Cosmic Chemistry: Planetary Diversity

How Did All of This Get Here?

APPENDIX B

INTRODUCTION

One of the unique things about humans (perhaps the only unique thing about humans compared to other animals) seems to be our persistent need to explain why things occur. As far as we can tell, small groups of dogs don't sit around and speculate on why the sun always rises in the east, or why heat and light come from the sun, or whether or not the planets are different from each other and are different from stars. Apparently neither do small groups of chimpanzees discuss the nature of the plants found in their habitats nor the factors that cause these plants to grow the way they do. The evidence that humans engage in these types of speculations is all around us, in our religious, sociological, psychological, philosophical, scientific, and other types of literature.

For most of human history it has been held that supernatural forces are responsible for the causes of natural events. Thus, the explanations of how our world arose and operates were found mostly in the religious literature of a particular culture. The view that a given culture developed about the relationship between the deities and members of the culture is mirrored in the view that developed about the relationship between the deities and the rest of the natural world. Even though humans are different from other forms of life, we still are part of the natural order of things. Four additional companion ideas seem to be embedded in the concept that the natural world was formed by the creative act of a supernatural force.

1) There is a great deal of order in the natural world, and the existence of this order is a testimony to the power and magnificence of the deity or deities who created the natural world.
2) There is purpose in nature. Things happen the way that they do because that is the will of divine creator.
3) Uncovering the essence of the "order" and "purpose" in the natural world will help to reveal the true nature of the creator(s). The order in nature is perceived as recurring patterns of objects, actions, and so on.
4) The deity or deities possessing the supernatural forces of creation do not normally reside with humans. They may come for visits now and then and share certain types of knowledge (such as how to domesticate animals and plants, how to use herbal medicines for various afflictions, etc.), but their primary residence is at some other place. More often than not, that residence is among the heavenly bodies.

The assumption that natural forces, rather than supernatural forces, formed the world and universe is the hallmark of the scientific explanations. Even in scientific explanations there is a great deal of order in the natural world, and the natural forces operate among us, and not from a distant residence. Furthermore, the natural forces, like the supernatural forces, act to control events occurring in the natural world today, and these actions are extensions of the events that occurred at the time of creation. The first known utterance of a concept that natural (rather than supernatural) forces are responsible for changes occurring the world, at least in western civilizations, can be attributed to the Greek natural philosophers (circa 600 BC–200 BC). In most of their conceptions, there is a substantial difference between the heavenly realm and the Earthly, with the latter being a corruption of one sort or another of the former.

Notice that many of the characteristics of religious explanations are maintained in scientific explanations, and in many instances the only difference is the nature of the forces involved. Are these shared characteristics a reflection of the nature of the universe, or are they manifestations of the assumptions behind our explanations of that universe? The answer to this question is not trivial.

ANCIENT CIVILIZATIONS

Several large civilizations with sophisticated cultures emerged in the fertile basins of great rivers and formed highly complex societies by circa 4,000 BC. The two cultures that had the greatest influence on the development of western thought were those of Egypt and of Mesopotamia. Egypt began (>4,000 BC) as two civilizations (Upper and Lower Egypt) that were distributed

along the length of the Nile River. The New Kingdom of Egypt ended around 1090 BC. Thus, this civilization developed and existed for almost 3,000 years. The Nile flows northward into the Mediterranean Sea. The flood plain of the Nile provided extensive amounts of rich, fertile soil to support agricultural practices. Even if the Nile did flood each year, it was worth farming in the flood plain. Agricultural productivity supported large numbers of people who were not directly involved in raising crops, and they could assume specialized tasks in the civilization (much as we do today). The Egyptians developed extensive knowledge of geometry and mathematics, so it is not surprising that they were very good engineers. The early Egyptians made astronomical observations and noted that the annual flooding of the Nile coincided, more or less, with the rising of the brightest star in the sky (Sothis). These, and other astronomical observations, were used to anticipate events and to guide the solutions to problems.

There is no indication that the early Egyptians attempted to offer explanations, other than mythical poetic, for the movements of the heavenly bodies. An early Egyptian conception was that the universe is a rectangular box. The Earth is slightly concave and sits at the bottom of the box. The sky is the top of the box, and it is supported by the peaks of four mountains located at the corners of the flat Earth. A river flows around the Earth, and carries the boat of the sun god. There was a belief that the universe came into existence from the primordial chaos of the waters, and that the heavens, Earth, and other natural objects and forces were personalized as gods. Nut, the sky goddess, arched over the flat earth with her four limbs supporting her. Shu, god of air, lifted Nut with his two hands. Nut gives birth to the stars every evening. In some depictions of Nut, astronomical tables of star risings are tattooed on her body. There apparently were no attempts (other than mythological) to explain the motion of the heavenly bodies, even though accurate observations were made.

Mesopotamia was settled first by the Sumerians, again some time before 4,000 BC. By 4,000 BC they had developed large-scale agriculture and had begun making detailed observations of the heavenly bodies. The Sumerians were conquered by Hamurabi (1728–1686 BC) who moved the capital to Babylon. Thus, the civilization came to be known as the Babylonians. In the 7th century BC, the empire was consolidated under the Assyrians, who later gave way to the Chaldeans. For the Sumerians, the Earth and the heavens were two flat disks supported by water. Later on, the heavens came to be viewed as a hemispherical vault resting on the water that surrounded the flat disk of the Earth. Above the heavenly vault was more water, and the dwelling places of the gods were located about that water. They believed that the sun and the heavenly bodies were gods who emerged from their dwelling places daily and traced a specific orbit over the immovable vault. The gods controlled events on the Earth. Initially this control was over the fate of the kingdom and the king, but in later conceptions the gods controlled the daily lives of everyone. Thus, observing the heavenly bodies was a mechanism of predicting the actions of the gods. In Chaldean times, this perspective lead to the beginnings of astrology.

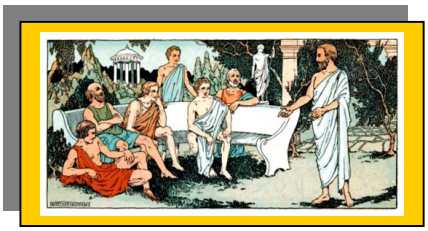
The Mesopotamian cultures developed mathematics to a higher level than did the Egyptians. The latter concentrated on geometric developments. Some of the Mesopotamian observations of Venus are quite remarkable for their accuracy, by contemporary standards. They accurately estimated the synodic period of Venus and of Mercury (to within 5 days). The reason for collecting all of these data was to predict the activities of the gods. Astronomical observations were purely phenomenological – they developed mathematical functions that described a phenomenon in which they were interested. They apparently never tried to construct a model or picture that would correspond to that function. There were none better at observational astronomy, but the explanations for the formation and movement of the heavenly bodies were mythological. Note the similarities in the Egyptian and Sumerian explanations of the structure of the heavens and Earth. These similarities attest to the fact that, even though separated by thousands of miles, these two early civilizations contacted each other and influenced each others development.

FOUNDATIONS OF CONTEMPORARY SCIENTIFIC EXPLANATIONS

Out of this cauldron, consisting of observation and mythical explanation, came the beginnings of scientific explanations for astronomical events with the early Greeks. The writings of Homer precede this period and represent other mytho-poetic explanations. These writings indicate that the sky was thought to be a solid hemisphere, like a bowl. It covered the flat Earth. The gap between the sky and the Earth was filled with MIST in the lower regions and with AITHER in the upper regions. A great river (Okeanos) encircled the shape of the Earth. The sun traveled across the sky in a horse-drawn chariot. At night the sun sailed in a golden bowl

around the stream of Okeanos, arriving just in time to rise the next morning. Notice that it wasn't the sun god that behaved this way—it was the sun. The hallmark of the explanations offered by the Greek Natural Philosophers (600–150 BC) and their followers was that the heavens and the Earth are shaped by NATURAL forces, rather than by supernatural forces. Reality consisted of the perennial transformations of matter. These transformations occurred to meet some purpose. Thus, the idea of purpose in nature has its formal introduction.

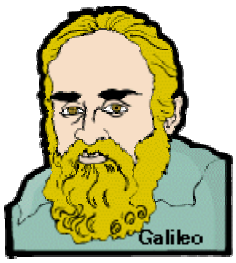
Anaximandros (Latin = Anaximader) was the first systematic Greek astronomer. He proposed that the world was a system in motion, like a vortex. Heavier objects would fall to the lowest place, water would remain higher in the vortex, and fumes (vapors) would remain higher still. The circular motion of the vortex was eternal and space was boundless. He proposed that the basic opposites of hot and cold began to separate in the "primary substance"—the material out of which all other substances were formed. This was followed by the development of a sphere of flame around the cold Earth and air. Anaximandros argued that the fire initially was close to the Earth and air, but that it later moved away from the Earth and air and became divided into several rings of fire. These rings of fire corresponded to the sun, the moon, and the stars. The appearance of the sun and moon results from the fact that there are circular holes in their respective rings of fire. Notice the absence of supernatural forces in this explanation.



Plato and his students held that a divine and permanent characteristic was attributed to everything, from the moon to the fixed stars. The planets, sun, and moon were located at intervals below the sphere of the fixed stars, and the space between the Earth and the fixed stars was divided into segments, the size of which corresponded to a specific numerical sequence. This exemplified the belief that the structure and the laws of the heavenly realm only could be understood in terms of geometry and numbers. The Universe was a geometric place and was the realm of the divine, where planets traveled in circular orbits around the Earth with uniform motion. Circular, uniform motion was not allowed on the Earth, since the Earth was a corruption of the divine world of the heavens. Change of any sort was outlawed in the heavens (at least to Plato, Aristotle, and their followers). The role of the deity was to make the heavenly bodies travel and behave in ways that can be described by geometry, and that included infusing all objects with a purpose. This way the planets could trace out their intricate paths in the sky. Later Greek astronomers abandoned speculations on the causes of the motions of planets and on the physical origination of the heavenly bodies. Rather, they spent most of their energy trying to fit the observations of planetary motion into the Platonic assumption (that the planets travel around the Earth with uniform, circular motion). For example, astronomers that followed Plato constructed models consisting of spheres within spheres to explain the **retrograde motion** (apparent backward motion of the planets when compared with the stars)of the planets. Ptlolemy's **epicycles** are an example of these sphere's within spheres.

Eppicuros of Samos (Latin = Eppicurius) lived from 341 to 270 BC. He was a follower of the "atomist" school of Democritos (Latin = Democritus). As such he held that all objects in the universe are composed of discrete particles of different sizes, shapes, and qualities ("atoms"). The "atoms" constantly change and are transformed in an infinite space. It was proposed that the formation of objects results from the random swerving and whirling of atoms. Collisions and combinations of whirling atoms result in the formation of larger bodies, including the sun, moon, planets, and stars. In this conception of the universe there is no place for orderly change and regularity. The atoms combine by chance events driven by natural forces. Notice, the only order in the universe comes from the ways in which "atoms" combine—it is not due to the directing hand of a deity or a natural force. The ideas of the "atomists" were so thoroughly criticized by Aristotle (whose own ideas attained paramount positions in the intellectual history of the western world) that this type of view of the universe was not put forward again until contemporary times.

The earliest voice for a heliocentric solar system was that of Aristarchos of Samos (circa 250 BC). He placed the sun in the very center of the planetary orbits and let the Earth move around the sun, just like the other planets. Copernicus came to the same point of view as he worked out the geometrical and quantitative problem of the "true ordering of the planets". The geometry that described the motion of the planets was the result of the actions of the "Supreme Artificer", who created geometric relationships. Notice that the role of the deity is to impose order on the universe, and this order can be described geometrically. Still, the causes of the motions of the planets, and their origins, were not the subjects of speculation.

Kepler's planetary system was a Copernican system with the sun at the center of the solar system. He tried to fit planetary distances and their orbital periods into mathematical progressions. At this he failed. On the other hand, his application of the five perfect solids (and the spheres circumscribed by these solids) fairly accurately described the orbits of the planets. Earth's spherical orbit was circumscribed on a dodecahedron. The sphere that enveloped this solid represented the orbit of Mars. A tetrahedron was fitted around the orbit of Mars, and the sphere that enveloped this solid represented the orbit of Jupiter. A cube was fitted into the sphere of the orbit of Jupiter, and the sphere that is circumscribed by the cube represents the orbit of Saturn. When the spherical orbit of Earth was fitted with a icosahedron, the sphere fitted to the outside of this solid described the orbit of Venus. This, in turn, enveloped an octahedron that, when fitted to a sphere, gave the orbit of Mercury. Again, the order of the universe is a geometrical order.

Galileo embraced the Copernican view that the sun is the center of the solar system. Aside from making more refined models of planetary motions, Galileo is most usually remembered as the scientist that was excommunicated for holding views that ran counter to church dogma. After all, the prevailing view of Medieval and Renaissance astronomers was that the ordered universe and its maintenance results from the hand of God. Once astronomers became more aware of the physical forces that drive motion on Earth, the extension of these forces to the heavenly bodies resulted in models that attempted to explain the causes of the motions. These explanations did not totally depart from a religious influence. Newton, for example, believed that the Supreme Being created the physical principles that drive the universe. Once put in motion, those forces have shaped the formation and maintenance of our solar system. Our contemporary theories on the origin and operation of the heavenly bodies are no less attempts to offer an explanation for the causes of things than are the religious-based explanations that dominated thought for several millennia.