Introduction

Genesis Revisited

There are many ways of looking at the Moon: with awe, with reverence, with longing, with fear. It is at once familiar yet mysterious, distant yet near, constant yet ever changing. Sometimes it seems close enough to be part of the Earth, at other times it seems as remote as the cosmos. High in the sky, it plays cat and mouse with the clouds, ducking behind them and then peeking out as if they were a flimsy veil. At moonrise it looms on the horizon like a big orange mountain, dwarfing houses and trees. On a spring night it consorts with Venus among the stars, the evening star dangling like a diamond earring from the Moon's crescent ear.

Men and women also have looked at the Moon for millennia as a practical aid for life on Earth. It has served as a torch for travelers, a timekeeper for farmers, a location finder for mariners. Occasionally it was a harbinger of doom, blocking the Sun during a solar eclipse, or turning bloodred during a lunar eclipse. Even in today's world of precision chronometers, its old role as timekeeper shows up in almost every culture. Christians still use the Moon to set the date of Easter; Muslims break Ramadan when they sight the crescent Moon; and countries such as China and Vietnam still use a lunar calendar along with the Western one.

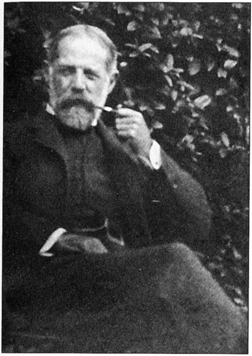
Only in the past four hundred years have we begun to look at the Moon through the eyes of modern experimental science. With the invention of the telescope in the seventeenth century, astronomers such as Galileo Galilei could, for the first time, summon the Moon closer and inspect its surface. A whole new Moon emerged, a world unto itself with mountains, "seas," and innumerable pockmarks that astronomers called craters because of their resemblance to volcanic craters. The Moon became, for the first time, a place with features one could name: the lunar Apennines, the crater Tycho, the Sea of Tranquility.

Not long after scientists began to conquer distances, they began to conquer time as well. They recognized that underground layers of rock are like pages in Earth's geological history. The fossils in the rock told of earlier epochs of life on Earth. In the heavens, they found nebulas and galaxies, protostars and perhaps proto-solar systems in the process of formation, and they wondered whether these could offer a glimpse into an earlier era of our own solar system. Inevitably, irresistibly, they were drawn to speculate on the origin of species, of stars and planets, and of our own Moon.

"Men will always aspire to peer into the remote past to the utmost of their power," wrote George Howard Darwin, "and the fact that their success or failure cannot appreciably influence their life on earth will never deter them from such endeavors." Darwin should have known: his father, Charles Darwin, was the great evolutionary theorist who wrote *The Origin of Species*. George Darwin is not as familiar a name, to modern readers, as Charles. In George's day, though, he was one of the leading scientists in England, and in 1905 he followed in his father's footsteps to be knighted by England's monarch.

Darwin followed in his father's footsteps in another way. Beginning in 1878, he developed what might be called an evolutionary theory of the Moon, although it is more commonly called the "fission theory." Darwin argued that the Moon could have split off from proto-Earth when it was still a liquid body, flung off by Earth's rapid rotation and the action of the Sun's tides. After that it gradually moved outward over the aeons to its present position. Darwin's theory, which he arrived at by applying accepted physical principles about the action of tides, was the first scientific speculation about the origin of the Moon that treated it as a unique event, rather than an unremarkable part of an ongoing process of the formation of the solar system.

For a while George Darwin's idea reigned supreme, but by the 1930s more careful calculations of the tidal effects had thrown it into doubt. Two more theories arose to challenge it: the "capture theory," according to which the Moon was formed independently of Earth and subsequently captured by Earth's gravity; and the "coaccretion theory," which said that the Moon and Earth had formed together out of essentially the same raw materials. With so many theories and



George Howard Darwin (1845–1912), son of the famous naturalist Charles Darwin, proposed the "fission" theory for the origin of the Moon. He was also the world's foremost expert on the theory of tides, and proposed a theory of tidal friction to account for the Moon's gradual movement away from Earth. *Photograph courtesy of Cambridge University Library.*

so little hope for deciding among them, the whole problem of where the Moon came from became a bit of a nuisance to scientists.

Then, in October 1957, the Soviet Union launched *Sputnik I,* the first artificial satellite. Fewer than four years later, in April 1961, U.S. president John F. Kennedy made his famous public commitment to send men to the Moon and back before the end of the decade. Suddenly scientists had a real opportunity to get some hard answers about the Moon, if they could only get on board. It was by no means a certainty, in the beginning, that any science at all would be done on the Moon. The Moon mission could have been nothing more than a public relations stunt, as suggested in a 1962 news parody in the *New Yorker,* in which the Soviets send an orchestra to the Moon while the Americans are still struggling to get a rocket into orbit.

Two people were most responsible for making sure that science got on the lunar agenda. Harold Urey, who had won the Nobel Prize in chemistry in 1934 for his discovery of deuterium (a heavy isotope of hydrogen), was the first big-name scientist on the bandwagon, advocating Moon studies even before NASA was formed. He was passionately interested in the Moon's origin, loosely committed to the capture hypothesis but ardently committed to the idea that the Moon had started out cold, not hot, as Darwin had assumed.

Eugene Shoemaker, unlike Urey, had his greatest moment of glory still ahead of him: he would be remembered as one of the codiscoverers of Comet Shoemaker-Levy, which plunged suicidally into Jupiter's atmosphere in 1994 and spectacularly confirmed, in living color, the reality of collisions in the solar system. He also is the only person buried on the Moon: his ashes were carried there by the *Lunar Prospector* spacecraft, which crash-landed in 1999.

Shoemaker was a geologist and, if the truth be told, had little to say about the origin of the Moon. But he did have very strong beliefs about the origin of the craters—another hotly debated question in pre-Apollo days. Shoemaker believed that the great majority of craters had been created by the impact of meteorites on the Moon's surface. It was really by pursuing Shoemaker's theory to its logical conclusion that William Hartmann, a self-described "crater counter," came up in 1974 with the story of the Moon's origin that most planetary scientists accept today. But for readers who like a modicum of suspense, I will leave that story for a later chapter.

On Christmas Eve 1968, humans for the first time orbited in the gravitational field of a planet that was not their own. On television screens, viewers around the world could see the cratered surface of the Moon up close, blurry but huge, seemingly close enough to touch. As the broadcast from *Apollo 8* ended, astronauts William Anders, Jim Lovell, and Frank Borman read from Scripture:

"'In the beginning God created the heaven and the earth,'" intoned Anders's staticky voice. "'And the earth was without form, and void, and darkness was upon the face of the deep. And the spirit of God moved upon the face of the waters, and God said, Let there be light: and there was light. And God saw the light, that it was good: and God divided the light from the darkness.'"

On the television screen, the Moon glided by in ghostly silence. It was easy to imagine the Supreme Being riding in the capsule with Anders, gliding over the face of the Moon just as in Genesis, dividing the light from the darkness of outer space.

Lovell and Borman took turns reading from the first book of the Bible, detailing the second and third days of creation. They stopped before the fourth, when the Sun and the Moon were created; perhaps they knew that this part of the story was due for a revision. "'And God saw that it was good,'" concluded Borman. "And from the crew of *Apollo 8,* we close with good night, good luck, a Merry Christmas, and God bless all of you—all of you on the good Earth."

Though some people later criticized the astronauts for reading from a religious text, their Christmas Eve broadcast was one of the emotional high points of the Apollo missions. It was the only time they fully lived up to the grandeur that was expected of them. No other moment, save perhaps the actual landing of *Apollo 11,* quite matched the poignance of those three distant voices reading those ancient but familiar words over an ancient and incomprehensibly alien landscape.

What better text for the occasion than Genesis? It was, after all, genesis that we were after. The trip to the Moon was a trip as far back in time as we can go, to a land older than any on Earth. The astronauts on later missions were trained to look for "genesis rocks." The very top question on Apollo's scientific agenda, a question that scientists had debated for nearly a hundred years, was to determine how the Moon got there in the first place.

The quest to understand the Moon's origin was the only scientific goal that could rival the audacity of going to the Moon in the first place. Of course, the clues would be indirect; no one was around to record the Moon's creation on television. Science proceeds by analogies and by reproducible experiments—but there is only one Moon, and no laboratory will ever be large enough to produce another. Moreover, planet formation (which includes moon formation) isn't exactly the province of any one science. Geologists can tell how a rock forms, but they can do so only if a context for the rock—a planet—already exists. Physicists can track a planet's orbit for billions of years, but they cannot say where it started from or what it was before it was a planet. Chemists can work out a planet's composition as surely as they can identify the compounds in a scrambled egg; but they can't unscramble the egg and describe how it was put together. Astronomers understand more or less how stars are put together, but even they have never witnessed the birth of a moon.

It's no surprise, then, that the answer emerged slowly—too slowly for a restless public to sit around and wait for it. By the time the story of the Moon's birth finally came out, the last lunar lander had long since been put on exhibit in a museum, the last Saturn booster turned into a truly immense lawn sculpture, and the last Moon rock locked away in the Lunar Receiving Laboratory. When it finally appeared, the story was tucked away in astronomical journals that the public never reads. Perhaps the wonder is that it ever came out at all. The trail could have been too cold, the clues too spotty or too contradictory.

There is another reason why the mystery took a long time to solve, even after we had all the clues. Scientists, like most people, prefer to look at the small picture: to analyze a particular rock, to measure a particular isotope ratio, to estimate a particular age. It takes a certain amount of courage to step beyond one's day-to-day experiments and look at the big picture—and the origin of the Moon is a "big picture" question *par excellence.* Perhaps it makes sense that William Hartmann, one of the two scientists who unraveled the Moon's biggest mystery, is not only a scientist but also a part-time artist and science-fiction writer. It took someone with an artist's eye and a fiction writer's speculative temperament to see the big picture.

This is a book about that big picture: the origin of the Moon, as interpreted by Hartmann and Alastair Cameron, the second patriarch of "The Big Splat." It is also about a doomed planet called Theia, and a familiar one called Earth that used to look vastly different from today's Earth. But most of all, it is about a long lineage of intellectual voyagers who began exploring the Moon long before Neil Armstrong planted his boot into the lunar dust. The lineage contains some household names (at least to scientists): Galileo, who first brought the Moon within arm's reach, and Johannes Kepler, who always believed that Copernican astronomy would take us to the Moon. It also includes some less familiar names, such as George Darwin, who may be unjustly neglected now because their theories are no longer in fashion. And it includes a bevy of scientists of today, who are still struggling to put together sketchy clues into a coherent history of our celestial companion. Even though Hartmann and Cameron have given us a framework, many of the details of the story are still uncertain.

As the text chosen by the *Apollo 8* astronauts shows, the Moon has extraordinary cultural resonance for all of us; our arts and traditions and religions have all been inspired by millennia of Moon-watching. I have not written very much in this book about the mythology of the Moon, because I have a story to tell about the Moon as seen by science. However, I do not want to minimize in any way the importance of the Moon as a cultural symbol. It is unfortunate, I think, that we *didn't* send an orchestra to the Moon—or an artist, a poet, a filmmaker, or anyone who could translate the spiritual meaning of what we had done and where we had gone. We need Moon enthusiasts as well as Moon scientists. It is to them—to everyone who has felt their breath catch as they looked out the window at our impossibly beautiful neighbor in space—that I dedicate this book.