Air and Space this Week

Item of the Week

Mars Meteorites, ALH 84001, and the Process of Scientific Inquiry

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Many people have a fundamental misunderstanding of this thing we call "Science." It is not merely the accumulated body of knowledge and experience from the observation of the world around us. It is that, but more importantly, "science" is the **process** *by which we go about learning new things. And, scientific inquiry is self-revising; our best understanding is often updated as new information, observations, experiments, etc. come to light.*

"Extraordinary claims require extraordinary evidence." *-Carl Sagan*

Sometimes, a new scientific idea comes forth, and the evidence leading to it is so overwhelming, that the new idea gets (almost) universally accepted (almost) immediately. Sometimes a bold new idea comes forth, has enough evidence behind it to be considered a "Hypothesis," but the evidence is not sufficiently compelling to consider the idea a "Theory." [Too many of us think "theory" means wild guess, rather than an idea that has several lines of solid supporting evidence.

An interesting example of each is presented below.

"I AM HOLDING A PIECE OF MARS IN MY HAND"

I used to work with the public in an informal education situation. When I wanted to get the audience thinking about how "science" operates, I'd tell them how happy I was to be with them today, and I thought about working with them as I was flying to work in my flying saucer. I'd act shocked when they laughed and challenged me, and say "What, I don't look honest? What would I have to do for you to believe me?" I didn't have to do much answer-coaching to get a "Show me the saucer" and "Better yet, take me for a ride!"

We learn from an early age to be properly skeptical of any claim, re-enforced by every legal-related TV series ever. Multiple lines of evidence have solved many a Hollywood criminal case!

The process of scientific inquiry works just the same way. An idea is generated, then additional information is sought from a variety of appropriate sources. Based on the additional information, the idea is strengthened to be considered a viable explanation ("hypothesis").

Only after continuous and rigorous observation, experimentation, and theoretical support does an idea become sufficiently accepted to be considered the likeliest explanation ("theory").

Now with all that in mind, consider the following semi-apocryphal scenario. A noted scientist stands at the podium in a science conference, stares at the audience and makes the extraordinary claim, "I hold in my hand a meteorite from Mars!"

There would be a number of snorts from the audience, as they politely tried to stifle the sounds of their amazed disagreement. But then…

The scientist surveys the auditorium, smiling, and says, "Please show slide number 1." (This was back in the Olden Days.)

The grumbles of derision abated, and were replaced by the squeaks of chairs as more and more of the scientists assembled leaned forward to get a better view of the screen. The crowd was shocked. The evidence shown on the screen was extremely supportive of the notion that the scientist's meteorite had, indeed, come from Mars. The only way it could have gotten to Earth was if it had been blasted off of Mars by an impact, a fairly recent one because the composition of the martian at the time of impact, and in 1976 when the Viking landers made detailed measurements of the gases comprising the martian atmosphere.

The scientist had made a graph, with the percentage concentration of the various gases in the martian atmosphere on the vertical axis. For the horizontal axis, the scientist had found small bits of glassy material in his meteorite. The scientist's laboratory was very well equipped, and they were able to isolate the bits of glass and extract all of the gases dissolved with it. Glass behaves like a very viscous fluid, and can have gases dissolved within its structure. The scientist calculated the relative percentage each gas contributed to the whole, and plotted those numbers against the gas concentrations measured by the Viking landers.

The graph (seen here) has a solid line, with a slope of 45° representing those percentages that are the same in both meteorite glass and the Viking results. Note that every gas in the data falls within experimental error around that "line of equality." The gases trapped in the meteorite glass and the gases in the martian atmosphere ALL have the same relative abundances, a circumstance extremely unlikely to be due to random chance (odds of billions to one against). There was an indelible connection between the extraordinary claim and extraordinary evidence, and the identification of other meteorites from Mars here on Earth quickly followed. The idea is (almost) universally accepted today.

Someone in the crowd pointed out that all of the impact lab and theoretical studies conducted to date indicate that an impact wouldn't impart enough speed to the ejected material to allow it to escape Mars' gravity. The speaker merely pointed to the graph, "That may be so, but how do you explain this?" Silence. [The questioner and others in the audience knew how to make such calculations, and were immediately planning to do so. It was found that, if the impacting body came in at a very shallow angle, the material sprayed downrange could, in fact, escape from Mars, a circumstance not previously appreciated. Such impacts would make a distinctively-elongated crater, and a number of those have been found on Mars, including one

that may well be the source of the SNC meteorites. The SNC "gas-in-glass" hypothesis had already stimulated an advance of our state of knowledge!]

OK, I admit, it didn't really happen exactly like this. But that is basically how it went down.

One more thing: The match between the gases in the Mars atmosphere and the SNC meteorites (and ALH 84001) *not only* proves the meteorites came from Mars…

The match also proves that Mars' atmosphere did not change in the 16 million or so years prior to 1976, when the Viking atmospheric measurements were made!

THERE IS EVIDENCE OF PALEO-LIFE IN METEORITE ALH 84001!

Most of the meteorites ever collected have come from Antarctica. It's not that the South Pole is some sort of meteor magnet. The ice covering most of the continent, and its movement, make a great "screen" to catch meteorites and congregate them together. As you helicopter along the ice, any rock that you see on top of the ice probably came from above rather than up through two miles of solid ice. The same meteorite falling in the woods somewhere, would never be recognized. The Antarctic climate restricts searching for meteorites to a "summer" season of only a few months. The hero of this part of the story is the first meteorite found in the search area in the Allen Hills in the 1984 field season, hence its designation as ALH 84001 (**AL**len **H**ills, 19**84**-85 field season, sample number **001**).

ALH 84001 wasn't a typical meteorite, and was culled for additional study. It was quickly found to be from Mars, based on exactly the same extraordinary evidence presented a few years before.

But there were some strange things about this meteorite that triggered even more study, and **twenty-five years ago, on August 6**, a paper was released that made the extraordinary conclusion that ALH 84001 contained evidence of past martian life!

The claim was based on four separate observations (more later). For each, there were several possible explanations; some were better than paleo-life. But paleo-life was a plausible explanation for all four, so the tentative conclusion that the common factor, paleo-life, was the cause.

The notion that life arose independently on Mars was a profound shock in the scientific, philosophic, and religious communities! Some were enthralled, some were aghast, but all were amazed at the idea that life could have arisen at two adjacent planets, out of the billions and billions of planetary systems in the Universe.

But the scientific community (and others) were properly skeptical. The four lines of evidence, even when combined, did not rise to the "extraordinary" category. Therefore, the presence of martian paleo-life or its by-products remains a hypothesis, not a theory.

But a lot of good science, and deeper understanding, can come from the additional research that a hypothesis, especially a provocative one, stimulates!

Four Lines of Evidence

ALH 84001 Came from Mars, and Was Wet at Some Point While There

First of all, there is no question that ALH 84001 originated on Mars, and that it contains minerals that indicate it was wet while on Mars (water is usually thought of as a prerequisite for onset of biological activity). This line of evidence shows that environmental conditions may have been favorable in the distant past, but it doesn't provide evidence that life actually arose. [A lack of evidence against is not evidence for!] The other three lines of evidence cited by McKay et al. are:

Possible Fossil Bacteria

Electron microscope observations of ALH 84001 revealed objects that resemble terrestrial bacteria. The objects in question are the same size and shape of terrestrial bacteria, but they could have been artifacts created in the electron microscopy preparation process, or contamination by terrestrial bacteria.

Possible Fossil Bacteria Poop

Small mineral grains were found in ALH 84001 near the putative bacteria. The grains are in the carbonates that formed when ALH 84001 was on Mars, so they aren't some type of Earth contamination. They do resemble some terrestrial crystals associated with bacteria "bodily" functions. But such grains can also form chemically, without any biological activity involved.

Possible Dead Bacteria Bodies: Polycyclic Aromatic Hydrocarbons (PAHs)

A class of organic molecules, PAHs, are found in and near the carbonate minerals present in ALH 84001. [Recall that "organic," to a chemist, means "contains carbon," not "is biological in origin!"] PAHs can be the result of the decay of bacteria, but they can also be produced by other, non-biologically-related, ways. McKay et al. did demonstrate that the PAHs did not get in the samples on Earth, nor were they the result of handling or detection errors.

CONCLUDING REMARKS

McKay et al. did manage to rule out some forms of measurement and experimental error in their analysis, but their argument type, the "our hypothesis is favored because it allows for each of the lines of evidence, is weak, as they acknowledge in their paper. The martian paleo-life hypothesis is still around, but it has few adherents, because the evidence to support it is not conclusive.

Scientists learned from the case of *Mariner 4* that making broad conclusions with only a little data could lead to error (Mariner 4 only saw 1% of the martian surface, and the part it saw was atypical for the rest, leading to the initial conclusion that Mars was much like the Moon. It wasn't until *Mariner 9* reached Mars orbit in 1971 that we saw just how complex Mars' geological processes have been).

Perseverance (and *Curiosity*) are presently roving areas of Mars that were once sediments deposited in a long-gone martian lake, environments relatively conducive to life. Mars may be barren and was always so, but we do know the Mars had a more benign climate in the past, and the process of blasting bits off Mars so fast they escape its gravity could be rather tough on fossils of any size, so we may not have reached the Mariner 9-level of understanding of Mars' paleo-environment.

Wouldn't it be cool if *Percy* turned up an obvious fossil?!?

REFERENCES

Meteorites from Mars

Abstract of paper by Allan Treiman et al. in *Planetary and Space Science*: https://www.sciencedirect.com/science/article/abs/pii/S0032063300001057

Another paper (abstract) by Treiman et al., with the "gas on Mars versus gas in ALH 84001" graph: https://ui.adsabs.harvard.edu/abs/2000P%26SS...48.1213T/abstract

Summary and reference list: https://www2.jpl.nasa.gov/snc

Abstract of paper by Hal McSween in Meteoritics: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1945-5100.1994.tb01092.x

Possible source craters for SNC meteorites:

https://www.lpi.usra.edu/publications/slidesets/redplanet2/slide_34.html,

https://www2.jpl.nasa.gov/snc/craters.html , https://www.higp.hawaii.edu/~pmm/SNC.pdf

Evidence of Paleo-life in ALH 84001

Discovery Paper: McKay D.S., Gibson E.K.Jr., Thomas-Keprta K.L., Vali H., Romanek C.S., Clemett S.J., Chillier X.D.F., Maechling C.R., and Zare R.N. (1996), Search for past life on Mars: Possible relic biogenic activity in martian meteorite ALH 84001, *Science* **273**, 924-930.

Description of ALH 84001: https://www2.jpl.nasa.gov/snc/alh.html

More of same, including the approximate time ALH 84001 was blasted off Mars and how long ago it landed on Earth: https://www.lpi.usra.edu/lpi/meteorites/The_Meteorite.shtml

ALH 84001 did come from Mars and it was wet: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3193235

Summary of McKay, et al. by Allan Treiman: https://www.lpi.usra.edu/lpi/meteorites/life.html

Conference abstract by team: https://mars.nasa.gov/mgs/sci/fifthconf99/6142.pdf

Evidence Against the Paleo-life Hypothesis

Annotated reference list of papers against the paleo-life hypothesis by Allan Treiman:
https://www.lpi.usra.edu/lpi/meteorites/alhnpap.html

More of the same, this time from Jeffrey Taylor:
http://www.psrd.hawaii.edu/Dec97/LifeonMarsUpdate2.html

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