GENESIS

One

1. Once upon a time, a man sat in front of his home just before sunset. It was a quiet evening, not a breath of wind, a magical time. An eggshell blue sky painted here and there with white clouds glowing pink from the setting sun, arced over him.
2. He immersed himself in watching the sunset, the changing colors, and the peacefulness settling on the Earth in the fading light.
3. Before long, his child came and sat beside him. Together they watched the blue shades and the fiery orange, pink and yellow colors fade into gray, dark blue and then darkness.
4. The child scooted closer to him. They sat quietly and watched. They shared a sense of awe at the majesty of the Earth and the sky around them, and there was a deep connection between them.
5. As the light faded, a star appeared in the deepening, dark blue sky. And then another. And another. By the time the light had faded completely, the sky was filled with stars, some bright, some faint, some lightly hued, millions of tiny twinkling lights.
6. And the man and his child thought it was good. "Isn't it beautiful?" whispered the child.
7. "Yes," murmured the father. A moment later, he said, "Our ancestors have sat as we sit and gazed in awe at it all. And they wondered whence it all came."

Two

1. Do you know where we came from, my child? It's a question that we humans have been asking for a long time. The story of our beginning, my child, the beginning of mankind, is long and more bizarre perhaps than anything you could imagine.
2. "Tell me, Father."
3. The Japanese believed that two great gods, Izanagi and Izanami, swirled the waters of the oceans and created the islands of Japan.[i] The Norsemen believed that fire melted ice, and the drops turned into humans.[ii] The American Indians believed that Mother Earth spawned people who came out of the ground.[iii] And, you may know that today, Christians and Muslims believe that a single god created heaven and Earth for us and that he then created us in his image.[iv] [v]
4. If you look at the many explanations of the origin of the world, my child, you will see that every people had their own and diverse beliefs. Some believed in many gods, some in a single god. Most people believed that their gods created the world.
5. Ancient people made up stories to explain things that they didn't understand. You will encounter many of these stories and beliefs as you grow up and meet other people. Many of them believe that their scriptures are word-for-word spoken by their gods.
6. You may read many of their stories and their scriptures. I found it fascinating to learn how people in history tried to explain things they didn't understand, like where the stars came from, where the Earth came from, and whence mankind came.
7. Today, though, scientists can explain where our universe came from. Scientists, thousands of them from all over the world, working hard over the last hundred and more years, have gathered evidence that our world, and not only our world, but our *universe* had a much different, and in some ways, even more bizarre beginning than those imagined by the Japanese, the Vikings, and the American Indians.
8. These worldwide scientists conducted experiments, they looked at evidence, at data, and they have been able to explain the origin of the universe. They dug in the ground, they examined fossils, they dissected living things and non-living things, they peered into space with telescopes, and they shared what they learned with other scientists so they could prove their findings.

9. Despite all that we have learned from science, my child, many people in the world still believe in the stories in the ancient scriptures that they were taught as small children. Many adults today still teach the stories in the scriptures as if they were truth.
10. But we have learned where we came from. We have learned how the universe began, we know where our Earth came from, and we know how we humans came to be. We even know how our Earth will end—when and how the world will end.
11. I want you to know these things, my child, because there are many people who will try to teach you the stories of the past as if they were true. I want you to be aware of what we have learned. I want you to understand what the thousands of scientists around the world have discovered. I want you to base your conclusions about the world around you on facts rather than other peoples' stories, beliefs, and myths.
12. "How can we know what is true, Father?" the child asked.
13. We gather data, my child. We gather from many different sources. We put our trust in evidence that is repeatable and verifiable.
14. I think it is important for you to understand this, my child, so that you will not be misled by the stories and myths that have been passed down from generation to generation by people all over the Earth. Those were stories created by ancient ancestors who did not understand the things we understand today.

Three

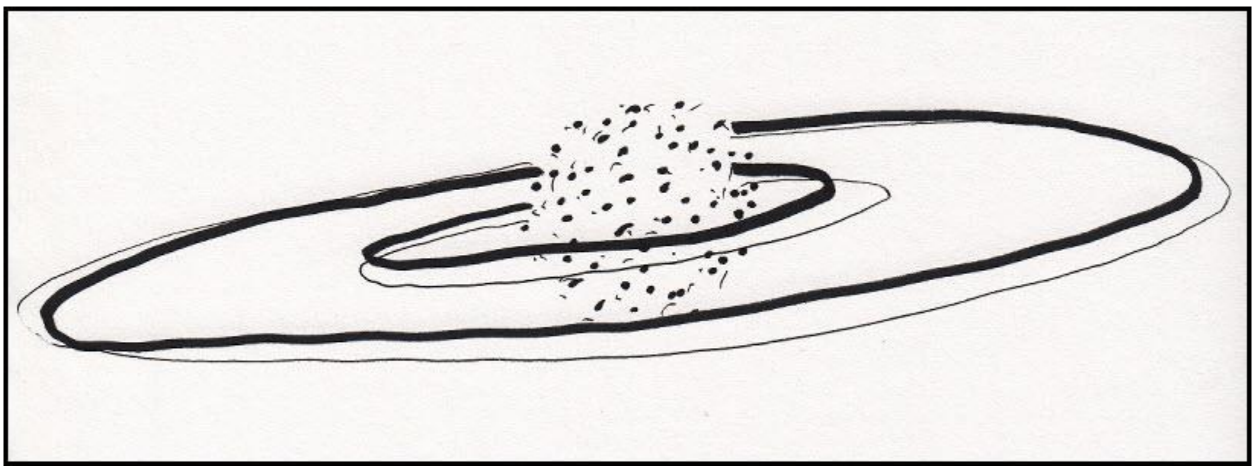
1. In the beginning, there was a Big Bang.[vi] [vii] All of the matter that we see and know of in our universe was so condensed and so very, very hot that it was a bubbling amorphous (shapeless) *plasma*.[viii] Plasma is like a thick hot soup or cooking oatmeal that boils and bubbles.
2. One of these bubbles expanded rapidly, very rapidly, faster than you and I can imagine, and then in a tiny fraction of a second, there was a huge, gigantic explosion--what we call the "Big Bang." Some say this was not an explosion as we normally think of one—emanating from one place—but arising all over the surface of this rapidly expanding bubble.[ix]
3. This expansion and then explosion, the Big Bang, marked the beginning of our universe and all that we see and cannot see in it.
4. The birth of our universe was great and terrible, explosive and violent, so explosive and so violent that it is beyond the minds of most people to comprehend. [x]
5. And so it was.
6. The Big Bang was a universe birthing from nothing, but not nothing really, a random occurrence in a plasma of energy and matter continuously annihilating one another, bubbling over and over again, here and there, until this particular bubble expanded and exploded.[xi] [xii] [xiii]
7. This was neither good nor bad, it just was.
8. This bubble and the huge explosion of it thrust hot matter outward in all directions and became all of the matter and energy in our entire universe.
9. "But what was there *before* the bubble, Father?"
10. What, if anything, was beyond and before the beginning makes no difference to us because it did not and could not affect time or space or anything in our universe as we know it because it did not exist.
11. But there *was* a beginning, a great and powerful beginning, in which matter and time and space as we know them were born. We know this because scientists tracking the stars observe that they continue to fly apart.[xiv]
12. The stars we see are moving farther and farther away from each other. If we go backward in time, the stars were closer and closer together until they were all in one place, the original bubble.

13. We think there may have been other bubbles as well. Maybe some of those bubbles bumped against ours. If they did, they would have left a circular residue where the bubbles touched. You have played with bubbles, yes/no? When two bubbles touch, there is a seam between them in the shape of a circle.
14. In 2015, scientists found the residue of what looks like the seam with another bubble that long, long ago was connected to our universe.[xv] Surely we shall learn more about this as we study it. What, if anything, including the bubbling plasma, was *before* the Big Bang, we do not know for sure. Scientists still debate the existence of these bubbles, but they agree on the explosion, the Big Bang.
15. We know that the Big Bang occurred about 13.8 billion years ago.[xvi] That is a very, very, long time ago, but we know from multiple sources that that is how long ago it was.
16. When in the beginning the plasma bubble exploded hot matter spewed outward in all directions. And there was no light; the universe was dark.[xvii]
17. And as the matter in the Big Bang began to spread out in all directions, it began to cool very slowly.
18. And as the matter began to cool, a complex series of events took place.
19. "Wow, I can't quite imagine an explosion that big, Father. It is almost too much to understand."
20. Yes, my child, yes, it is. If you only understand a little now, that's okay. Later if you read and study, you will understand more. But don't let your inability to understand it all at first deter you. Keep learning a little bit at a time.
21. Some people will use your inability to understand everything to confuse you. In the *Old Testament*, for example, it says that god's thoughts are higher than man's thoughts.[xviii] People use that as a way of explaining what they do not understand. They say, "Don't worry about it. God knows." But we *can* understand where the universe came from, and we have. We may have to study it and work on it, but bit by bit, we have understood—and so can you.

Four

1. The next night, the mother and her child sat together quietly at sunset.
2. Scientists, the mother said, have studied the light from the stars in the sky to understand the events your father told you about. Others have re-created some of these events on a small scale in their laboratories. Amazingly, we have learned a lot about what happened way back then at the beginning of our universe.
3. As the boiling mass of the Big Bang spread out and began to cool, tiny, tiny bits of matter began to come together. We call these tiny bits strange names like quarks, mesons, anti-quarks, positrons, gluons, and bosons.[xix] [xx]
4. The heat of the Big Bang was so intense that it took 400,000 years of expansion and cooling before the tiny quarks and gluons could stick together. Can you believe that? 400,000 years to cool that little bit.[xxi] [xxii] [xxiii]
1. Now, my child, I say 400,000 years, but there were no years then, no time as *we* experience it. There was only space and a kind of time. In 1910 and shortly thereafter, we learned that space and time were really one thing—*spacetime*. [xxiv] [xxv]
5. "What?"
6. Yes, I know, my child. It is confusing. But remember, learn slowly, one thing at a time. Is this weirder than giant gods swishing their spears in the sea and creating islands? The difference is that scientists all over the world have confirmed the discovery of spacetime. [xxvi] [xxvii] [xxviii]
7. We call all of the non-material universe *spacetime* because space and all that is in it and time as we know it are connected, connected in ways that our ancestors did not realize. For instance, the faster you go, the slower time becomes.
8. "Hmmm. Really?" Yes, really.

9. As the hot boiling plasma from the Big Bang spread out in all directions creating spacetime as it went, it gradually, very gradually began to cool.
10. The tiny bits of matter finally cooled enough so that they could stick together more and more, and eventually they formed the first parts of *atoms*.
11. Atoms are tiny chunks of matter that have two main parts, a center or core that we call a *nucleus* and a *shell* or shells of orbiting *electrons*. [xxix]
12. The nucleus of an atom has a positive electrical charge, and the shell or shells of electrons orbiting around the nucleus have a negative charge. So, the positive and negative electrical charges in an atom balance out.
13. As the universe continued to expand and cool, more and more bits of matter could stick together. These bits of matter grew and grew, larger and larger, like snowballs when you add more and more snow to them. Or a mud ball when you add more and more mud to it. Or a ball of dough when you make bread, and you add more and more dough to it, the dough ball gets bigger.
14. As the balls of matter got bigger and bigger, something we call *solar nebulae* formed.



Solar Nebula
Source: Hand drawn by author from multiple images including [xxx]

15. A solar nebula is a huge swirling flat cloud of space dust that collects a sphere or ball of matter at its center.
16. There were lots of these swirling clouds of space dust in spacetime. And the flying matter continued to swirl and collide with other bits of flying matter. These collisions created clouds and rings and the debris of space.
17. And the debris of space swirled, collided, and swirled more.
18. And there was no day and no night, only space and time. [xxxi]
19. Eventually, so much matter came together in each solar nebula that the weight of it caused the core of the ball of matter to grow hotter and hotter until it burst into an intense fire.
20. And there was light.
21. These burning globes are what we call *stars*. And light radiated outward from each of the stars. And the birth of the first stars, the beginning of light in the universe, occurred about 500 million years after the Big Bang. Scientists continue to seek and study the first light even today. [xxxii xxxiii xxxiv xxxv]
22. The matter in space continued to fly and collect and form more and more stars, and there was more and more light in the sky, light from hundreds of billions of stars.
23. On a clear night, away from cities, you can see millions of stars in the sky, each of them a burning inferno like our sun, each created by enormous pressure from a massive accumulation of matter.

24. The stars have been very important to us, my child. And not just to look at and wonder. They have helped us navigate around the world, but more importantly, much of what we see around us on Earth came from the death of ancient stars.
25. You see, stars die when they have burned up all of their fuel. And when stars die, they collapse and explode again, and the heat of these explosions created many of the heavier elements that we have here on Earth. [xxxvi]
26. The dust left over from those exploding stars billions of years ago eventually came together again elsewhere and formed planets like the Earth.
27. "What? What did you say, Mother?"
28. Yes, you and I and much of what we see around us came from stardust, the residue of exploding stars. Strange, yes? [xxxvii]
29. "Yes, Mother," the child said, "it's hard to take in."
30. We shall talk more of this. But for now, my child, understand that in the beginning there was a very hot bubble that inflated and blew up. When that explosion cooled down enough, bits of matter came together and formed stars. When those stars burned out, they exploded and created many of the elements that we are made of.
31. Bizarre, yes? But that is the broad story of where our universe came from. And we know this to be true. If you'd like to know a little more about the details of what happened in that Big Bang, we can sit tomorrow and talk some more. Would you like that?
32. "Thank you, Mother. I like sitting with you and talking about where we came from. I like learning from you."

Five

1. Last time, my child, we talked about the origin of the universe—bubble inflation (which we are still studying) and the Big Bang. We know quite a bit about that event, actually. Let's talk a little bit more about the Big Bang.[xxxviii] [xxxix]
2. Almost in the moment of the great explosion, 1/100th of a second afterward, the heat was so intense that none of the elements as we know them could exist.
3. You have seen fire, and you know that when things get very hot, the heat destroys them. Things burn or melt and eventually if there is enough heat, things disappear.
4. Heat, *temperature*, is a very important concept to understand. If you are too hot, you will die. If you are too cold, you will die.
5. "You won't let me die, will you Father?" the child asked.
6. Not if I can help it, my child. Not if I can help it.
7. Now, temperature affects the nature of things. We measure temperature in three different ways. People in the United States use the Fahrenheit scale, most other people use the Celsius scale, while scientists use the Kelvin scale. The Fahrenheit scale is based on the choices made by its German designer. The Celsius scale is based on the temperatures at which water freezes (0°) and boils (100°).
8. The Kelvin scale is based on absolute temperature. Absolute zero kelvin is the coldest possible temperature. At 0 K, all particles of matter lose energy and stop moving—the atoms and the quarks that make them up all stop moving. Zero Kelvin equals –459°F or –273°C.
9. Most matter has four different states depending on its temperature: solid, liquid, gas, and plasma. Every element has unique and different temperatures at which it changes from one state to another. Below certain temperatures, things become *solid*. Water, for example, below 32°F or 0°C becomes ice. Above that temperature, ice becomes liquid water. Iron is a solid until it reaches 2,800°F when it becomes a liquid.

10. Above certain other temperatures, things become *gasses.* Above 212°F or 100°C, for example, water boils and becomes a gas—steam.
11. At even higher, very, very high temperatures, things become *plasma*, the hot amorphous soup we talked about earlier. We never experience these temperatures, my child. They would kill us. Scientists sometimes create them in their experiments, but you and I will never see them.
12. In the Big Bang, the heat was enormous, a hundred thousand million degrees Celsius or 180,000,000,000,032°F! This was so hot that nothing like what we can see could exist. At that temperature, all matter was in plasma form. The tiny quarks were constantly forming and being obliterated into pure energy, back and forth, back and forth, because of all the heat. [xl]
13. The universe in that first second was also incredibly *dense*, 4 billion times as dense as water, millions of times denser than the hardest rock we know. [xli]
14. *Density* means packed in together—which makes things hard. As the universe began to expand and spread out, it became less dense.
15. So, my child, as I mentioned before, the expansion of the universe also caused it to begin to cool.
16. And it was the beginning of spacetime.
17. Fourteen seconds after the Big Bang, the temperature of the universe had fallen to about 3 billion degrees Celsius or 5,400,000,032°F. After three minutes of expansion, the temperature had fallen to 1 billion degrees Celsius or about 1,800,000,032°F, which is still very, very hot. [xlii]
18. At this temperature, the tiny particles were able to begin to come together, and the cores, the centers, of the basic elements began to form. The universe was still too hot, however, for electrons to hook onto the cores, so there were no atoms or elements yet.
19. After 400,000 years, do you remember, during which the universe was expanding and cooling rapidly, the temperature had cooled enough—to 3,000 K—for the quarks to stick together to form the *nuclei* or centers of atoms and for electrons to begin to attach to the outer shells of those nuclei. When electrons began attaching themselves to the nuclei, the simplest elements were born.
20. And this was good.
21. The simplest and lightest element to form was *hydrogen*. Hydrogen has one proton in its nucleus and one electron in its shell. Hydrogen is the most common element we know; it makes up about 75% of the universe. At the temperatures in which we live, hydrogen is a colorless, highly combustible gas. That means it burns and explodes easily. [xliii]
22. And there was no light in the universe yet—that is, light that humans could see. The universe was dark from a human point of view.
23. As the universe continued to cool, helium was the second element able to form. It has *two* protons and *two* electrons. Helium is the second most common element in the universe making up about 24% of the mass in the universe. [xliv]
24. "But where were we, Father?" the child asked.
25. We humans were not yet, my child. In fact, there wasn't even an Earth yet. Shall we talk some more tomorrow?
26. "Please!"

Six

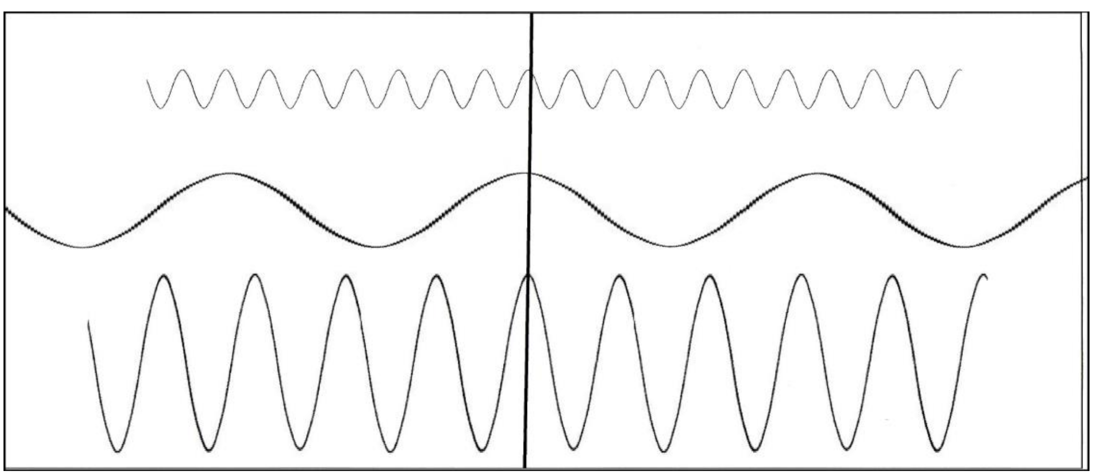
1. When you look around you, my child, you know that most people can see. You can see because of light and our bodies' reactions to light.
2. When the stars formed, about 560 million years after the Big Bang, the pressure created by their size or mass forced hydrogen atoms to fuse together to become a new element—helium. That process released great amounts of energy into the universe. Some of this energy was in the form of light.

3. The stars created light for the first time in the universe. So there was light, enormous amounts of light, HUGE amounts of light in the universe.
4. And it was good. It was good because this light has allowed us to see and to study the origin of the universe. Light allows plants to grow. Light is essential for the kind of life we know.
5. Did you know that light is actually a tiny massless particle that we call a *photon*? When the stars formed and the hydrogen fusion took place inside them, the transformation of hydrogen into helium created a thousand million photons for every tiny nuclear particle. [xlv]
6. And light, billions and billions of photons, began to stream outward at an incredible speed—186,000 miles per second or 670 million miles per hour or 1,079,252,848 kilometers per hour. This is the speed of light. It is a very important number, my child. A number you should remember. It is one of the few constant things in the world. Light always travels at 186,000 miles or 299,337,984 kilometers per second.[xlvi]
7. And this light from the stars has been traveling outward that fast for over 14 billion years since the beginning of the universe!
8. Even stranger to us, my child, the father said, is that what we see and all of the things around us make up less than 5% of all the matter in the universe. Most people have a hard time understanding this, but we know it to be true.[xlvii] More of that in a while.

Seven

1. Remember, my child, how the stars formed? The super-heated matter streaking outward from the Big Bang cooled at different rates and began to coalesce and adhere here and there. These clumps continued to grow.
2. “How did the clumps grow, Father?”
3. Hmmm, why do things clump together? It’s a very important question. The first answer has to do with *gravity*.
4. Gravity is what keeps you here beside me. Gravity is what pulls you back down to the Earth when you jump. [xlviii]
5. You see, as it turns out, there are only four forces that we know of in the universe, only *four*. *Gravity* is one of those, and along with light, the most obvious. [xlix] [l]
6. Gravity is the attraction between objects. The larger an object is, the more gravity it has—the more it attracts other things. If it weren’t for gravity, we would fly off of the Earth. Although when you try to jump, gravity may seem like a strong force, it actually is relatively weak compared with the other forces.
7. The second force is the *electro-magnetic* force.[li] The electromagnetic force radiates in waves, like when you throw a stone in a pond. Remember when you do that how the waves radiate outward in all directions? Electromagnetic waves do that, too, in all directions.
8. Electromagnetic waves have a magnetic force and an electric force that are inseparable and arranged at right angles to each other.
9. Light is an electromagnetic wave, and as you already know, it radiates across space. Light is made up of tiny, tiny little packets called *photons*, remember? [lii]
10. “But, Father! The light doesn’t look like it has waves!” said the child.
11. That’s right, my child. The waves are very small, and they are traveling so fast you cannot see them with your naked eye. But scientists can see them with their instruments.
12. Every day we can see the sun; that is, the light, the photons, from the sun hits our eyes, and we see.
13. The Sun is burning hydrogen at a very high temperature, and that burning sends off energy in the form of electromagnetic waves, some of which are light. Those electromagnetic waves send us light and heat and, yes, they even cause us to get sunburned if we stay out in the sun too long.

14. We know that we cannot look at the sun because those waves can burn our eyes and make us blind. You know not to look directly at the sun, yes/no? [liii]
15. "Yes, Father. I know that."
16. Good. Interestingly, most of those electromagnetic waves we cannot see.
17. But "electromagnetic" is such a long word, let's call them EM waves for short, okay?
18. Remember that EM waves all travel at the speed of light—which is also an EM wave. Nothing we know of can travel faster than the speed of EM waves.
19. Scientists have created machines called *particle accelerators* that make particles travel very fast, almost to the speed of light. They use these machines, some 30,000 of them, to study the tiny particles like quarks and bosons. [liv]
20. EM waves can be very, very short and very, very long. We give different names to EM waves depending on how long they are.
21. Radio waves, for example, can be as short as one millimeter or as long as several hundred meters. These waves carry the information we listen to over the radios.
22. Then, there are the visible light waves. Some shorter waves we call *X-rays.* And the shortest waves we know of we call *gamma rays*. [lv]
23. Scientists can count the number of waves that pass a given point in a second. Since they are all traveling at the same speed, the shorter the wave is, the more waves will pass that point per second. We call that number the wave's *frequency.* The shorter the wave, the higher the frequency, that is, the number of waves that go by.
24. A German scientist, Heinrich Hertz, was the first man to count EM waves, so we call the number of waves that pass in a second a *hertz* in his honor. [lvi]
25. So, 10 hertz means ten waves pass any single point in a second, but because waves travel so fast, most waves have a much higher frequency.



Sine Wave Representation of Electromagnetic Waves
Source: Created by the author.

26. Long radio waves may have a frequency as low as 3,000 per second or 3 *kilohertz*. A radio wave 300 millimeters long has a frequency of 1,000,000,000 or one billion, what we call one *gigahertz*.
27. The EM waves that we can see we call *light* or the visible color spectrum. [lvii]
28. Our eyes can detect waves between 430 trillion hertz, which we see as red, and 750 trillion hertz, which we see as violet. You know that some people are colorblind; their eyes cannot detect the differences between these wavelengths.

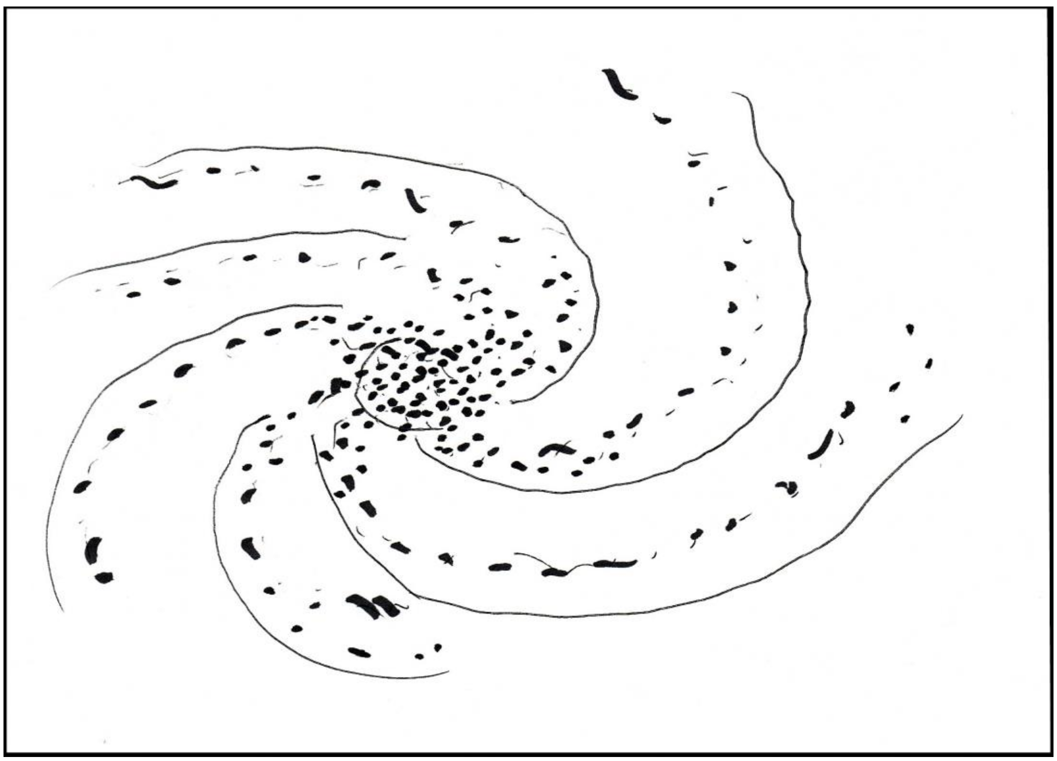
29. But think about it: *730 trillion* waves of photons go by every second! That's 730,000,000,000,000 waves every second! The color band of EM waves, the range of light waves, is very, very, VERY short. [lviii] [lix]
30. You know that waves in a pond or a river or on the sea can be small or large, and that big waves can be very powerful. This is true of EM waves, too. The *taller* the wave, the more energy it has. We call a wave's height its *amplitude*. The more power a wave has, the taller it is.
31. The third force we call the *strong force*. The *strong force* is what holds tiny pieces of atoms together. The strong force is 137 times stronger than EM waves, and as much as 1,000 times stronger than gravity.[lx] The strong force is very short, though; it doesn't reach very far. In fact, the strong force has a very, very short reach. The strong force is so strong, though, that when we disturb it, we get huge releases of energy, forces as we see in atom bombs and hydrogen bombs. [lxi]
32. The *weak force*, like the strong force, has a very short reach, but it is millions of times weaker than the strong force. The weak force is what causes some minerals or elements to glow in the dark. The weak force is what causes natural radioactivity. [lxii]
33. These, my child, are the only four forces in the universe: gravity, electromagnetic waves, the strong force, and the weak force.
34. As the universe expanded and cooled after the Big Bang, bits of matter began to accrete, or come together, first because of the strong force that created protons and neutrons, and then later because of gravity.

Eight

1. So, gravity, my child, is very important. When bits of matter came close enough to other bits of matter, gravity would pull them together, and they would clump. The larger these orbs, these balls, became, the stronger their gravitational pull became and the more matter they attracted.
2. If an orb collected enough matter and grew dense enough, its core might grow so hot with the pressure caused by all that weight that it would burst into combustion. These burning orbs began to consume the fuels of which they were made, but their mass was so large that they might burn spontaneously for eons.
3. Do you remember what we call them?
4. "Stars?"
5. Yes! Stars! We call them *stars*. Good for you!
6. Medium-sized stars, my child, like our Sun, are big enough that the gravity that holds them together is strong enough to create a fusion fire at their cores.
7. At that core, the pressure and heat are so intense that hydrogen atoms are forced together or *fused* into helium atoms, and when that happens, lots of energy including billions of light photons are released.
8. These photons bounce around *inside* our Sun for a long time—until they reach the surface, and then they streak away into space. It can take tens of thousands of years, even a million years, for a photon to get to the surface of the Sun. Isn't that amazing? [lxiii]
9. The Sun and all of the stars are boiling masses, fusion engines, burning vast amounts of hydrogen as the pressure of gravity presses inward, and the pressure of the fusion explosions push outward in a violent balance.
10. When a star is much larger, about 200 or more times larger than our Sun, the pressure at the core is much higher, and the burning is much more intense. [lxiv]
11. In these giant stars, the hydrogen is burned much faster and, before long, the pressure of the gravity of these larger stars presses inward and creates heavier and heavier elements.
12. When these heavier stars begin to create *iron*, they are doomed to die, because iron consumes energy and will not combust.

13. Iron has 26 protons and 30 neutrons in its nucleus, and 26 electrons in its shells. Iron is the most common element inside the Earth, my child. [lxv]
14. But wait a minute! How did iron get into the Earth?
15. Iron is important to stars because once a giant star gets so hot that it begins to make iron, it will compress very rapidly and then explode violently. The explosion of a giant star is the most powerful explosion in all of the universe after the Big Bang, something we call a *supernova*.
16. The power and force of supernovae are so large that they create all of the elements that we know of. For instance, gold, silver, and platinum—all of these heavier and rarer elements, *all* of them—come from the explosions of ancient supernovae that then spewed their remains out into space.[lxvi]
17. As this residue from the supernovae flew into space, some of it was attracted to other matter by gravity.
18. All around these stars, other bits of matter were flying by, some so fast that their speed overcame gravity, and they flew away from the stars. Some of the matter began to circle the stars in large clouds; other balls of matter had just enough mass that they began to circle the stars.
19. Stars, then, have many objects orbiting around them, objects like planets, comets, asteroids, and other bits of matter.
20. Are you with me, my child?
21. “Yes, Father. Space dust was circling the stars.”
22. Yes!
23. “But, Father! Where did *our Earth* come from?”
24. Good question, my child. In one tiny, tiny part of the seeming void of space, about 10 billion of our years after the Big Bang, the gravity of a medium-sized star, our Sun, had twisted the flight paths of bits of dust, gas, and rock enough that, over time, these coalesced into several flying orbs, which slowly settled into orbits around the Sun. We have evidence that this was a very violent and lengthy process. [lxvii]
25. Most of these orbits were circular in nature, some were somewhat elliptical, like a squashed circle, the shape of an egg.
26. We call our Sun and all of the things that revolve around it our *solar system*. [lxviii]
27. Have you learned in school yet, my child, that in our Solar System we have many *planets* including Mercury, Venus, our very own Earth, Mars, an asteroid belt, Jupiter, Saturn, Uranus, Neptune, and a collection of smaller planets, comets, and meteors? [lxix]
28. “Not yet, Father.”
29. Well, Mercury is close to the Sun and very, very hot. Venus is the bright evening star we often see after dusk. Venus is covered with hot gasses. Let’s watch for it tomorrow night, okay?
30. “Yes! I’d like that.”
31. Mars looks red in the sky as if it is angry. Jupiter is a huge planet, much larger than Earth. Saturn has rings of gas around it. Uranus, Neptune, and tiny Pluto are way, way out in the outer reaches of the Sun’s gravity field.
32. “Can I see Mars, Father?”
33. Yes, you can. You just have to know where to look. Some of our smartphones today have programs that can find the stars and planets for you! Isn’t that cool?[lxx]
34. But only Earth so far as we know has sustained life in our Solar System. Scientists have discovered more than 2,000 planets in other solar systems thousands of light years away.[lxxi]
35. “Really? Is there life on those planets, Father?”
36. Who knows if life has spawned there as well? Scientists are looking at those planets all the time. We do know now that there was water on Mars at one point. [lxxii]
37. The planets in our solar system revolve around the Sun. The Earth is 93 million miles from the Sun. It takes sunlight about 8 minutes and 20 seconds to travel from the surface of the Sun to Earth. [lxxiii]

38. And as planets revolve around the Sun, many of the planets have moons that revolve around them. Earth, as you know, has one moon. Can you see it?
39. “There it is!” Yes, there it is.
40. Jupiter, a huge planet, has 67 moons! One of them, Ganymede, also has water on it. [lxxiv]
41. On a clear night, my child, you can see what looks like a river of stars in our sky. We call this the Milky Way because it casts a whitish swath across the sky. [lxxv]
42. “Can we see it tonight?”
43. Yes, we can. This swath of stars in the sky, the Milky Way, is a huge spiral disk of stars seen on edge. Our Sun is one of those stars. This huge disk is shaped like a spiral, flattened with trailing arms as it spins around. Imagine looking at a dinner plate from the edge. You cannot see the whole plate, just an edge-wise slice of it. That’s the Milky Way!
44. We call these huge spiral disks of stars *galaxies*. We can’t see other galaxies clearly without a telescope, but we can see our galaxy because we are in the middle of it. Well, not really in the middle of it, on an outer edge more.



Spiral Galaxy
Source: Hand drawn by author after viewing multiple sources including [lxxvi]

45. Using telescopes, we can tell that there may be as many as a *hundred billion* stars in our galaxy alone and as many as a hundred billion galaxies in the universe! [lxxvii] [lxxviii]
46. Sooo many stars in sooo many galaxies. It is hard to comprehend.
47. “Yes, it is! Like all the grains of sand?”
48. Yes, my child, like all the grains of sand.
49. But you know what? Each human, yes, even you, has a hundred billion brain cells in your brain. Did you know that? You have as many brain cells in your brain as there are stars in the Milky Way. [lxxix]
50. For thousands of years, people have looked at the sky and wondered what those little points of light were and where they came from. And more, where *they themselves* came from.

51. And now you can begin to understand the story, this song of mankind, in a way that our distant forefathers could not.
52. You know now where the universe came from and where our solar system came from.

Nine

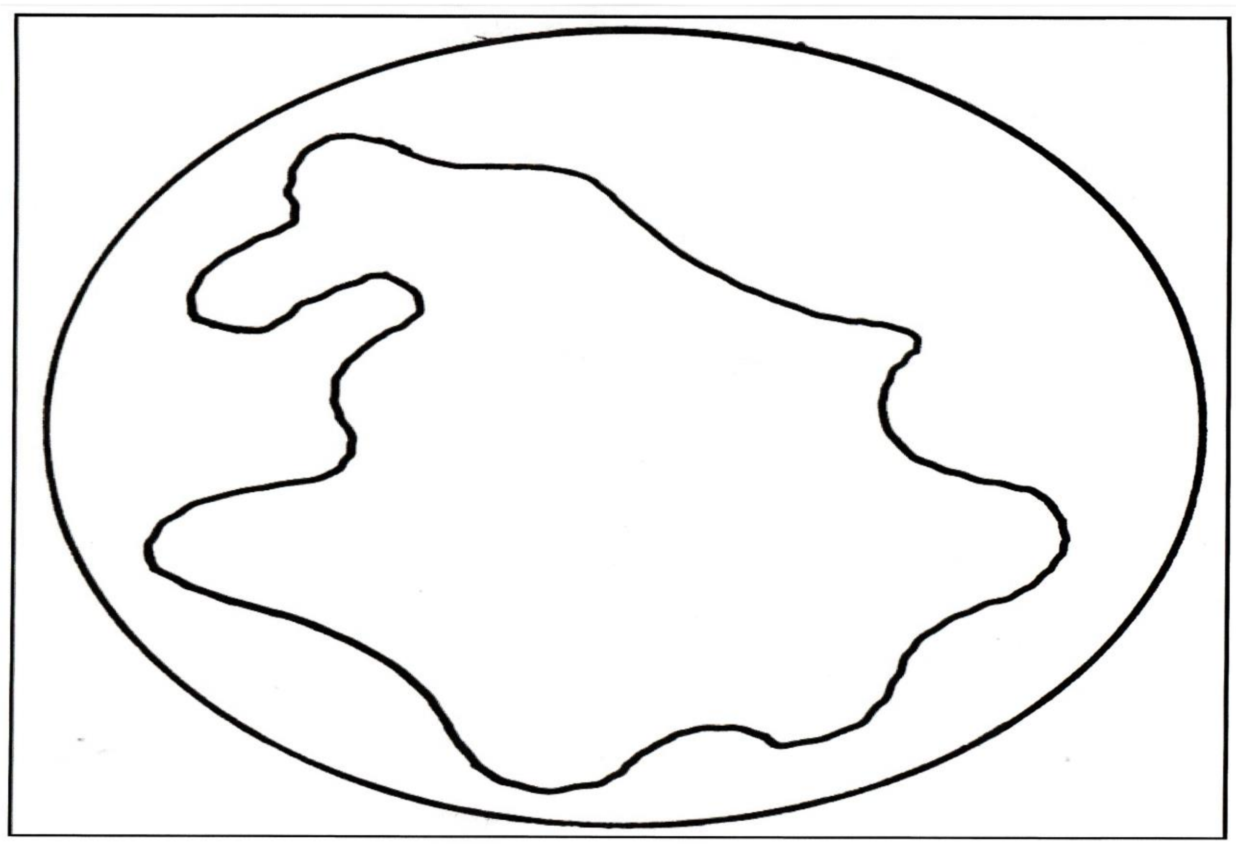
2. You know, my child, that light radiated from the stars. Close to the stars there was much light. And the light spread outward in waves so that the farther away from the star you got, the less light there was and the more it seemed like one huge empty space. Far away from the stars there was little light and the void was, to man, terribly cold and barren.
3. This void we call *space*.
4. Strangely, my child, we are learning that space is not empty. It only seems empty to us.
5. "It does *look* empty, Mother!"
6. Yes, it does. The nearest star, for example, is over four light years away. That is a long, long way.
7. "What is a light year?"
8. A *light year* is the distance a photon of light can travel in a year. Remember, light always travels at the same speed, 670 million miles an hour or 1.1 billion kilometers. So one light year would be 5.9 trillion miles or 9.9 trillion kilometers! That's 5,880,000,000,000 miles! [lxxx]
9. The nearest star, Alpha Centauri, which is actually three stars revolving around each other, by the way, would be about 25 trillion miles or 40 trillion kilometers away! [lxxxi]
10. Can one even understand such a large number?
11. But where is this star, Alpha Centauri? Does it have a "place?"
12. "Of course, Mother, it is up there!"
13. Of course, you say. I am here, you are there, and the star is out there!
14. Ah! Wait a minute, my child. Hold on to your brain, now.
15. Scientists struggle with the concept of place. The problem is how does gravity connect two things? There is no string. No rubber band, nothing we can see. Somehow, one mass attracts another mass across "empty" space. How does that happen?
16. One of the things that scientists continue to struggle with is the issue of *nonlocality*. This means that some things seem to be affected by other things that are not near them. In other words, if you want to throw a rock, you have to pick it up and throw it. When you pick the rock up, you are *local* to it; you are touching it. [lxxxii]
17. What if you could make the rock move without being near it? What if you could just think it and the rock would move? This action would demonstrate the dilemma of *nonlocality* because you are not near the rock nor are you attached to it in any way.
18. Scientists have found several strange, even spooky, things or what we call *phenomena* in the world where it seems that nonlocality reigns.
19. This phenomenon seems like magic. How can something be affected by something with which it is not connected? No touching, no string, no medium like water in between? How can that be? Scientists continue to wrestle with this dilemma.
20. They are trying to figure out how something can affect something that is millions of miles away. Like the distance between our Sun and the Earth.
21. And in 2015, scientists discovered gravitational waves, waves that pass right through bodies of matter. These gravity waves are what connect distant bodies and allow the force of gravity to affect two different bodies. This discovery confirms much of the Theory of Relativity and the nature of spacetime. [lxxxiii] [lxxxiv]

22. Maybe someday, my child, you will study problems like this.
23. For now, though, let's turn our attention to the Earth.

Ten

1. Stomp your foot on the ground, my child.
2. "Why would I do that?"
3. Just try it.
4. It feels really solid, yes? Do you remember that the Earth is a big ball, what we call a *sphere*?
5. "Of course. Everyone knows that!"
6. Hmmm. Maybe. We didn't used to. Most people used to think the Earth was flat. Or the back of a huge turtle! Anyway, the Earth is a big ball or sphere 7,917 miles or 12,741 kilometers straight through to the other side. *That* is a big ball! [lxxxv] [lxxxvi]
7. "Yes, it is!"
8. On Earth, the heavier elements began to collect into a clump while the lighter elements remained more on the surface. There was much hydrogen and carbon. As the orb that would become the Earth collected more and more detritus or debris from space and grew larger, the core of the planet grew very hot from the pressure of gravity and of the material compressing on itself, so hot, over 1,000°F, that the rock melted and became liquid.
9. You know that matter goes from solid to liquid when it reaches a certain temperature. And you know that if the Earth had collected enough matter, as much as the Sun, the weight of all that mass would have caused hydrogen combustion.
10. But the Earth did not collect that much matter, so the weight of the Earth only created as much heat as would melt the inner materials.
11. And nine billion years had passed since the Big Bang. [lxxxvii]
12. At some point, while the Earth was collecting by gravity more and more material from space around it, a large object hit the Earth and caused a huge explosion. Large pieces of the Earth flew into space, but not far enough to escape the Earth's gravitational pull. Some of those pieces also clumped together by gravity and became our Moon. [lxxxviii]
13. Meanwhile, the Earth developed several layers, four layers actually, like an onion. At its middle, the Earth has a solid, very, very dense inner core about 1,500 miles across. [lxxxix]
14. Next, comes a liquid outer core made mostly of iron and nickel that extends outward from the center another 1,400 miles. As the Earth formed, and the pressure and heat caused the by the weight of the material gathering plus the heat caused by the radioactive decay of the weak force liquefied the matter, the heavier elements iron and nickel sank to the middle. Iron doesn't melt until it reaches 2,800°F or 1,538°C.
15. We think that the liquid iron has created giant crystals extending north and south deep inside the Earth. [xc]
16. The third layer from the center is the *mantle*, the thickest layer in the Earth. The mantle is about 1,800 miles thick. The mantle is dense and hot, but not really liquid. Rather it is what we call *ductile*, that is, it flows very slowly, kind of like very thick mud. This liquid outer core is twisting and curling as the Earth spins on its axis.
17. The heat at the innermost area of the mantle causes the lower mantle to move outward toward the outer mantle. When the lower mantle material rises, it gradually cools and then wants to sink, so there is a kind of circular motion to the mantle as it rises and falls. We call this heat-generated circular motion *convection*. This motion causes the layers above it to crack and move about slowly. [xci]

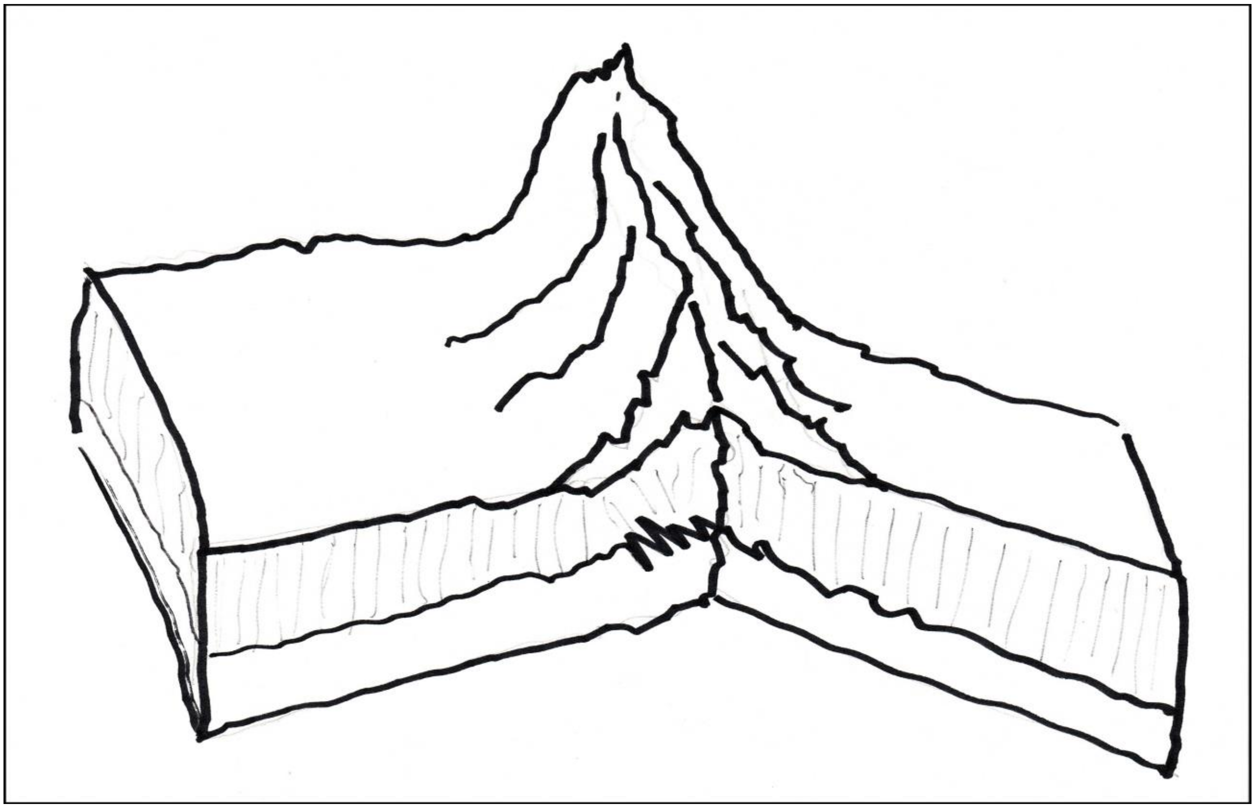
18. The fourth layer is the Earth's crust, which is anywhere from 3 to 44 miles thick. Some of the crust lies beneath the oceans while other parts of it are above the oceans and form the land that we can see.
19. Since the Earth was spinning, the liquid outer core and the hot, ductile mantle was moving, too. This movement and the heat pushes up on the Earth's crust, and sometimes this made, and still makes, cracks in the Earth's crust.
20. "Cracks? Really? Will the Earth break?"
21. No, the Earth won't break, my child. But from time to time, the hot molten rock at the core of the planet bursts or oozes out between cracks in the outer surface, or crust.
22. When the hot molten rock, what we call *lava*, bursts out, we have volcanic eruptions. When it oozes out, we have lava flows.
23. The cracks in the Earth's surface created huge plates or sections of the Earth's crust that move a little. We call these *tectonic plates*. [xcii]
24. These plates have been moving very slowly ever since the Earth formed.
25. Early in the life of the Earth, about 2.5 billion years ago, all of the visible land was in one place, not like it is now. We call the land at that time the supercontinent *Rodinia*. [xciii]



The First Supercontinent Rodinia
Source: Hand drawn by the author after viewing multiple sources including [xciv]

26. "Rodinia? Hmmm. Where is it now?"
27. Well, over time, a long time, Rodinia split up and spread out in pieces, these tectonic plates. We can see the boundaries between these plates today, the cracks, where volcanoes still erupt from time to time and where the hot liquid rock from deep inside the Earth flows up and out.

28. The pressure as these plates push against each other has formed mountains, cliffs, valleys, and wrinkles of all kinds on the surface of the planet.
29. “Really? The mountains are large wrinkles?”
30. Yes, my child, yes they are. Wrinkles where these tectonic plates are slowly crashing into each other.



Tectonic Plates pushing up mountains
Source: Hand drawn by the author after viewing multiple sources including [xcv]

31. “Where did the oceans come from?”
32. Great question! Scientists wrestled with this for a long time. Recent research confirms though that when the Earth formed there was water in the mix. There was some water added later, no doubt, from ice-laden meteorites that struck the Earth. [xcvi]
33. There was water on the Earth, lots of water, covering the surface of most of the planet.
34. When the volcanoes and lava flows erupted along the tectonic fault lines or cracks, gasses spewed into the air. The gravity of the Earth kept the gasses from flying away, so gradually the Earth acquired an atmosphere, a layer of air.
35. Sometimes, comets or asteroids would hit the Earth, and those crashes would send huge clouds of dust and dirt and matter into the air.
36. The particles in the clouds would fall back to Earth while the gravity of the Earth kept the lighter elements in the atmosphere. Over thousands of years, the clouds settled down.
37. The water in the oceans evaporated, formed clouds, and the clouds moved and dropped rain, and the rain seeped into the Earth and formed streams and rivers and flowed into the oceans where it evaporated again. This process is the Earth’s water cycle.

38. The water cycle of the Earth was good. It fed the land; it seeped into the land, and it allowed things to grow. And who is to say it was good or bad, it just was. But the water was essential for the future development of life, so we can say it was good.

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