own. The end result is presented in the form of a fable, an amended version of Wednesday's tale from the Prologue. For those who wish to consult the technical papers used to compile this narrative, I have provided a list in the references at the back of the book.

Wednesday's Tale (Revised)

Once, a long time ago when the earth was quite young, a group of high mountains rose above the ocean, forming a large island. It was volcanic, somewhat like a Hawaiian island of today, for continents as we know them had not yet formed. Because of the height and extent of these mountains, and because of the prevailing wind and weather patterns, a variety of climate zones existed on the island.

Thunderstorms were frequent on the rainy side, where it was always cloudy. In the high altitudes, near the mountaintops, the rain froze, and the precipitation came down as snow or hail. The atmosphere was reducing, and these conditions favored the formation of hydrogen cyanide in the discharges. The rain and snow were rich in this chemical.

Large glaciers descended from the highest peaks. At their base, in the summer season, lay a number of partly frozen alkaline lakes. Hydrogen cyanide collected in them, and reacted with itself extensively, until the time came when the lakes froze solid in the winter. When warmer weather resumed, the lakes thawed in part and the reaction started again. In one very important year, however, spring did not return. The climate in the highlands had taken a turn for the worse. More snow fell at the mountaintops and the glaciers advanced, pushing the frozen lakes down the mountain. The flow path of one glacier led it away from the wetter side of the island toward a central plateau, which was geothermally active. In this more temperate climate the glacier tip melted, and the hydrogen cyanide reaction mixture flowed into a boiling acidic spring.

Such boiling springs exist today in areas like Yellowstone Park and Iceland. Bacteria, which belong to the same broad class as the methanogens, are able to grow there. In the early days that we are considering, of course, no life existed, but over the course of an hour the boiling acid converted a small amount (about 0.1 percent) of the solids that the glacier had brought into adenine. The acid would eventually also have destroyed the adenine, but before that could happen the spring waters flowed into a broader stream. In doing so, they passed over some alkaline soils which neutralized them.

It seldom rained in this broad plateau area, and when it did, it fell in the form of sunshowers, rather than thunderstorms. The rays of the sun caused formaldehyde, rather than hydrogen cyanide, to be formed. The formaldehyde rain flowed in tiny streams into a geologically different, but also geothermally active, part of the central plateau, which contained boiling neutral pools, thick with suspended minerals.

As each formaldehyde stream flowed into a boiling mineral pool it was converted into a complicated mixture by a process called the formose reaction. The sugar ribose formed a small part of this product. Moving waters carried the mixture down the length of the pool over the next several hours, allowing enough time for the change to be completed. At this point the product flowed out of the hot pool and was swept downstream by a rapid icy brook. This escape was fortunate, as the ribose would have decomposed if it had remained too long in the pool.

The adenine and ribose streams merged in the central plateau, but they could not yet form adenosine. They needed a hot environment and the presence of sea salt for that purpose. Happily, a precipitous waterfall took them almost to sea level, on the hot, dry side of the island. Time was of the essence, as the sugar was not stable and was being lost.

At the base of the waterfall, the stream widened to form a broad delta. The waters flowed over a variety of different types of rock and mineral formations. At some point they entered a tidal pool which had been cut off from the sea at low tide. Minerals lining the pool had a special affinity for both adenine and ribose, and retained them, while most of the other substances were swept away as the tide filled and drained the pool.

It was a very hot day. The sun evaporated the remaining water in the pool and heated the adenine and ribose in the presence of salt, converting them in part to the nucleoside adenosine. As this was happening, a violent storm occurred far out at sea, creating large waves.

The tides returned to the tidal pool in a rush, sweeping out its contents and transporting them farther inland. They were deposited in a nearby pond, which we name Darwin Pond. This was to be the chosen site for the origin of life.

No sooner had the adenosine reached Darwin Pond when successive waves, each flowing from a different direction, brought in supplies of the other nucleosides needed to make RNA. Had these chemicals only been human, they would have embraced at the joy of their first meeting, and in anticipation of the glorious future that lay ahead of them. They would then have taken turns, each describing the marvelous and different series of events that had led to its own creation. We must not inject our own feelings into the story, though. Let nature continue the synthesis.

Phosphate was needed for the conversion of nucleosides to nucleotides. Several geologists have contended that phosphate was not readily available on the early earth, and only increased in concentration in the waters gradually, as appropriate rocks weathered. Darwin Pond, however, was one of the few choice locations blessed with the right kind of mineral; it already had abundant phosphate. Thus, when the continuing heat wave evaporated the pond almost to dryness, the nucleosides were converted to nucleotides. This process was aided by an additional catalyst which was found in the minerals lining the pond.

The nucleotides now needed to combine, to form the replicator. This process was helped greatly by the presence of certain chemicals called amines which were brought in by another temporary flood. The amines would have been unwelcome earlier in our account, as they would have interfered with several earlier steps.

The climate now stabilized. Days were as hot as before, enough to dry up the pond. Each night, however, winds brought in enough moisture to form a thin liquid film at its bottom. These alternative periods of heat and moisture afforded the nucleotides a chance to come together in various ways and then to break apart again. One evening, by chance, the replicator was formed. It took charge immediately, assembling other nucleotides into copies of itself, more rapidly than they could come apart. Life had been created and evolution could begin.

Before ending this tale, we must comment on the name of the pond. Charles Darwin himself did not extend his theories to the question of the origin of life, and publicly identified himself with a belief in Creation. In 1863, in a private letter to the botanist Joseph Hooker, he wrote that "it is mere rubbish, thinking at present of the origin of life; one might as well think of the origin of matter." Yet he himself could not resist the temptation of playing with such rubbish, for he wrote in 1871, again to Hooker:

> It is often said that all the conditions for the first production of a living organism are now present, which could ever have been present. But if (and oh! what a big if!) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, lights, heat, electricity, etc. present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed.

This quote is often reproduced in texts and articles on the origin of life. Many workers would prefer to replace the word "protein" with "nucleic acid," as we have seen. Otherwise, it is remarkably current today, which is a tribute either to his foresight or to our lack of progress.

The Skeptic, who had looked ill earlier in the chapter, has recovered during the tale and is in fact rolling on the floor with laughter. He stops to ask how much of the tale I have composed and how much actually has been published in the scientific literature.

I respond that the very different reaction conditions have been published, as well as suggestions for appropriate prebiotic locations, such as the frozen pond, the boiling mineral pool, the tidal pool, and the dry, desertlike environment. I had to devise most of the transport to move the chemicals between locations. The glaciers and the separate rains of hydrogen cyanide and formaldehyde have also been published, however.

"It is very imaginative," he says, "but frankly, for a fairy tale, I prefer Father Raven."