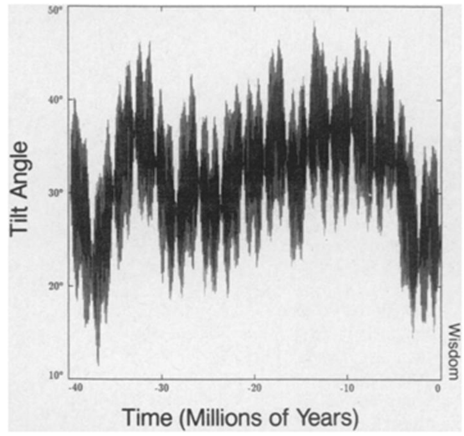
Tilted: Stable Earth, Chaotic Mars

Without the moon, life on Earth would likely face the same kinds of wild fluctuations in climate that Mars has apparently experienced through the eons. Its spin axis no longer maintained by the moon at an angle of 23.5 degrees, Earth could drastically change its tilt in just a few million years, sometimes dipping enough to bring more sunlight to polar regions than to equatorial zones.

These startling conclusions arise out of new calculations revealing that the chaotic wobbles of a planet's orbit around the sun can have a strong influence on the angle at which the planet's spin axis is tilted with respect to the plane of its orbit. In Earth's case, the moon has a stabilizing influence. In contrast, the tiny satellites of Mars are too small to keep the tilt, or obliquity, of the planet's spin axis from varying erratically over a wide range of angles.

These results follow from the recent discovery that the evolution of the solar system appears chaotic (SN: 2/22/92, p.120). Because the details of its evolution over millions of years are sensitive to precisely where the planets are at any given moment, researchers cannot accurately calculate and predict the erratic variations possible in the past or future shapes and inclinations of planetary orbits.

"One of the most dramatic consequences of this chaotic evolution of the planets turns out to be that the [tilt of the spin axis] of Mars is wildly irregular over multimillion-year time scales," says Jack Wisdom of the Massachusetts Institute of Technology. The new results may alter considerably the kind of information that planetary scientists must put into computer models used for tracing and predicting the evolution of the climate and surface features of Mars.



The obliquity of Mars over the last 40 million years shows large, irregular shifts.

Wisdom and Jihad Touma of the Massachusetts Institute of Technology report their findings on the chaotic obliquity of Mars in the Feb. 26 SCIENCE. Jacques Laskar and his colleagues at the Bureau des Longitudes in Paris describe in the Feb. 18 NATURE how the moon may act as Earth's climate regulator.

Astronomers have long known that the spin of Mars is strongly affected by variations in its orbit. However, previous calculations disagreed on how large this effect has been in the past and when changes in tilt might have occurred. Some researchers had also suggested that intense volcanic activity and other geologic processes could play an important role in these tilt fluctuations by altering the planet's mass distribution sufficiently to change its spin and cause large shifts in its tilt angle.

"All sorts of things happen when you change the obliquity of Mars," Wisdom says. "At high obliquity, the ice at the poles is probably no longer stable. At low obliquity, the atmosphere freezes out."

Wisdom and Touma's calculations show that orbital variations alone can cause such drastic changes. Their model suggests that the resulting tilt angles can range from about 11 degrees to 49 degrees (see diagram). Moreover, these irregular variations in the tilt of Mars over intervals longer than 10 million years appear inherently unpredictable.

However, despite this long-term uncertainty, orbital models can provide a glimpse of what has happened to Mars in the last 10 million years. Indeed, different orbital models now qualitatively agree that the average obliquity of Mars

Antibody mimics rival the real thing

Custom-tailored by the immune system to identify and nab specific chemical invaders, antibodies are masters of molecular recognition. Scientists often use them to target a substance within a mixture and measure the amount present. Now, a group of European researchers report they can make artificial antibodies that match the real thing when it comes to detecting minute quantities of two drugs in blood serum.

The researchers built their synthetic antibodies out of polymers, using a technique called molecular imprinting to construct a cast around a target molecule. Because these mimics are robust, reusable, and inexpensive to produce, they may one day replace antibodies harvested from laboratory animals for use in diagnostic tests. "Molecular imprints may be made against a great number of organic molecules, for example, drugs, hormones, and toxins," Klaus Mosbach of the University of Lund in Sweden and his colleagues write in the Feb. 18 NATURE. "This technique may have many applications."

The team made antibody mimics against two chemically unrelated drugs, the asthma medication theophylline and a tranquilizer called diazepam. They used a "cocktail" approach, Mosbach says, adding simple organic chemicals called monomers that interact with the "print" molecule in a variety of ways. For instance, methacrylic acid linked up in repeating units to form a polymer cage around the drug molecule, while a chemical cross-linker called ethylene glycol dimethacrylate strengthened the cage. After removing the drug molecule, the researchers had a rigid, insoluble polymer imprinted with the exact shape of the drug, like a handprint set in concrete.

The group found that the mimics showed the same specificity as their antibody counterparts. The synthetic antibody for theophylline invited into its folds only one of the eight structurally related drugs and metabolites tested. The synthetic antibody for diazepam was tricked by several compounds, just as real antibodies are.

The proof came, however, when the researchers used the antibody mimics to determine the amount of drug in serum samples from 32 patients. The team compared the results with those obtained through a technique using real antibodies, called enzyme-multiplied immunoassay technique (EMIT). The two methods showed complete agreement, Mosbach's group reports.

This is the first demonstration that such antibody mimics can perform as well as real antibodies in a practical application, says Frances H. Arnold of the California Institute of Technology in Pasadena. "This is quite an exciting paper that clearly shows the potential for these imprinted molecules."

At present, imprinted polymers need organic solvents around them in order to work, which makes them more cumbersome to use in biomedical assays than water-loving antibodies. However, Mosbach says, "It's only a matter of a year or so before the molecular imprint methods will be as good as, if not better than, current immunoassay techniques." *—K.F. Schmidt* abruptly increased about 4 million years ago.

Curiously, Wisdom and Touma found no such tilt transition when they excluded the effects of general relativity from their equations of motion for the planets. These gravitational effects have a subtle, but apparently significant influence on the evolution of planetary orbits in the solar system.

"Perhaps the geology of Mars will ultimately provide another test of the validity of general relativity," the researchers note.

In Earth's case, the moon's hefty mass forces Earth's spin axis to rotate, or precess, rapidly enough to forestall wildly erratic variations in Earth's tilt. Although one complete rotation of the spin axis requires about 26,000 years, that's fast enough to keep Earth out of the range of disturbing resonances with other motions in the solar system.

"If [the moon] were not present, or if it were smaller, for many values of [Earth's] primordial spin rate, the obliquity of the Earth would be chaotic with very large variations, reaching more than 50 degrees in a few million years and even, in the long term, more than 85 degrees," Laskar and his colleagues conclude.

Thus, the moon may play a crucial role in regulating Earth's climate, stabilizing it enough to permit the evolution of life, the researchers speculate. Indeed, the presence of a moon-size satellite may be a necessary condition for finding Earth-size planets with Earth-like climates in orbits around neighboring stars.

In a separate paper in the Feb. 18 NATURE, Laskar and his colleagues suggest that the tilts of all the inner planets could have evolved chaotically at various times in the past. Earth itself may even enter such a chaotic zone when the distance between Earth and a slowly departing moon shifts in 2 billion years from its present-day distance of about 60 Earth radii to 68 Earth radii. Given that variations in tilt angle as small as 2 degrees may trigger ice ages, the forecast for Earth when its axis shifts to an angle of nearly 60 degrees would certainly be bleak. *— I. Peterson*

Mixing Earth's mantle with a delayed flush

Journeying deep into computer versions of the Earth, two research teams independently have found evidence that could force a compromise in a divisive debate about the currents of rock flowing inside the mantle — the thick layer separating the planet's metallic core from its thin veneer of a crust. Over geologic time, these currents send Earth's continents slowly careening around the world, slamming together to form mountain ranges and rifting apart to create ocean basins.

For decades, geoscientists have argued over whether convection currents stir the entire mantle or whether the mantle is layered into upper and lower parts that do not mix. The new supercomputer simulations suggest that the real world may combine elements of both ideas, with a generally stratified mantle that occasionally flushes great masses of rock across the boundary and down toward the core.

Although the two groups have taken different routes in creating numerical versions of the mantle, both sets of calculations show flushing patterns, a correspondence that lends credence to the concept. "It seems to be something that might really be happening inside the Earth," says Paul J. Tackley of the California Institute of Technology in Pasadena, a member of one of the modeling teams. Tackley and his colleagues published their findings in the Feb. 25 NATURE.

The other modeling group, led by Satoru Honda of the University of Hiroshima in Japan, discuss their simulations in the Feb. 26 SCIENCE.

Both models are three-dimensional representations of the mantle that depart from previous ones by including a critical transition at a depth of 670 kilometers — the boundary between the upper and lower mantles. Seismologists discovered the boundary when they noticed that seismic vibrations speed up when descending past 670 km. To explain the speed change, mineralogists have theorized that the transition marks a phase change: Rock below the boundary is thought to have a denser crystalline structure than rock above the boundary.

In the model simulations, as rock at the top of the mantle cools, it sinks until it reaches the 670 km boundary. Initially, the cooler, downwelling rock is not dense enough to sink into the lower mantle, so it pools right above the boundary. Eventually, however, the puddle of cooler rock grows heavy enough to break through the boundary and cascade into the lower mantle, flowing toward the core.

While the flushing pattern appears in both simulations, it takes different forms in the two models. Tackley's group found three or four breakthroughs occurring around the world at any one time. Honda and his colleagues saw the cascades developing one at a time and affecting the entire Earth. As it sinks into the lower mantle, the downflowing material would send plumes of hot material from near the core rising into the upper mantle.

The discrepancy may stem from basic differences in the models. Tackley's team uses a spherical mantle, whereas Honda's group represents the mantle as a wide fish-tank-like box.

The modeling results may help explain observations made by seismologists who study slabs of ocean floor that get pushed down into the mantle during collisions with other pieces of ocean floor or continents. In some places, the boundary at 670 km appears to deflect the slabs, preventing them from sinking into the lower mantle. In others, the slabs seem to penetrate the boundary. That pattern may match the simulations, which show flushing occurring only in limited locations, says geophysicist Scott D. King of Purdue University in West Lafayette, Ind.

While the new models show promise, everyone involved realizes that the present generation of numerical simulations lacks important elements that could alter the mantle picture considerably. Researchers are currently trying to add the effect of tectonic plates, which are much stiffer than the mantle rock.

— R. Monastersky

Baldness: Heart-risk marker

Middle-aged men who lament the loss of their hair have another reason to worry: A new study links baldness with increased risk of heart attack.

Epidemiologist Samuel M. Lesko of the Boston University School of Medicine and his colleagues studied 665 men age 21 to 54 who had been admitted to one of 35 hospitals after suffering their first heart attack. The authors also looked at 772 male controls matched for age who had gone to the same hospitals but who did not suffer from heart disease.

The researchers rated each man's hair loss using a five-point scale. The team observed a higher frequency of vertex scalp baldness (hair lost from the top of the head) in the group of men who had suffered a heart attack.

Indeed, the group's statistical analysis revealed that men with top-of-the-head baldness faced a 40 percent greater risk of heart attack than men with a full head of hair. Men with the greatest vertex scalp baldness had the highest risk, Lesko says.

For men with a receding hairline, this study offers reassuring news: Men with frontal hair loss showed no increased heart attack threat, he adds.

The association between baldness and heart attacks remained after the researchers accounted for other risk factors, such as a family history of heart attack, smoking, and high blood pressure. The team published their findings in the Feb. 24 JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION.

"Is baldness bad news for the heart?" asks an editorial written by Peter W. F. Wilson and William B. Kannel, both of the Framingham (Mass.) Heart Study. "It is premature to provide a verdict," they say. Lesko agrees, noting that additional studies must confirm the link between baldness and heart attack risk. □