greater than the 10^5 tons per second carried by the Amazon River, the largest river system on Earth.
- Flooding shaped the outflow channels about three billion years ago, about the same time as the northern volcanic plains formed.

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Evidence of Liquid water

- There is no evidence for liquid water anywhere on Mars today and the amount of water vapor in the Martian atmosphere is tiny.
- Yet the extent of the outflow channels indicates that a huge total volume of water existed on Mars in the past.

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- Where did all that water go?
- One possible answer is that much of Mars's original water is now locked in a layer of permafrost, which is water ice lying just below the planet's surface, with some more water contained in the polar caps.
- Permafrost: A thick subsurface layer of soil that remains below freezing point throughout the year, occurring chiefly in polar regions]

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- Figure shows evidence for the permafrost layer in the form of a fairly typical Martian impact crater named Yuty.

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- Unlike the lunar craters, Yuty's ejecta blanket gives the distinct impression of a liquid that has splashed or flowed out of the crater.
- Most likely, the explosive impact heated and liquefied the permafrost, resulting in the fluid appearance of the ejecta.

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Mars' Atmosphere made of:

- The atmosphere of Mars is about 100 times thinner than Earth's, and it is 95 percent carbon dioxide.
- Here's a breakdown of its composition:
- Carbon dioxide: 95.32 percent
- Nitrogen: 2.7 percent
- Argon: 1.6 percent
- Oxygen: 0.13 percent
- Carbon monoxide: 0.08 percent
- Also, minor amounts of: water, nitrogen oxide, neon, hydrogen-deuterium-oxygen, krypton and xenon

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Atmosphere of the Mars

- Mars has a thin atmosphere — too thin to easily support life.
- The extremely thin air on Mars can also become very dusty.
- Giant dust storms can blanket the entire planet and last for months.

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Climate and weather

- Mars' thin atmosphere and its greater distance from the sun mean that Mars is much colder than Earth.
- The average temp. is~(-80)ºF or (-60ºC)
- Although it can vary from (-195 ºF) or (-125 ºC) near the poles during the winter to as much as a comfortable 70ºF (20ºC) at midday near the equator.

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- The atmosphere of Mars is also roughly 100 times thinner than Earth's, but it is still thick enough to support weather, clouds and winds.
- Curiosity, which four years ago landed on Mars verified the organic matter may be widely distributed on Mars.

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- Curiosity has climbed Mount Sharp, it also has discovered increasingly enriched concentrations of boron inside rock fractures
- (boron is tied to the formation of ribose, a key component of RNA.)

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- The organic molecules found by the team
- Also have chlorine atoms, and include chlorobenzene (C_6H_5Cl) and several dichloro-alkanes, viz., Dichloroethane ($C_2H_4Cl_2$) dichloropropane ($C_3H_6Cl_2$) dichlorobutane ($C_2H_8Cl_2$).
- Chlorobenzene is the most abundant with concentrations between 150 and 300 parts-per-billion

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Possibility of life

- Mars could have once harbored life. Some conjecture/speculation that life might still exist there today.
- A number of researchers have even speculated that life on Earth might have seeded Mars, or that life on Mars seeded Earth.
- Oceans may have covered the surface of Mars in the past, providing an environment for life to develop.

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- Although the red planet is a cold desert today, researchers suggest that liquid water may be present underground, providing a potential refuge for any life that might still exist there.
- Several studies have shown that there is abundant water ice beneath the surface

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