sciences, climatology, geology and biology. He explains that the neoclassical buildings of modern cities, such as London's British Museum, give a false impression. The famous centres of antiquity were "far less grandiose" – Athenian assemblies, for example, debated in the open air. He wryly notes that rats and humans thrive in cities, because both can survive on diverse food sources and cope with prolonged periods of hunger.

When did cities first appear? The answer depends on definitions. In today's Nicaragua, notes Woolf, any settlement with street lights and electricity counts as a city. In Japan, a population greater than 50,000 is required. A prime candidate for the world's first city is perhaps Jericho in what is now the Palestinian territories. It was founded before 9000 BC and about a millennium later had a wall – the earliest such barrier discovered. But Jericho's population at the time is uncertain. Estimates range from a few hundred to 2,000 or 3,000. As Woolf observes, it is tricky to determine population size in early societies without written records. One option is to analyse the water supply to work out how many people it could have served, but this reveals maximum carrying capacity rather than use, and struggles to take into account public baths and fountains.

Like most specialists, Woolf prefers to give the title of first city to Uruk, in Mesopotamia. This settlement had an estimated 10,000–20,000 inhabitants in 4000 BC, rising to between 60,000 and 140,000 after a massive protective wall, ascribed to King Gilgamesh, was built around 2900 BC. Here, in the late fourth millennium BC, writing probably originated in the form of cuneiform script on clay tablets, used to record bureaucratic information such as economic transactions. One such tablet displays the world's oldest known mathematical calculation, of the surface area of a roughly rectangular field. Yet the factors that drove the creative outburst that built the city remain mysterious. As Woolf admits: "For all the attention that has been devoted to the Uruk phenomenon, there is still no consensus about why it happened."

Mediterranean metropolises

Cities arrived much later in the ancient Mediterranean. Athens became an important centre of the Mycenaean civilization around 1400 BC; Rome was founded in the eighth century BC; Alexandria dates from 332 BC. Mediterranean farmers generally lacked access to the flood water and fertile alluvial mud provided by Mesopotamia's great rivers, the Tigris and Euphrates. For centuries, people lived in villages and hamlets rather than cities, which are at risk from crop failures and water shortages. Again, the driving forces are often debatable. The chief period of Roman urbanization is now known to have coincided with a period of increased temperatures during the last century BC and first two centuries AD. But, as Woolf warns, this might be a coincidence: "It is perfectly possible to explain urbanization without recourse to climate change."

Another source of uncertainty is how ancient diseases affected urban centres. Written accounts suggest, for example, that the Antonine plague claimed at least five million lives in the Roman Empire in AD 165–180, spreading so fast that an emperor and his entourage tried to outrun it on horseback. Yet its cause remains undetermined. Fast-developing techniques of ancient DNA analysis promise a more precise picture, notes Woolf. A crucial question is whether particular ancient epidemics affected city-dwellers more severely than their rural neighbours.

"No city lasts forever, however solidly founded."

One thing is clear: no city lasts forever, however solidly founded. This is Woolf's key point, backed up with four striking examples. In the northwest of the Indian subcontinent, the Indus civilization flourished in the third millennium BC, with remarkable cities at Harappa and Mohenjo-daro that featured brick houses, advanced drainage and a large public bath. Around 1900 BC, the civilization mysteriously disappeared. In the eastern Mediterranean, Bronze Age civilizations suffered an unexplained collapse around 1200 BC, followed by a centuries-long dark age during which the poet Homer recalled the legendary magnificence of cities such as Knossos and Troy.

Rome's population plummeted to perhaps 10,000 after the fall of the Roman Empire in the fifth century. And in Britain, Roman London had become prominent in the first century because of its maritime connections, with a forum, amphitheatre and walls. It withered after the Romans left but was revived under the Anglo-Norman state, becoming a centre of government in the thirteenth century.

The rise of cities might look inexorable, but urbanization has retreated as well as advanced over the millennia. "If we are urban apes it is not because we were ever designed to live in cities," Woolf emphasizes. Indeed, cities have existed during a mere 3% of the estimated 300,000-year existence of our species.

As we struggle to adapt to the latest pandemic, it might be some comfort that ancient plagues don't seem to have killed off any major cities. But in his final pages, Woolf – writing before the coronavirus outbreak – implies that pandemics might slow their future growth. There is "absolutely no guarantee" that our current rate of globalization will continue until we are "uniformly urbanized", he writes. "If the study of ancient cities teaches us anything it is that there have been many urban moments, but few that lasted more than a few centuries."

Andrew Robinson is the author of *The Indus: Lost Civilizations* and *Earth-Shattering Events: Earthquakes, Nations and Civilization*.
e-mail: andrew@andrew-robinson.org

The many roads to the red planet – a memoir

As three spacecraft set off for Mars, a planetary scientist tells of those that went before. **By Alexandra Witze**

Once every 26 months, planetary orbits align in a way that makes it favourable to launch spacecraft from Earth to Mars. This July and August, three nations are aiming to take advantage of this window of opportunity. If all goes well, the United States and China will both launch rovers, and the United Arab Emirates will dispatch an orbiter.

These craft are the future of Mars exploration. What of the past? Planetary scientist Sarah Stewart Johnson lays it out vividly in *The Sirens of Mars*. Through a mix of personal memoir and scientific primer, she illuminates the history of astronomers and explorers who have been fascinated by this neighbouring world, known to the ancients as a ruddy dot shining in the night sky.

Johnson runs through all the usual highlights of people's obsession with the red planet over the years. There's Giovanni Schiaparelli in the nineteenth century, observing dark lines he called channels or *canali*, which were later misinterpreted as canals from a Martian civilization. There's Percival Lowell decades later, using his family fortune to build an observatory in Arizona and map Mars through the telescope night after night, hoping to reveal a world teeming with intelligent life. There's astrobiologist Carl Sagan, dreaming

DAVID GOERLITZ

Author Sarah Stewart Johnson hunts for microbial traces on Earth that could inform the search for life on other planets.

of turtle-like Martian creatures and working with NASA's Viking landers in the 1970s to see whether they could definitively detect life on the planet's surface. (They failed.)

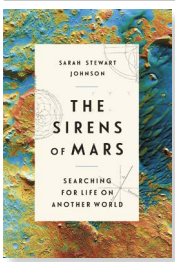
The strength of Johnson's narrative lies in interweaving these better-known stories with her own development as a planetary geologist. When she describes NASA's Mariner 4 mission flying past Mars in 1965 — taking the first photographs of another planet from space — she embeds the story in that of her father, then 18 years old, avidly following the mission by newspaper from his home in the Kentucky mountains. She contrasts the bombshell 1996 report of potential fossil microbes in a Martian meteorite (later discredited) with family hunts for fossils in the Appalachian cliffs. And when she talks about how colossal dust storms can scour the surface of Mars, she takes us into a wind tunnel where she uses fake Mars dust to study how particles are lofted and spread in these planetary whirlwinds.

Rockets and rovers

More broadly, Johnson sketches the full sweep of Mars exploration, with an emphasis on the space age. The famous modern US Mars scientists are here: Raymond Arvidson, peering at Mars in different wavelengths of light to tease out the mineral content of the rocks; Maria Zuber, mapping the planet's gravity with an orbiting spacecraft; Steve Squyres, orchestrating twin rover missions simultaneously. But don't expect to read much about Europe's or India's exploration of Mars — this is a strictly US perspective.

Still, there's no better guide to what NASA's various Mars missions have revealed, from the surprisingly varied landscape explored by the Sojourner rover in 1997 to the peculiar rock 'blueberries' — small blobs of minerals formed in wet sediment — at Opportunity's landing site in 2004. All paint a picture of a once-active Mars, filled with shifting dunes and eroding rivers and blowing winds.

In such a place, one might expect to find life. Wherever she can, Johnson hunts through Earthly environments for clues to how life could survive on Mars. On the dormant volcano Maunakea in Hawaii, she finds a tiny fern thriving beneath fragments of broken lava. On Australia's Nullarbor Plain, she fills vials with corrosively acidic water from primordial pools teeming with microbes. These are signs that life can thrive in the most unexpected of places, against all odds — and so, perhaps, on our neighbouring planet.



The Sirens of Mars: Searching for Life on Another World
Sarah Stewart Johnson
Crown (2020)

Did life ever exist on Mars? Answering that is part of the goal of one of this year's missions: NASA's Perseverance rover will hunt for life in the Jezero crater. An ancient river once vomited sediment here; the rover will sift through it for signs of Martian creatures, present or past. With any luck, it will find the remains of ancient biofilms, or chemical signatures of elements processed through the bodies of extraterrestrial organisms.

Life on Mars might not be like life on Earth. But if it is there, it will be close enough to be recognizable to scientists like Johnson, because of their work on extreme life on our planet. She has written a true love letter to geology, on this world and others.

Venus is Earth's twin in size and mass, but Mars is the abode of imagination and wonder. It is the planet we have always seen ourselves exploring, across its airless plains, mountains and valleys. Our knowledge of it has come piecemeal, one astronomical photograph and spacecraft image at a time, cobbled together as the red planet revealed itself. Now we wait to see what humanity's next three envoys will unearth there.

Alexandra Witze is a correspondent for *Nature* based in Boulder, Colorado.