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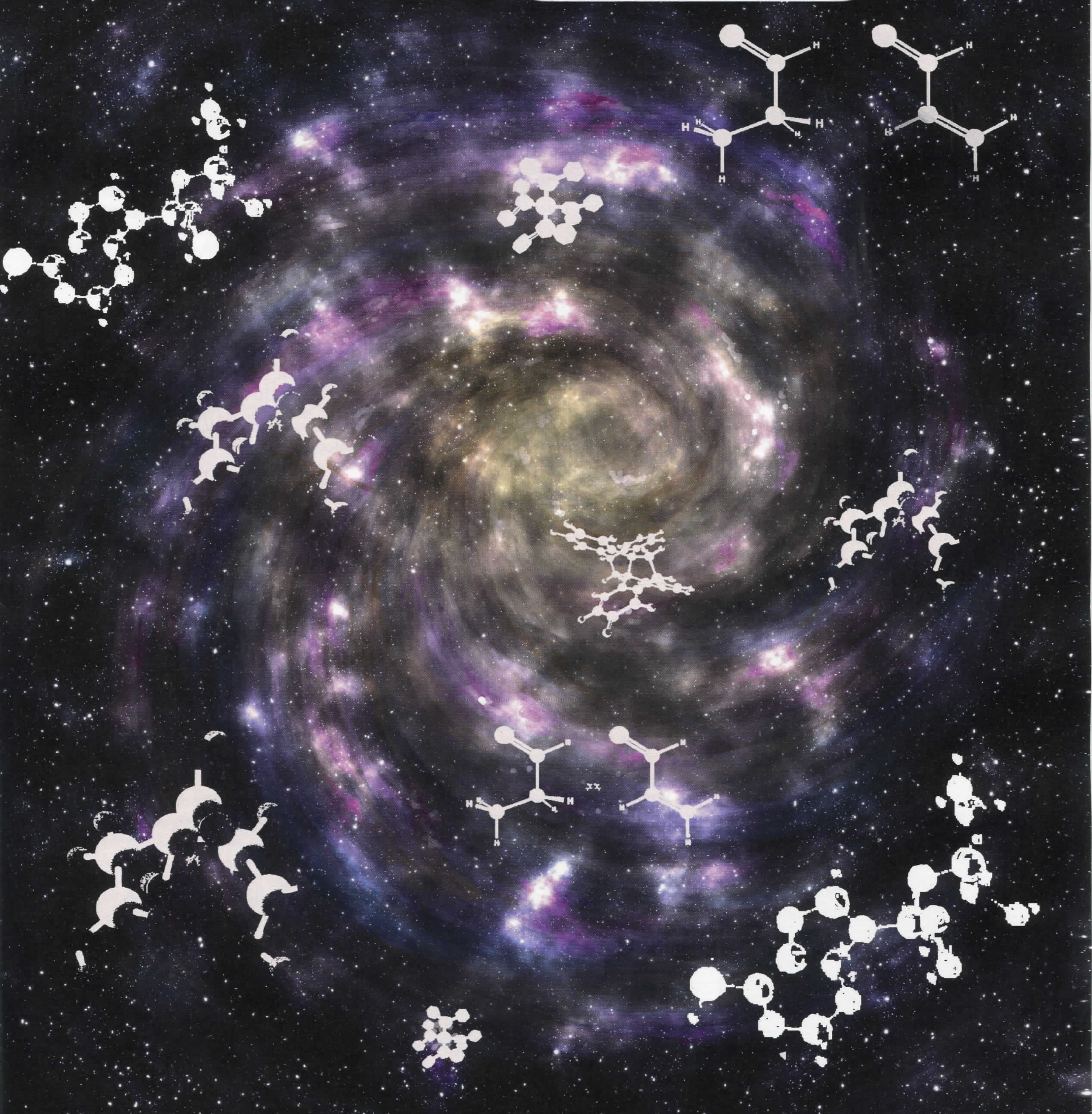


Cover Illustration by: Vicky Hoznek

EARTH WAS PROBABLY UNINHABITABLE UNTIL SEVERAL HUNDRED MILLION YEARS AFTER ITS FORMATION

REINVENTING THE ORIGIN OF LIFE

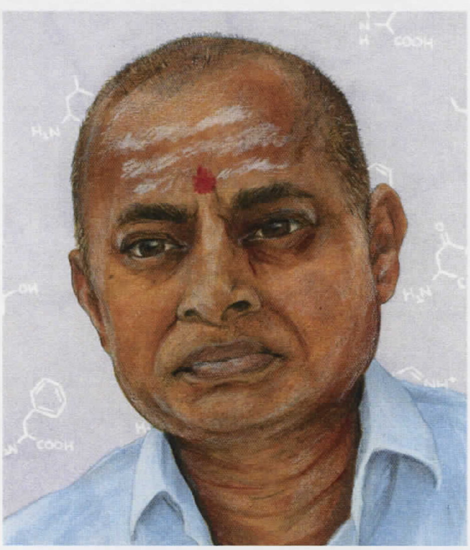
Written by:
Liam Huber
Online Reporter

Illustrations by:
Vicky Hoznek
SQ Illustrator

The question that forms the crux of astro biology is whether there is life on other worlds. Ultimately, this uncertainty hinges on another question: how does life originate? Admittedly, scientists do not fully understand how Earth, the one planet that definitely has life, came to have it. Unravelling the mechanics of the transition from inanimate stardust to living beings could help determine if this transformation was inevitable or a cosmic fluke, and therefore if it likely took place anywhere else. In other words, in order for astrobiologists to say with certainty that life could exist on exoplanets, chemists must be able to demonstrate how life could have begun here on Earth.

Associate Professor Ramanarayanan Krishnamurthy of the UC San Diego Chemistry Department is trying to do just that. His synthetic organic chemistry laboratory at the Scripps Research Institute is currently investigating some of the most enduring questions in the life sciences. In approaching this task, Krishnamurthy stresses that he deals not in history, but in possibilities. He and his researchers focus on demonstrating that simple, chemical building blocks can, over time, assemble into biological polymers — namely, proteins and nucleic acids. Can these ingredients, if distilled in the proper environment, transform into a self-assembling, self-sustaining, self-functioning system?

DR. RAMANARAYANAN KRISHNAMURTHY STUDIES THE CHEMICAL ORIGINS OF LIFE AT THE SCRIPPS RESEARCH INSTITUTE.



Their research operates under a central assumption: instead of the pristine molecular architecture that is inside every functioning cell today, life began out of a rag tag mixture of chemical compounds, reacting chaotically in the crucible of young Earth. For example, prebiotic processes might not only produce ribose and alpha-amino acids, integral components of nucleic acids and proteins, respectively, but also compounds like arabinose, glucose, and beta-amino acids, among a plethora of other organic molecules, similar to what is sometimes found in meteorites. According to Krishnamurthy, life might have begun on makeshift mechanisms that utilized this vast arsenal of compounds. Over time, natural selection could have whittled down that arsenal, guiding primordial life toward the simpler, protein-enforced and DNA-entrusted medium that biologists are familiar with today. Krishnamurthy refers to this as the "heterogeneity-to-homogeneity" scenario because it describes the handing-off of life processes from diverse and complex training wheels to simpler and more effective mechanisms.

Krishnamurthy's lab is currently applying this model assumption to the sugar backbone of nucleic acids. Their efforts could demonstrate that these pivotal polymers can be produced by sloppy, low-yield reactions suited to primordial environs. Previously, their experiments with nucleic acids have demonstrated that chimeric RNA-DNA systems have a weaker affinity than pure RNA or DNA. These findings challenge the RNA World hypothesis, the conception that RNA evolved earlier and later became the progenitor of proteins and DNA. Rather, Krishnamurthy speculates, RNA and DNA might have co-evolved. This alternate theory has been entertained by various researchers, including UC San Diego's Stanley Miller, who designed the famous Miller-Urey experiment demonstrating how conditions on primordial Earth could generate amino acids. It is characteristic of the heterogeneity-to-homogeneity scenario, says Krishnamurthy, for molecules to be selected for based on their usefulness and not just their propensity to pop up in the primordial soup.

As far as astrobiology is concerned, Krishnamurthy urges caution in extrapolating any discoveries to make generalizations about the origins of life on other planets. With Earth being the only world with confirmed life forms, Krishnamurthy is hesitant to apply that lonely data point to the entire universe. As he points out, his research is challenging enough confined to a single planet: in the words of his mentor, Albert Eschenmoser, "The origin of life cannot be discovered, it has to be reinvented." Speculation about alien worlds may continue, but it requires hard scientific evidence, such as organic chemists' attempts to reinvent life's origins on Earth, to back it up.

Currently, the Kepler telescope scans the heavens for flashes of habitable planets. Rovers probe Mars for traces of water, and life. Closer to home, the Krishnamurthy lab is getting ready to publish how the base-pairing rules of DNA and RNA, the crucial means by which genetic information is recorded and transmitted across generations, can be reversed. Stay tuned: although the definitive discovery of life beyond Earth may be years or lifetimes away, groundbreaking studies will continue to upend what we thought we knew about life on our own planet.

BRINGING SPACE TO SAN DIEGO

Written by:
Madeleine Yu
Online Reporter

Photos from:
Hargens Lab

Space is hardly welcome territory. In addition to extreme temperatures and high levels of radiation exposure, the extraterrestrial environment involves the disabling factors that accompany zero-gravity conditions. In 2015, National Aeronautics and Space Administration (NASA) implemented the year-long Twins Study with the help of identical twin brothers and astronauts, Scott and Mark Kelly, to compare the physiological effects of living in space versus on Earth. Preliminary findings indicated clear distinctions such as differences in the expression of over 200,000 RNA molecules. Before further space exploration can be given the green light, it is essential that scientists uncover all of the potential ramifications that those who embark on long duration travel will undergo.

THIS SUCTION CHAMBER USES NEGATIVE PRESSURE TO COUNTERBALANCE ZERO-GRAVITY CONDITIONS FOUND IN SPACE, REMEDIATING ADVERSE EFFECTS ON THE MIND AND BODY.

After serving as the Chief of the Space Physiology Branch and a Space Station Project Scientist at NASA's Ames Research Center, Dr. Alan Hargens decided to bring his expertise back to La Jolla, where he had earned his doctorate at the Scripps Institute of Oceanography. Today, he concurrently teaches a freshman seminar on space physiology and exploration and directs the Orthopaedic Clinical Physiology Lab at UC San Diego. There, he continues his research on gravitational effects on the cardiovascular and musculoskeletal systems of humans and animals.

Because gravity is simply another part of everyday life on Earth, the human body is accustomed to the differential pressure that the unseeable force enacts on it. However, in space, gravity releases its pull and normal hydrostatic pressures are lost. There is a headward fluid shift, resulting in increased pressure in the head. Unsurprisingly, this leads to physiological and cognitive changes like increases in intracranial pressure, inactive skeletal muscle fibers that normally provide postural support, and improper sleep. As a result, astronauts experience problems such as nearsightedness, herniated discs, and impaired cognitive abilities.

Hargens hopes to solve some of these problems with the use of exercise hardware designed to counterbalance the gravitational changes. Astronauts currently use treadmills with bungee cords that enable them to exercise "up to 70% of their body weight"— the limit for comfort. Since such research cannot be done in space, space is brought, in some fashion, to Earth. Hargens and his team of researchers recruit identical twins as participants and assign them to thirty days in a tilted head down position. One is then chosen to exercise with a suction chamber that introduces the lower half of the body to negative pressure. Blood and other fluids shift from the upper body to the lower body, remediating the headward fluid shift and allowing participants to exercise up to "1.4 times their own body weight comfortably."

Hargens' research is especially relevant given that just last September, SpaceX CEO Elon Musk, released his plan to colonize Mars. However, there is a lack of information regarding how to address crewmembers' basic needs during the duration of the mission. "So far all astronauts have been in low Earth orbit where they are not exposed to that much radiation, so there's a lot of worry that [the Mars Mission crewmembers] will have high cancer rates," says Hargens. "Also, if you put a lot of people in a small aircraft, there will be lots of interpersonal problems. They have to pick the right crew and the right conditions." The latter is something that Hargens believes can be remedied by virtual reality technologies. Such tools could enable astronauts to feel as if they are with their family or even running on the beach from millions of miles away.

In addition to maintaining the physical and mental well-being of their astronauts, space-based travel organizations must also consider other factors such as the growth and maintenance of food and water supplies as well as access to micronutrients, like vitamin C and calcium. Components of our daily environment, so often taken for granted, become essential for survival when it comes to the vastness of the cosmos. We are inextricably linked to life on planet Earth, and the replication of its conditions is the key to making long term space travel possible.

While it will certainly take a lot of time, energy, and thought before space can be considered a safe medium for travel, it is undeniably an endeavor that is well worth the wait. Until then space can be found a little closer, in the labs and classrooms of UC San Diego.

ONLINE: TARDIGRADES

TESTING THE LIMITS OF SPACE

Written by:
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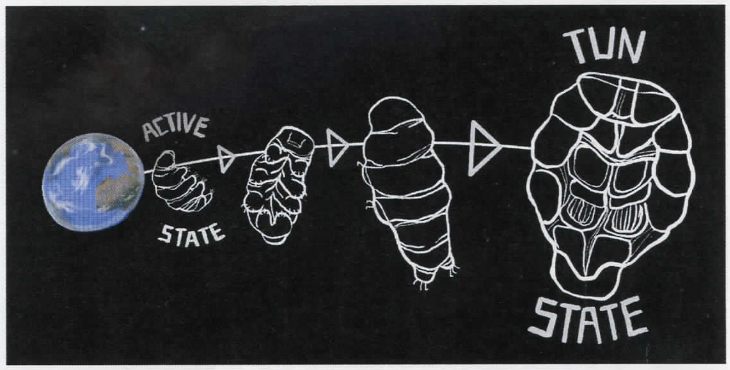
SQ Illustrator

In 2016, the National Aeronautics and Space Administration reported a record-breaking 18,300 applications from aspiring astronauts. It may be surprising that so many people seem to be eager to launch themselves into space, considering that they would have to forgo Earth's mild temperatures, clean water, and rich atmosphere of nitrogen, carbon dioxide, and oxygen. Space may be alluring, but it can be very unforgiving: along with the complete lack of oxygen, astronauts would be exposed to cosmic radiation, extremely low temperatures, and dangerously low pressures.

While humans are unable to survive outside the comforts of Earth, the tardigrade, an aquatic micro-organism, is the first and the only animal known to survive conditions in space. Found in environments with temperatures ranging from -273 to 150 degrees Celsius, tardigrades can survive in extreme temperatures and can be found anywhere from the Himalayan mountains to the bottom of the ocean.



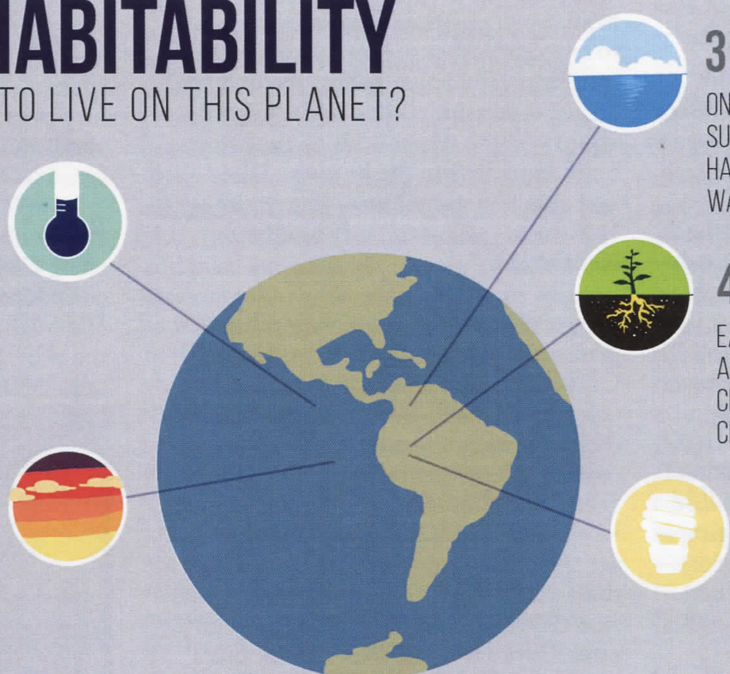
A TARDIGRADE CAN SURVIVE SPACE-LIKE CONDITIONS IN THE "TUN" STATE, IN WHICH IT RETRACTS ITS HEAD AND LEGS INTO ITS BODY, DRYING OUT TO FORM AN ALMOST LIFELESS SPHERE.

Studies have shown that the microorganisms can survive for months in severe environments, such as those that lack oxygen and water, have extreme salinity, radiation, and poisonous chemicals.

For the full story, visit sqonline.ucsd.edu

EARTH'S HABITABILITY

WHAT ENABLES US TO LIVE ON THIS PLANET?



1 | TEMPERATURE

ONLY EARTH'S SURFACE IS IN THE RANGE CONDUCIVE TO LIVING (-15°C TO 115°C); IN THIS RANGE, LIQUID WATER CAN STILL EXIST UNDER CERTAIN CONDITIONS.

2 | ATMOSPHERE

EARTH IS THE RIGHT SIZE TO HOLD AN ATMOSPHERE ABOUT 100 MILES THICK. IT KEEPS THE SURFACE WARM & PROTECTS IT FROM RADIATION & SMALL TO MEDIUM-SIZED METEORITES.

3 | WATER

ONLY EARTH'S SURFACE HAS WATER (TO SUPPLY ORGANISMS), THOUGH MARS ONCE HAD SURFACE WATER AND STILL HAS WATER ICE IN ITS POLAR ICE CAPS.

4 | NUTRIENTS

EARTH HAS A WATER CYCLE, AN ATMOSPHERE, AND VOLCANOES TO CIRCULATE NUTRIENTS AND REPLENISH CHEMICALS REQUIRED BY LIVING ORGANISMS.

5 | ENERGY

THE EARTH IS JUST FAR/CLOSE ENOUGH TO THE SUN TO RECEIVE THE NECESSARY STEADY STREAM OF LIGHT OR CHEMICAL ENERGY, ALLOWING CELLS TO RUN REACTIONS NECESSARY FOR LIFE.