THE SEARCH IS ON

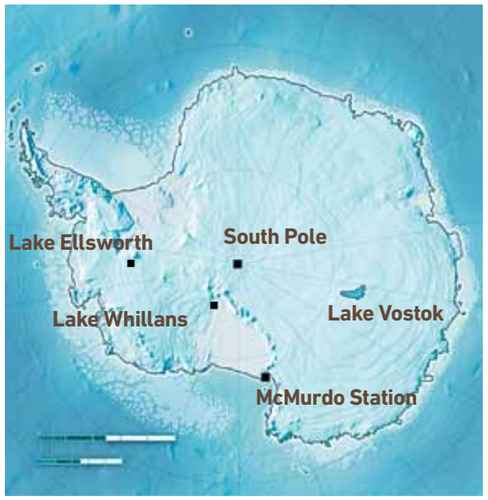
New missions and discoveries on Earth, within our solar system and beyond are bringing us closer than ever to finding alien life on other planets

BY JENNIFER ABBASI

NICK KALOTERAKIS

"The genesis of life is as inevitable as the formation of atoms," is how Andrei Finkelstein, the director of the Russian Academy of Sciences's Applied Astronomy Institute, explained his ambitious timeline for finding alien life to an audience of astrobiologists and reporters in June. "There is life on other planets, and we will find it in 20 years."

BUT TULLIS ONSTOTT, a geologist at Princeton University who specializes in astrobiology, makes an even more ambitious prediction. "In the next 15 years," he says, "we will likely discover life on an exoplanet near us." Scientists have long predicted the discovery of extraterrestrial life, but Finkelstein and Onstott have good reason to be optimistic. Researchers are devoting more resources to the search for alien life than ever before, and they are getting some enticing results. Since 1996, when NASA created its current astrobiology program, the agency has increased the annual budget from $10 million to $55 million. In that same period, the overall number of astrobiologists increased to a few thousand worldwide, and the number of papers they published rose from around 40 to nearly 3,000. Informed by such work, NASA has planned a full slate of search-for-life missions for the next two decades. This year, scientists using data from the Kepler space telescope have found evidence of more than 1,200 new exoplanets, 54 of them potentially habitable, and this fall, NASA will send a rover to Mars to search for the chemical signatures of life. In 2018, it plans to send another rover to Mars—one that will eventually provide soil samples that return to Earth. Scientists have also outlined a two-craft mission to Jupiter's icy moon Europa, and they are designing new telescopes, more sophisticated than Kepler, that could look into distant star systems to spot signs of life directly. What we'll find remains a mystery, of course, but the way we'll find it is well mapped out.



◀ ALIEN GROUND
Scientists could use microbes found in Vostok, Whillans and Ellsworth, three subglacial lakes in Antarctica, to create DNA probes and biosignature models to be used by future search-for-life missions in our solar system.

KEVIN HAND

THE BACKYARD

The first work starts here at home. By studying life that exists in extreme environments, scientists are learning a great deal about how and where to look for it on other planets. Researchers have found microbes in volcanic calderas, deep ocean vents and arsenic-laden lakes [see "Scientist in a Strange Land," page 46], and the existence of these "extremophile" life-forms has redefined the concept of habitability on this planet and elsewhere.

Alfonso Davila, a research scientist at the NASA Ames Research Center, was part of a team that found microorganisms living in salt crystals in Chile's ultra-dry Atacama Desert. The organisms managed to survive on atmospheric water vapor, Davila says, so similar organisms might also survive in salt deposits on Mars, which has enough atmospheric water vapor to form frost. Microbiologist Lyle Whyte of McGill University in Montreal found bacteria living at subzero temperatures in a methane-rich spring on Axel Heiberg Island in the Canadian Arctic Ocean. Similar life-forms could also be the source of the recently discovered methane plumes on Mars. "There could be microorganisms in the deep subsurface of Mars that produce the gas," Whyte says. And this winter, scientists will get a look at how life might exist on the ice moons of Jupiter. Scientists have yet to tap any of the more than 150 lakes sealed beneath the Antarctic ice cap, but starting in December, research teams will complete three drilling projects in as many years.

DRILLING FOR EXTREME LIFE

For the past 20 million years, Lake Vostok has been sealed beneath the Antarctic ice sheet. This winter, after nearly 22 years of work, Russian researchers will use mechanical and thermal drills to punch through the final 100 feet before liquid water. Microbes found in Vostok could inform the search for life on the Jovian ice moon Europa, for which a mission could launch in the next decade, and other moons in our solar system thought to contain bodies of liquid water, such as Enceladus and Ganymede.

THE SITE

Vostok Station once recorded the lowest temperature on Earth: –128°F. Fortunately for researchers, average temperatures in the austral summer hover around –33°. The Russian team will commence drilling in December. Once scientists reach liquid water, they will allow water to rise up the borehole and freeze over the winter. They will return to Vostok Station in December 2012 to test the core for life.

THE DRILL

A thermal drill tethered to a power cable from the surface will penetrate the final 30 feet of ice. When the drill approaches the water surface, pressure and water sensors will trigger an expandable borehole packer to seal off the channel, preventing drilling fluid from contaminating the lake and allowing scientists to control how quickly the water will rise.

THE LAKE

Lake Vostok, one of the world's largest lakes by volume, contains more than 1,000 cubic miles of water. At its farthest depths, some 14,000 feet below the surface, pressure reaches up to 438 atmospheres. If drilled improperly, the pressurized water could race up the borehole, causing an explosion powerful enough to destroy Vostok Station.

DO GOOD, FIND ALIENS

After losing the funding to run its telescopes, the SETI Institute enlisted a powerful ally: the people

◀ LISTENING POST Scientists and amateurs use radio telescopes at the Allen Telescope Array to listen for alien transmissions.

In April, after the National Science Foundation and the state of California cut funding for radio astronomy, the Allen Telescope Array (ATA) at Hat Creek Radio Observatory, the SETI Institute's primary listening post, went dark for the first time in nearly four years. The ATA scans deep space for alien radio signals, which some scientists say could be our best chance of finding intelligent life.

To replace the estimated $5 million it will cost to get the ATA back online full time for two years, SETI introduced a new program called SETIStars in June. For $15, doners can sponsor three-minute blocks of telescope data. In March, SETI launched the beta version of another program, a citizen-science application called setiQuest Explorer. Amateur alien hunters will be able to analyze radio-telescope data for signs of contact on their computers, tablet or mobile phone. The institute's public outreach is paying off. By August, SETIStars had generated more than $200,000, enough to turn the ATA back on, at least for a little while.

Researchers from the Arctic and Antarctic Research Institute in Russia will reach water first when they drill into Lake Vostok, a body of water roughly the size of Lake Ontario that has been isolated for as long as 20 million years under an ice cap that is now well over two miles thick. Because the water beneath the lake is sealed off, devoid of light and extremely cold, it is an unusually close analogue to Europa, where a thick layer of ice blocks sunlight from reaching a suspected subsurface ocean. "Life in Antarctic subglacial systems will allow us to focus our search for life in Europa's ocean," says John Priscu, a microbiologist at Montana State University who in 2014 will melt through half a mile of ice to reach Lake Whillans, 650 miles west of Lake Vostok. "It will allow us to design DNA probes and look for biosignatures in Europa's ocean."

The challenge is to get samples without disturbing or contaminating the delicate system. Last February, the Russian team drilled to within 100 feet of the lake water but then had to stop for winter. When work resumes in the austral summer, researchers will switch from a mechanical corer to a heated drill bit to melt through the last 30 feet of ice. The lake water, slowed by an expandable borehole plug on the end of the drill, will rise 100 feet up the hole and freeze. In December 2012, the researchers will return to core and sample it. The samples should generate many clues as to what kind of life can survive in such conditions, even as researchers learn how to better gather such samples in more-difficult conditions. "If there is any chance that Europa's ice might be thin enough in places for humans to drill or melt into it," says Robert Pappalardo, an astrobiologist at NASA's Jet Propulsion Laboratory who is heading up the science team on the future mission to Europa, "perhaps Vostok and other subglacial lakes can teach us techniques for doing so."

THE NEIGHBORHOOD

Scientists are using lessons learned on Earth to guide upcoming missions within our solar system. Mars will receive the most attention in the near term. At 35 million miles away, the planet transits at the margins of the sun's habitable zone, the orbital region at which liquid water—and therefore life as we know it—has the best chance of existing on the surface. Mars has no known permanent water flows, but scientists have found ice there and, this summer, evidence of seasonal water flows. They have also found signs of ancient rainfall, lakes and even oceans, which suggests that the planet was once much warmer.

In late November or early December, NASA will launch the Mars Science Laboratory to explore an ancient crater that probably once held water. The car-size rover will search for signs of subsurface ice and scan rocks for carbon compounds, including amino acids, that could indicate the presence of life.

In 2018, NASA will join with the European Space Agency (ESA) to launch an even more ambitious venture: the three-stage Mars Sample Return. In the first stage, a rover will excavate and store 19 to 37 small cores from the planet's surface in a sealed container, and as early as 2025, a lander will arrive to retrieve the cache and launch it into space, where a final-stage orbiter will intercept it and return the samples to Earth.

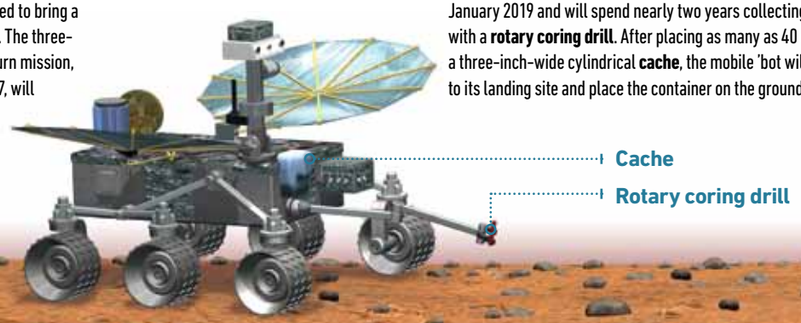
"There's only so much you can do with robotic instruments on the surface of another planet," says Cynthia Phillips, a planetary scientist at the SETI (Search for Extraterrestrial Intelligence) Institute. "If we can bring pieces back to Earth and study them in laboratories with all of our instruments, we're going to learn so much more."

Such a mission may well turn up evidence, in the form of microbial fossils, that life existed on Mars billions of years ago. But some scientists, including Davila and Whyte, say life could exist there right now. In June, Tullis Onstott co-published a paper in *Nature* that suggested where it might be. The paper described how a previously unknown species of roundworm survived in an African gold mine nearly a mile below the Earth's surface—100 times as deep as multicellular life had been observed previously. If it can happen here, Onstott says, it may also be possible on Mars. Complex life may no longer exist on the surface, but this "shows multicellular life could still exist beneath the surface."

Other nearby worlds may offer even better chances for finding life. NASA plans to send an orbiter

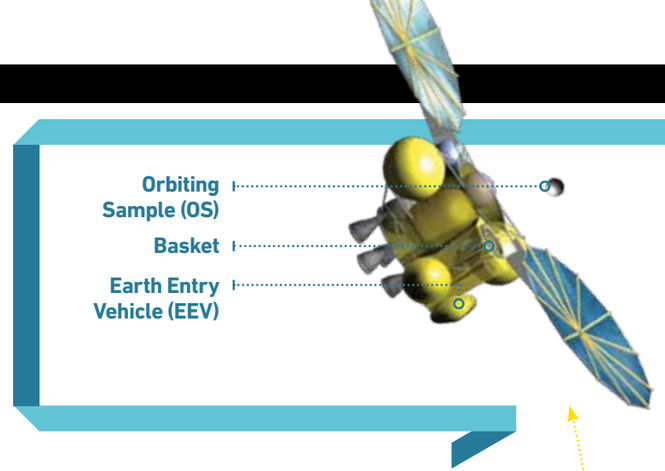
BRINGING MARS HOME

To determine whether life lives or has lived on Mars, scientists will most likely need to bring a sample of the planet back to Earth. The three-stage NASA-ESA Mars Sample Return mission, scheduled to run from 2018 to 2027, will involve rovers, a launcher, and an orbiter equipped with an Earth Entry Vehicle (EEV) that will carry the rocks to Earth for testing.



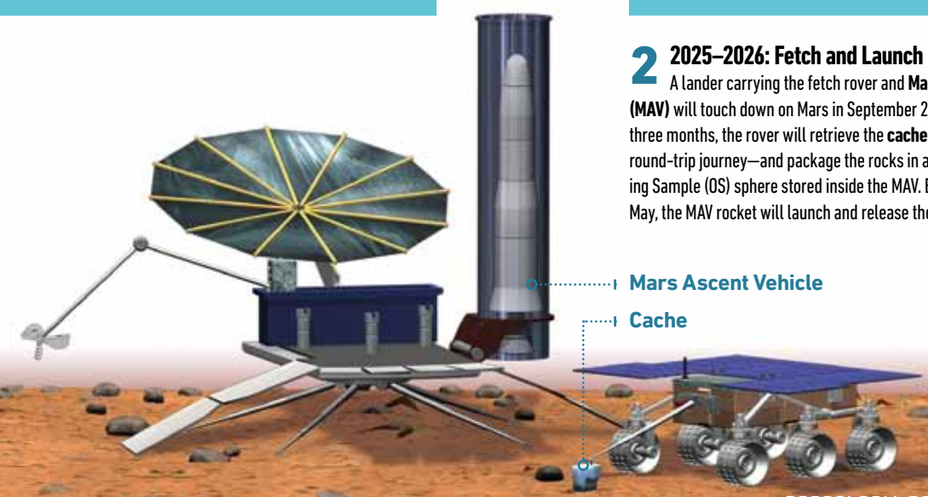
1 2019–2021: Collect and Cache

Following launch in 2018, a rover will arrive on Mars in January 2019 and will spend nearly two years collecting rocks with a **rotary coring drill**. After placing as many as 40 cores in a three-inch-wide cylindrical **cache**, the mobile 'bot will return to its landing site and place the container on the ground.



3 2026–2027: Rendezvous and Return

An orbiter will arrive at Mars in the summer of 2023. The craft will use optical and radio-frequency tracking systems to monitor the **OS** launch and will rendezvous with the samples in around May 2026. The orbiter will capture the OS in a **basket** and transfer it to the onboard **EEV**—a three-foot-wide, impact-resistant, heat-shielded craft—before setting out for Earth. On descent to Earth in late 2027, the EEV will decouple from the orbiter and crash-land on the planet. The quarantined samples would then be safely recovered.



2 2025–2026: Fetch and Launch

A lander carrying the fetch rover and **Mars Ascent Vehicle (MAV)** will touch down on Mars in September 2025. Over the next three months, the rover will retrieve the **cache**—up to a nine-mile round-trip journey—and package the rocks in an 11-pound Orbiting Sample (OS) sphere stored inside the MAV. By the following May, the MAV rocket will launch and release the OS into orbit.

ILLUSTRATION: KEVIN HAND; PHOTOGRAPH: REDDING RECORD SEARCHLIGHT/ZUMAPRESS.COM

"KEPLER IS A GAME-CHANGER. IT REACHES OUT TO THOSE PLANETS WE ARE MOST INTERESTED IN AND EXCITED ABOUT."

and a flyby vessel in a two-stage mission to Europa. The orbiter would send back data that could help scientists confirm the existence and character of a subsurface ocean first detected by *Galileo* in 1996. The flyby vessel would then examine the moon using infrared spectroscopy, high-resolution imaging and ice-penetrating radar to determine the chemical composition of the surface, the ice cap's thickness and its subsurface processes. The measurements could also suggest whether life developed organically on the moon or was introduced from a meteorite. Neither vessel would probably be able to detect life itself. "We're not really there yet," Pappalardo says. "We're at the habitability stage: Does this environment really have water within, like we think it does?"

Researchers are asking similar questions about two moons of Saturn. The small moon Enceladus ejects a large plume of water vapor from its south pole, and in June researchers studying data from the *Cassini* orbiter reported that the plume may originate from subsurface saltwater reservoirs. "If there are microbes being spewed out into space by the plume," Phillips says, "it's possible that a spacecraft could sample those and find real evidence [of life] without even having to land." *Cassini* has also confirmed the presence of methane lakes on the surface of Titan, Saturn's largest moon, and NASA is debating whether to send a ship-like probe to search for signs of life within them in 2016 [see "Space Boat!" Headlines, September].

THE BEYOND

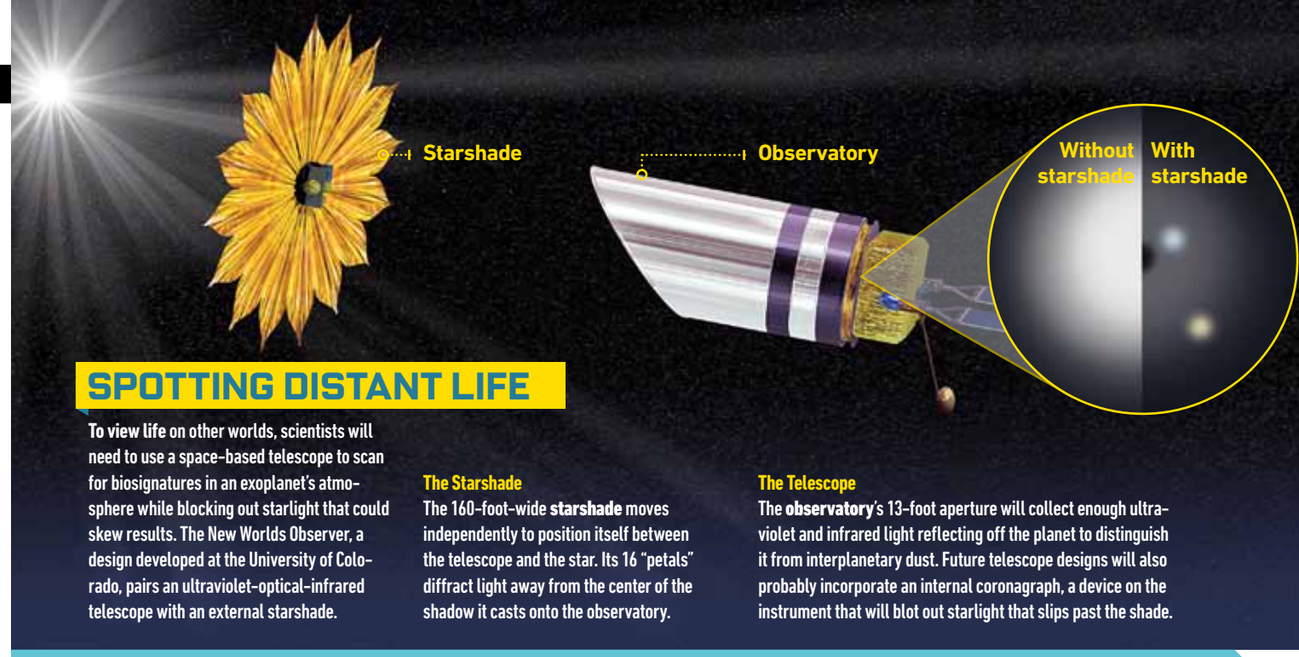
In 1995, Swiss researchers confirmed the existence of 51 Pegasi b, the first-known exoplanet orbiting a sunlike star. Since then, astronomers have catalogued more than 500 exoplanets. Many of these planets are gas and ice giants incapable of supporting life as we know it, but a few of them, especially those with a mass closer to that of our own world, could have conditions much more amenable to life.

Using the Kepler space telescope, launched in March 2009, NASA scientists can now measure changes in the brightness of some of the 156,000 stars in the constellations Cygnus and Lyra. Such changes indicate that a planet is transiting in front of the star, and they enable astronomers to calculate not just the planet's physical size, but also its mass and density and thereby its basic makeup—rocky or oceanic versus gas, for example. Since NASA first began releasing Kepler data in February, scientists have confirmed the existence of 17 exoplanets. More than 1,200 other candidates remain to be vetted, and 54 of those candidates lie within the habitable zone of their central star. Dimitar Sasselov, director of the Harvard Origins of Life Initiative, studies Kepler worlds. He says scientists using the telescope will find an Earth-size planet in a habitable zone within the next two years. "Kepler is a game-changer," he says. "Not only because of the accelerated rate of planet discovery, but particularly because it reaches out to those planets that we are most interested in and excited about."

Scientists are devising ways to test those planets for signs of life directly. Atmospheric spectra in the visible and infrared wavelengths correspond to the presence of various combinations of gases, and some combinations may indicate that life processes are at work. The presence of water, carbon dioxide and ozone on a planet, for example, would indicate that photosynthesis is taking place on its surface.

Scientists do not yet have the tools to determine atmospheric biosignatures at great distances. Funding permitting, in 2018 NASA will join ESA and the Canadian Space Agency to launch the James Webb Space Telescope, which will begin to provide some data. NASA and ESA are also considering concepts for larger, higher-resolution infrared observatories. The New Worlds mission, a NASA project that could fly sometime after 2027, would use an internal coronagraph and an external occulter to block out starlight that can skew biosignature readings. In one concept, the University of Colorado–designed New Worlds Observer, a 160-foot flower-shaped "starshade," would fly more than 50,000 miles in front of the observatory, casting a shadow onto the telescope and allowing for better resolution of the target exoplanet.

By the time such an observer launched, scientists would have accumulated a sizable roster of promising exoplanets. For now, the best target is Gliese 581 d, a planet 20 light-years away that is at least five times the mass of Earth. This summer, French scientists working with computer models predicted that the planet, which orbits a red-dwarf star at the cold outer edge of



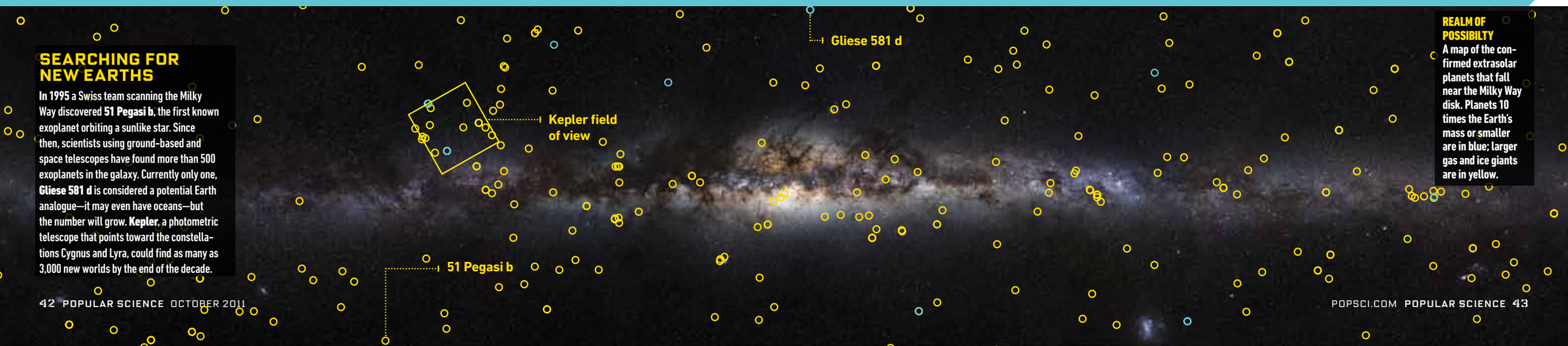
SPOTTING DISTANT LIFE

To view life on other worlds, scientists will need to use a space-based telescope to scan for biosignatures in an exoplanet's atmosphere while blocking out starlight that could skew results. The New Worlds Observer, a design developed at the University of Colorado, pairs an ultraviolet-optical-infrared telescope with an external starshade.

The Starshade
The 160-foot-wide **starshade** moves independently to position itself between the telescope and the star. Its 16 "petals" diffract light away from the center of the shadow it casts onto the observatory.

The Telescope
The **observatory**'s 13-foot aperture will collect enough ultraviolet and infrared light reflecting off the planet to distinguish it from interplanetary dust. Future telescope designs will also probably incorporate an internal coronagraph, a device on the instrument that will blot out starlight that slips past the shade.

ILLUSTRATION: KEVIN HAND; PHOTOGRAPH: COURTESY EUROPEAN SOUTHERN OBSERVATORY/S. BRUNIER



SEARCHING FOR NEW EARTHS

In 1995 a Swiss team scanning the Milky Way discovered **51 Pegasi b**, the first known exoplanet orbiting a sunlike star. Since then, scientists using ground-based and space telescopes have found more than 500 exoplanets in the galaxy. Currently only one, **Gliese 581 d** is considered a potential Earth analogue—it may even have oceans—but the number will grow. **Kepler**, a photometric telescope that points toward the constellations Cygnus and Lyra, could find as many as 3,000 new worlds by the end of the decade.

REALM OF POSSIBILTY
A map of the confirmed extrasolar planets that fall near the Milky Way disk. Planets 10 times the Earth's mass or smaller are in blue; larger gas and ice giants are in yellow.

"WE KEEP LOOKING FOR CRITTERS LIKE US. THE MAJORITY OF INTELLIGENCE OUT THERE IS NOT BIOLOGICAL."

its habitable zone, could have a stable atmosphere and liquid surface water. Astronomer Stéphane Udry, whose team at the University of Geneva in Switzerland discovered Gliese 581 d in 2007, says the planet probably formed farther from its sun and then moved to its current position. Ice on the planet could have melted and created oceans as it migrated inward, making it the first known ocean world.

THE SHAPE OF THINGS TO COME

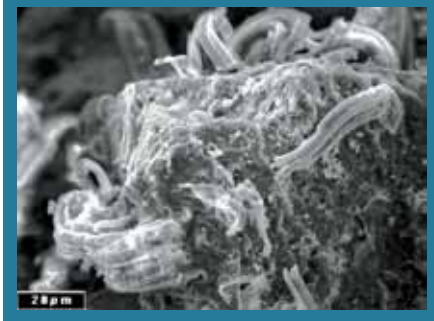
Just as scientists can use atmospheric clues to determine how likely it is that life exists on a given planet or moon, they can also use them to guess what form that life might take. Nancy Kiang, a biometeorologist at the NASA Goddard Institute for Space Studies, says that plants adapted to dim red-dwarf stars might look black because they would have evolved to absorb infrared light. Meanwhile Seth Shostak, an astronomer at the SETI Institute, says that animals, especially those on rocky or oceanic worlds similar to Earth, might have more-familiar designs. Heads, for instance, put the sensory organs—eyes, ears, whiskers—close to the brain, reducing reaction time and increasing an animal's chances of survival. A design that efficient, he says, would probably be common. At the astrobiology conference in June, Andrei Finkelstein said that aliens would probably look a lot like us: not just a head, but also two arms and two legs. Paleontologist Simon Conway Morris of the University of Cambridge has also put forth a humanoid model of intelligent life.

Shostak is not so sure that the highest form of life will be at all familiar, though. "The timescale to go from being technological to having an artificial-based intelligence is very short," he says. "We keep looking for critters like us living on a planet like ours, where in fact I would argue that the majority of the intelligence out there is not biological" but artificial.

John Priscu is similarly open-minded about the appearance of alien life. "I bet we have looked it straight in the face already," he says, "but didn't know what we were looking for."

Jennifer Abbasi is a regular contributor to Popular Science. *Her article on the International Space Station appeared in the August issue.*

A BRIEF HISTORY OF UNSOLVED ENCOUNTERS



◀ PROOF? Evidence of fossilized bacteria, potentially flown in from space, was found on three meteorites in March.

Portage County UFO Chase, 1966

On April 17, two officers of the Portage County Sheriff's Department saw a moving oval-shaped object in the sky near Ravenna, Ohio, around 5 a.m. Joined by two other officers, they pursued the object for 85 miles until they lost sight of it near Conway, Pennsylvania. The incident inspired a similar police chase in the movie *Close Encounters of the Third Kind*. After an investigation, the Air Force said the officers saw a satellite and Venus. This clashed with the officers' reports, which said that the object was flying low in the sky and moving from side to side.

"Wow!" Signal, 1977

Astronomer Jerry Ehman stumbled onto a two-minute radio signal from the Big Ear telescope at Ohio State University in which the unique code "6EQUJ5" appeared. Radio telescopes used to use alphanumeric codes to indicate signal intensity. 6EQUJ5 indicated a signal 30 times as loud as normal deep-space radiation, prompting Ehman to scribble "Wow!" in red pen in the margin. The signal has never been explained or seen again. Another mystery: It was broadcast at near 1,420 megahertz, the frequency at which hydrogen resonates and the frequency of choice, scientists think, for extraterrestrial communiqués.

The Rendlesham Forest Incident, 1980

In late December, Lt.-Colonel Charles Halt took a team of more than a dozen men into England's Rendlesham Forest to follow up on a report of an alien craft. In the forest, they encountered what Halt described as a floating red eye that "suddenly exploded" and began raining down light before disappearing completely. The incident is arguably the most highly documented encounter known: Team members have given corroborating accounts, signed affidavits, and have audiotapes of the encounter. The most common explanation is that the team saw the nearby Orford Ness lighthouse instead.

Richard Hoover's Microbes on a Meteorite, 2011

In a paper published on March 4, NASA scientist Richard Hoover claimed to have found fossilized microorganisms in three carbonaceous chondrite meteorites that date back more than four billion years. The discovery could strengthen the theory that life was delivered to Earth. Some scientists dispute the paper, saying that unique geology or contamination from bacteria here on Earth could explain the results, but opinion in the scientific community remains divided.

—NICK STATT

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