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A note on vocabulary: Throughout, I tend to use the terms “theory” and “hypothesis” interchangeably. A twenty-first century scientist might point out that a theory is more comprehensive than a hypothesis, or longer-lived, or has stronger mathematical underpinnings. But both words refer to a theoretical structure that makes sense of evidence. Since it isn’t always clear when a hypothesis becomes a theory, and since scientists in different centuries and different fields tend to use the words in different contexts, I have declined to struggle over the distinction.

Explain the scientific difference between theory (i.e. Scientific theory) and Hypothesis. Why has the author “declined to struggle over the distinction”?: This sentence explicitly states that the author has chosen not to emphasize the difference between a theory and a hypothesis because the usage of these terms can vary widely. The author’s decision is based on the understanding that both terms relate to the process of making sense of evidence, and that focusing too much on the distinction could detract from the broader purpose of the book, which is to trace the development of scientific writing and thought.

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Thales . . . stated [the foundational principle of the universe] to be water. (This is why he declared that the earth rests on water.) Perhaps he got this idea from seeing that the nourishment of all things is moist . . . and also because the seeds of all things have a moist nature; and water is the principle of the nature of most things.5 Water (as it turned out) was the wrong explanation. But Thales’s theorizing is the earliest known attempt to peer inside the universal watchcase and see what else, independent of divine power, might be causing it to tick. Thales’s attempt to discover an underlying truth about the universe without reference to the gods (“Thales’s Leap,” biologist Lewis Wolpert calls it) was probably not the first Greek theory of its kind, but it is the first preserved by name.

Explain the significance of Thale’s Leap: The first known attempt to comprehend the universe without calling upon the gods is said to have been Thales' Leap. This marks a turning point in the development of human thought, when the natural world started to replace the supernatural in the explanation of natural phenomena. Thales was wrong to believe that water was the primary material of the universe, but his method—seeking an underlying truth by observation and reasoning instead of attributing everything to divine action—makes his leap significant. This method established the foundation for subsequent scientific investigation.

Side Notes

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Thales's attempt to discover an underlying truth about the universe without reference to the gods ("Thales's Leap," biologist Lewis Wolpert calls it) was probably not the first Greek theory of its kind, but it is the first preserved by name. Thales's actual works have disappeared, though. Thales's Leap may be the first known scientific theory, but the Hippocratic Corpus—a collection of some sixty medical texts that explain disease without blaming or invoking the gods—is the first surviving book of science.

Explain the significance of the Hippocratic Corpus: Because it is the oldest surviving collection of scientific writings, the Hippocratic Corpus is significant. These writings are significant to the history of medicine because they attempt to explain disease through natural causes rather than attributing illnesses to the actions of gods. This shift in the history of science is marked by the abandonment of mystical explanations in favor of naturalistic and empirical approaches. The Hippocratic Corpus established the groundwork for modern medicine by stressing physical causes of illness rather than supernatural intervention in observation, diagnosis, and treatment.

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Many of Hippocrates's contemporaries were priest-physicians, devotees of Aesculapius (son of Apollo, god of healing). To be cured by Aesculapius, a patient would travel to one of the temples of the god and spend the night in the abaton, the temple's sacred dormitory, surrounded by the free-slithering snakes that represented the god's presence. Sometime during the night, healing would take place. The serpents would lick the patient's wounds and mend them, or the god would send a dream explaining how the illness should be treated. Or perhaps Aesculapius himself would appear to carry out the cure. "Gorgias of Heraclea had been wounded with an arrow in one of his lungs," writes the Greek chronicler Pausanius:

How were the temples of Aesculapius used to treat illness and injury in ancient Greece: Patients would travel to the ancient healing centers known as Aesculapius' temples to seek remedies for their illnesses. Incubation, or sleeping in the temple, was a common procedure in these establishments where patients hoped to receive divine messages about their healing through dreams. The fact that Aesculapius, the god of medicine, revered snakes and thought they had therapeutic properties makes their mention noteworthy. As part of the healing ritual, patients' wounds were licked by snakes in this practice. This illustrates how the temples treated disease and injuries by combining traditional medicine with their religious beliefs.

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Hippocrates blamed stomach upsets, fevers, epilepsy, plagues, and illnesses of all kinds on imbalance—too much or too little of one of the four fluids, or "humors," that course through the human body. When these four fluids (bile, black bile, phlegm, and blood) exist in their proper proportions, the body is healthy. But any number of natural factors might throw them out of whack. For Hippocrates, the chief causes of unbalanced humors were winds (hot winds, for example, caused the body to produce far too much phlegm) and water (drinking stagnant water could lead to an overabundance of black bile). The recommended treatment: restore the body's balance. Purges and bleeds were prescribed to get rid of excess humors. Herbs (rue, mustard, fennel, stinging nettle) helped to draw out some humors and renew others. Sick men and women were often sent to different climates, away from the winds and waters that were deranging their natural harmonies.9

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3. What are the '4 humors' and explain how Hippocrates thought they were related to disease: The idea of Hippocrates' four humors—blood, phlegm, black bile, and bile—is explained in this sentence. According to him, disease results from an imbalance between these humors, which must be maintained for optimal health. A number of elements, including water and winds, may upset this equilibrium and cause disease. Restoring balance was the goal of the treatment, which included bleeding, purging, and the use of herbs.

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he monists believed that it all began with a single underlying element, one sort of stuff, containing within itself the principle of its own change: “This, they say, is the element and this the principle of things,” Aristotle wrote much later of the monists, “some entity . . . from which all other things come to be.” Thales, one of the earliest monists, had proposed water; the sixth-century philosophers Anaximenes and Heraclitus suggested air and fire, respectively; Anaximander, around 575 BC, proposed something called “the indefinite,” a thing that has itself no characteristics but contains opposite qualities that separate, producing change. The pluralists, on the other hand, were in favor of multiple underlying elements; Empedocles, around 460 BC, suggested four—earth, air, fire, and water—an arrangement widely adopted by other thinkers.3 And then there were the atomists, most notably the shadowy Leucippus and his much-better-known pupil Democritus, both of them teaching and writing in the last quarter of the fifth century. “Leucippus . . . posited limitless and eternally moving elements, the atoms,” the philosopher Simplicius explains. Democritus expanded on his master’s theory; these atoms “are so small that they escape our senses. . . . From them, as from elements . . . the visible and perceptible masses” are formed.4 As it turned out, this was more or less true.

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1. Find the definitions of monist, plurist, and atomist as they pertain to the scientists in this chapter. What is one example of each from the text?: Greek philosophers discussed various basic theories regarding the composition of the universe in Chapter 2. Monists, such as Thales, who postulated water as the fundamental element, held that the universe was born of a single substance or principle. Though not stated specifically in the text, pluralists asserted that the universe is made up of several fundamental substances. They usually cited the work of Empedocles and other thinkers who supported the idea of four root elements. Proponents of atomism, such as Democritus, postulated that all substances and objects in the world are composed of indivisible, minuscule particles known as atoms.

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So in the Timaeus, written late in his life, Plato offered his own sketch of the universe and how it works—the first self-consciously big-picture neoscientific treatise, the first known attempt to offer a theory of everything. It is a hybrid work, beginning with the origins of the universe at the hands of a divine creator—a divine force, an unknown Craftsman—and then moving from origins to an explanation of the universe's present function that has no reference to the divine. Plato lived in a world where it was no longer possible to ascribe the rising of rivers and the motions of the moon to the will of gods. Yet he could not imagine a universe that had always been, or a beginning that was not sparked by the divine.

Describe Plato's theory on the origin of the universe (physical and corporeal).In Plato's Timaeus, the Demiurge—a divine craftsman who brought order to chaotic matter—is portrayed as the creator of the universe, creating a good but slightly imperfect physical world. Earth, fire, air, and water are the four elements that make up the universe, and humans are able to comprehend it through their senses because of the way the universe is structured. Even though the universe has a divine origin, it functions independently of the Craftsman in the present, favoring natural explanations over ongoing divine intervention.

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Yet the Timaeus affected the practice of Western science for the next two thousand years. Plato divided origins from observation, creation from the explanations of everyday phenomena. He acknowledged the importance of the senses in the study of the world around us—and, like Hippocrates, opened up an ever-widening space in which science could be practiced without appeal to the supernatural.

What was the significance of Plato's Timaeus to science? This sentence highlights the long-lasting impact of Timaeus on Western science, particularly how Plato separated the divine origin of the universe from the natural explanations of its current functions, thus creating a framework where science could explore the physical world without invoking the supernatural. This acknowledgment of sensory observation as a legitimate tool for understanding the world was a crucial step in the development of scientific inquiry.

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Like his teacher Plato, Aristotle saw beauty and order around him. But while Plato saw this beauty as proof of a Craftsman at the beginning, Aristotle saw it as a signpost pointing toward fulfillment at the end. This altered everything—most especially, change. For Plato, change does not mean progress. Only decay. His natural world is an inferior copy of the Craftsman's original concept, which means that it is an inherently flawed work of art—like a perfectly written play that inevitably accumulates myriad minor defects as soon as it is staged by real actors, in real costumes, wandering through real scenery. The physical world is always less than it was meant to be, and any change inevitably pulls it further and further away from the ideal. But Aristotle, watching a sprout grow into a tree, a cub into a lion, an infant into a man, saw something else. First, he wanted an explanation of the process: How do these changes happen? In what stages does one entity, one being, assume more than one form? What impels the change, and what determines its ending point? Then, he wanted a reason. Why does a kitten become a cat, a seed a flower? What impels it to begin the long journey of transformation? Why is the state of kittenness, the existence of a seed in itself, not enough? Today, when the cellular changes of growth are common knowledge, when every kindergarten class sprouts a bean on damp cotton, these questions seem superfluous. But part of the genius of Aristotle (wrongheaded though his conclusions often were) was to ask them. He did not assume that growth and change, as natural processes, were simply to be accepted. It was because they were natural processes that he questioned them; it was because they occurred as part of the natural cycle that he hoped to understand them. This was science. And so Aristotle's most seminal scientific work, the Physics, is all about change.

How did Aristotle's vision of the world differ from Plato's? Why was this vision important at the time? : The significant distinction between Aristotle and Plato is emphasized in these sentences: Aristotle saw change as a natural progression toward a more perfect state, in contrast to Plato who saw the physical world and change as a fall from a perfect ideal. Decay if you will. This vision was significant at the time because it established the foundation for scientific investigation by defending the study of the natural world as a means of gaining meaningful knowledge.

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Aristotle's vision of a world where movement is always forward, always purposeful (never purely random, as Democritus and the atomists had proposed) served as the framework for what he called the scala naturae, the Scale of Nature: a graded, continuous ranking of natural organisms from the simplest to the most complex. Plants were at the bottom, human beings nearer the top. In the hands of medieval philosophers, Aristotle's Scale of Nature would become the Great Chain of Being, a connected ranking of all natural elements and beings. Rock sat on the bottom rung, God at the top.2

Describe Aristotle's Scale of Nature. This eventually lead to the Great Chain of Being in the 1500s- describe this as well.: Aristotle's Scale of Nature, or scala naturae, was a hierarchical structure of all life forms, ranging from inanimate matter to humans at the top, with each step representing increasing complexity and perfection. This concept laid the groundwork for the medieval Great Chain of Being, which further expanded this hierarchy to include all entities in the universe, from God down to the simplest forms of matter.

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To locate living organisms on the Scale of Nature, the natural scientist had to understand them. Aristotle's other great scientific works, his natural-history compendiums (History of Animals, Generation of Animals, Parts of Animals), describe, organize, and classify living things, discovering within unwieldy nature itself the principles of purposeful change laid out, in the abstract, in the Physics. This task was complicated by the total lack of Greek terms for such an enterprise. Doing science before the language of science had been created, Aristotle had to make up his own vocabulary, his own terms and titles and divisions, as he went along. In doing so, he invented taxonomy: the science of grouping living things together by their shared characteristics.

Explain why Aristotle can be called the 1st taxonomist and explain how he classified life.: Aristotle created a system to categorize living things according to the traits they had in common, which is why he is regarded as the first taxonomist. His work in natural history, in which he painstakingly characterized, arranged, and classified different kinds of life, established the basis for the science of classification known as taxonomy, which is still in use today. His system of classification made it possible to study and comprehend the natural world by arranging it into a logical structure.

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The most influential science book in history

Why is Chapter 6 of the text subtitled "The most influential science book in history"? The reason Chapter 6's subtitle is "The most influential science book in history" is that it looks at Ptolemy's Almagest, which was instrumental in influencing astronomy theory for more than a thousand years. The Almagest offered a thorough geocentric model of the cosmos that served as the basis for astronomical research and was regarded as authoritative in both medieval Europe and the Islamic world. It had a significant impact on the understanding of the cosmos up until the 16th century due to its intricate mathematical models and predictive ability, which made it a vital resource for researchers, explorers, and teachers.

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By the second century AD, astronomers and mathematicians had used Aristotelian physics, Archimedean calculations, and Lucretian principles to construct a completely erroneous model of the universe. This universe was spherical, and it contained five types of matter: earth, water, air, and fire, plus a fifth, mysterious substance whose existence was deduced rather than seen—the ether, thought to fill the celestial realm. Careful observation and rigorous deduction had yielded an obvious conclusion: Our planet sat at the universe's center. After all, if you hurl a handful of dirt or toss a basinful of water into the air, it falls down; thus, earth and water were clearly seen to be "heavy matter," meaning that they are drawn toward the center of the universe. The earth is made of heavy matter. But since the earth is obviously not falling through space (this was scientific: no one could observe this movement; therefore it did not exist), it must already be at the universe's core.* Fire and air do not fall. In fact, fire can even be seen to reach upward. So fire and air were classified as "light matter," which constantly moves upward, away from the center. The stars above the earth, along with the seven independently moving celestial bodies known as the asteres planetai (wandering stars) did not seem to be drawn to the center; ergo, they were made of light matter. And since light matter moves more easily and more quickly than heavy matter, it seemed clear that the light stars were moving around the heavy earth. To assume the opposite would have been entirely counterintuitive.1

By Ptolemy's time, a completely erroneous model of the universe had been pieced together. Describe a few of these erroneous elements.: Earth was positioned at the center of a faulty geocentric model of the universe by Ptolemy's time. In this model, fire and air were categorized as light matter moving upward, while earth and water were classified as heavy matter moving toward the center. In addition, it presented the idea of planetary retrograde motion, which is the idea of planets pausing and turning around in their orbits. The heavenly realm was also thought to be filled with ether, a fifth element. These false components belonged to an ultimately false conception of the universe.

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This manual, the Almagest, makes use not only of Hipparchus's epicycles and eccentrics, but also of a new ploy. Ptolemy, unable to find the exact equations that would make planets move at the same rate all the way around their larger orbits, proposed that while the eccentric should remain the center of the deferent, the speed of planetary movement should be measured from an imaginary standing point called the equant. The equant was self-defining—it was the place from which measurement had to be made in order to make the planet's path along the deferent proceed at a completely uniform rate. It was, in other words, a mathematical cheat. But it was no more of a cheat than the epicycle or the eccentric, and since it gave even more accurate predictions, it, too, became part of astronomical tradition. As mathematician Christopher Linton points out, any planetary orbit, no matter how complex, can be predicted by using the equant and eccentric and by building epicycle upon epicycle—which explains why this type of calculation remained "the cornerstone of all quantitative planetary theories" until the sixteenth century.4 • For the next fourteen hundred years, the Almagest was almost entirely unquestioned.

What did Ptolemy's Almagest contribute to the knowledge of the day? Why was this important? It demonstrates how important Ptolemy's Almagest was in forming astronomical theory. More precise predictions of planetary movements were made possible by astronomers with the advent of the equant, a mathematical innovation. The Almagest's significance in the history of science is demonstrated by its accuracy, which made it a vital resource for astronomers and guaranteed its influence for fourteen hundred years.

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For the next fourteen hundred years, the Almagest was almost entirely unquestioned. In the Greek-speaking empire centered at Constantinople, the Almagest was continually studied and its calculations practiced. But there were no innovations, no paradigm shifts. The earth's position at the center of the universe remained a fundamental truth; Ptolemy's epicycles and equants were accepted as law.

In particular, why did European scholars (up to the 1500s) fail to dispute Ptolemy?This sentence directly supports the idea that Ptolemy's model went unchallenged for centuries. It highlights the longevity of Ptolemy's influence, suggesting that European scholars did not dispute his work largely due to its entrenched position in scientific and intellectual tradition.

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During this time, there were "no innovations, no paradigm shifts". Define paradigm (as in a scientific paradigm) and explain what the author means by this statement. A widely acknowledged framework that directs knowledge and research in a field is known as a scientific paradigm. According to the author, in the centuries that followed Ptolemy's *Almagest*, the geocentric model remained unquestioned and no new theories surfaced that would have fundamentally altered our understanding of the universe. This is what they mean when they say there were "no innovations, no paradigm shifts." Without any notable advancements or modifications, scientific research proceeded within the preexisting framework.

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Over time, the handbooks and digests essentially replaced the Almagest itself. The text became rarer and rarer in the West. The educated European knew his Ptolemaic universe but knew nothing of Ptolemy. The earth-centered universe had passed into common knowledge; it was no longer a theory proposed by a single scientist that might still be disproved, but a truism authored by no one and accepted by all. Not until the twelfth century, when the Christian kingdoms of the Spanish peninsula began to push against the Muslim dynasties to their south, did the Almagest itself reappear.

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the West. The educated European knew his Ptolemaic universe but knew nothing of Ptolemy. The earth-centered universe had passed into common knowledge; it was no longer a theory proposed by a

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For a time, the Almagest was 'lost' to scholars. Why and how was it resurrected?: This sentence directly explains how the Almagest was resurrected in Europe after being lost for a period, largely due to the interaction between Christian and Muslim territories during the twelfth century.

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By 1514 he had formulated a more graceful theory. He wrote it out in a simple and readable form, eliminating all of the mathematics involved, and circulated it to his friends. This informal proposal, the Commentariolus, began with an admission that the Ptolemaic system worked reasonably well; Copernicus's primary motivation was to get rid of the mathematical gyrations that it required.

Copernicus wasn't the first to propose his theories- why did his work make such an impact?This sentence highlights why Copernicus's work was impactful: it offered a simpler and more elegant solution to the complex and unwieldy mathematics of the Ptolemaic system, making his heliocentric model more appealing and influential.

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"All the spheres revolve about the sun as their mid-point, and therefore the sun is the center of the universe." The earth was merely the center of the "lunar sphere," and it did not remain motionless. Instead, it sped in a rapid orbit around the sun (like the other spheres), moving at an amazing clip in order to complete its trip within a year, and also performed a "complete rotation on its fixed poles in a daily motion." This earthly rotation actually caused the apparent movement of the sun and the retrograde motions of the planets. "The motion of the earth alone," Copernicus concluded, "suffices to explain so many apparent inequalities in the heavens."5

What assumptions did Copernicus lay out in his Commentariolus? These assumptions formed the core of Copernicus's heliocentric model, which posited that the sun, not the Earth, was at the center of the universe, and that the Earth both rotated on its axis daily and orbited the sun annually. This explained the apparent motions of the sun and planets, including retrograde motion, in a more straightforward manner than the Ptolemaic system.

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This manual, On the Revolutions of the Heavenly Spheres, was a masterpiece of mathematics. Like the Greek astronomers before him, Copernicus set out to “save the phenomena”—to produce a series of calculations that would line up with the data. The difference: he manipulated planets in their paths around the sun rather than the earth. And this he did successfully—without making use of Ptolemy’s off-center rotations. He had, as his single private pupil Rheticus put it, “liberated” astronomy from the equant.7 But On the Revolutions, even in its final form, had massive credibility problems. For one thing, in order to fully save the phenomena, Copernicus had to insert even more interlocking, rotating celestial spheres than his Ptolemaic colleagues had used; he had done away with the equant, but not with the overly elaborate gear system of the heavens. For another, his insistence that the earth was both rotating and hurtling through space at a ridiculously fast pace simply didn’t line up with experience. It was obvious to anyone with eyes that a man who jumped up would come down in exactly the same place; the earth did not rocket out from beneath him while he was suspended in the air. Sixteenth-century physics had absolutely no way to explain this reality, and it was much more reasonable to believe that the earth was doing exactly what it appeared to be doing—standing still.8 On top of all this, the heliocentric theory seemed to contradict the literal interpretation of biblical passages such as Joshua 10:12–13, in which the sun and moon “stand still” rather than continuing to move around the earth. The theological problems were actually less troublesome than the scientific ones; but taken together, they cast serious doubt on Copernicus’s new model.

What were the major controversies regarding his On the Revolutions of the Heavenly Spheres? The major controversies surrounding On the Revolutions of the Heavenly Spheres included the complexity and unwieldiness of Copernicus’s model, its apparent contradiction with observable physical experience, and theological concerns about its alignment with biblical scripture. These issues collectively cast serious doubt on the acceptance of Copernicus’s heliocentric theory during his time.

Exam 9/2/2024

Francis Bacon, Novum organum (1620) William Harvey, De motu cordis (1628) Galileo Galilei, Dialogue concerning the Two Chief World Systems (1632)

Week 2 Chapters 8, 9, and 10

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