Remote Learning Module for 1 April 2020

Lecture Notes for Fernando Espinoza's *The Nature of Science,* Chapter 3

Last time we considered the development of scientific knowledge as beginning with the earliest tools. We found that people were keeping track of lunar cycles as long ago as 35,000 BCE. We also found that the ancient Babylonians and Egyptians developed a number of heuristics or rules of thumb for solving geometrical problems, but that the notion of rigorous proof did not appear in the Western tradition until around the time of Pythagoras (582-500 BCE).

I left you with two questions last time as well. The first concerned Pythagoras and the time-honored story of his discovery of the rational fractions that mapped the consonances (octave, fourth and fifth interval tones in the diatonic scale) in ancient Greek music. In the story, Pythagoras was thought to have determined these by weighing hammers in a blacksmith's shop. But we learned that this could not have been true—that Pythagoras simply *could not have used the weights of hammers* to have determined the numerical ratios 2:1, 4:3, and 3:2 for string lengths on a monochord. The reason for this conclusion depends on what Marin Mersenne discovered in the 17th century about the relation between pitch and frequency of vibration. From his observations, Mersenne was able to identify three laws: that frequency of vibration is (a) proportional to the square root of string tension, (b) inversely proportional to string length, and (c) inversely proportional to the square root of string thickness (that is, its density). Now, the reason these results show that Pythagoras couldn't have used hammer weights is this: for weights, the *ratios of squared reciprocals* (that is, the weights will vary reciprocally as squares of the pitch), so that to double the pitch, the weight must be *quadrupled* (not doubled) in order to produce the octave.

The second question asked for an algorithm that will generate a Pythagorean triplet for every *even* number. Remember that for every odd number, we could use the algorithm: Let a = any odd number, then let $b = (a^2 – 1) / 2$, and let $c = b + 1$. For every even number, we could use this algorithm:

Let a = any even number, then
Let $b = (a/2)^2 - 1$, and
Let $c = b + 2$

And here is a fully general formula: When m and n are any two positive integers ($m > n$):

$a = m^2 – n^2$

$b = 2mn$

$c = m^2 + n^2$

Today we'll turn our attention to Chapter 3: What is Rational Inquiry?

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(1) Rational Inquiry.

Rational inquiry involves understanding the differences among the several sources of knowledge available to us as we go about investigating the natural world. Espinoza lists these as sources as (a) Authority, (b) Reasoning, (c) sense perception, and (d) intuition. We should additionally note that our reasoning comes in three flavors: Deduction (sure bets), Induction (good bets), and Abduction (or the method of hypothesis).

(2) Why the Greeks?

In the West, the Greeks were the first to trade in mythological explanations for rationalistic, naturalistic explanations of phenomena. You'll note on p.35 that Espinoza divides Greek philosophy into four periods; the more common division is simply three: early, middle, and late. The early period is the time of the *phusikoi*; the middle period is often called the Golden Age of Athens (the time of Plato and Artistotle), and the late period is known as the Hellenistic Age (which also includes Greco-Roman thought).

As we learned last week, the first *phusikoi* hailed from the port city of Miletus in Ionia. But why there, and nowhere else in the ancient world? This is not an easy question to answer, but we can go a long way towards assembling an explanation by looking back to the time before philosophy, and the fate of the Bronze Age Greeks who lived on the mainland in the area known as Mycenae. These were the people celebrated in the Homeric poems, the *Iliad* and the *Odyssey*. Sometime after the time of the Homeric stories, these Mycenaeans were invaded by the Iron Age Dorians from the north. As you might expect, bronze is a poor match going up against iron, and thus the Mycenaeans were routed. In fact, their entire culture was destroyed; they even lost their system of writing (imagine the sort of catastrophe this must have been: to retain one's spoken language but to have lost the transmission of ideas through the written word). Over time, the Mycenaeans who remained on the island of Crete crossed the sea and settled in Ionia. As they rebuilt their culture, they adopted a scheme of writing from their neighbors, the Phoenicians—the scheme we know today as the alphabet (from the first two letters, α, β (alpha and beta).

The diaspora, however, gave these Greek-speaking peoples an advantage seen nowhere else in the ancient world: having lost the hierarchical order of the Homeric Greeks, they needed to form political alliances throughout Ionia; they no longer maintained a hereditary priesthood, and were therefore free from *mytho-poeic* justifications for authority. Likewise, they were able to dispense with mythological explanations of phenomena, and to seek naturalistic explanations instead. Moreover, these descendants of the Mycenaeans came to understand their shared culture as stemming from their shared language rather than their bloodlines (of which they'd lost track during the Dorian invasions). Consequently, they divided the peoples of the world into two categories: Greek-speaking and non-Greek-speaking; for this latter category, they used the terms *barbaros* (singular) and *barbaroi* (plural)—from which our term, "barbarian" derives. But to the Greeks, this didn't mean that non-Greek-speakers were at all uncivilized or uncultured; rather, when they heard Egyptians or Babylonians speak, the words came out sounding like, "bar-bar-bar-bar"; hence the term *barbaros*.

In addition to forming political alliances up and down the Ionian coast, these early Greeks began using their new written language to record and share their inquiries into natural phenomena, from the movements of the sun, moon, and stars throughout the year to the appearance of earthquakes and storms on Earth. The Greek term for these inquiries was *historia*, from which we get our English word, "history." These histories or inquiries ranged considerably in quality and content, but in any event, they ran rampant in Miletus when the first *physikoi* appeared.

(3) The Early Period.

The early period of Greek philosophy is sometimes called the time of the Pre-Socratics (the philosophers before the towering figure of Socrates, whose most illustrious follower was Plato). This is really not the best designation because the atomists (whom we will encounter next time) were born after Socrates. A much better distinction comes on the heels of recognizing that what Socrates accomplished in his teaching was to turn the direction of philosophy away from natural science and towards the moral sciences of ethics and politics.

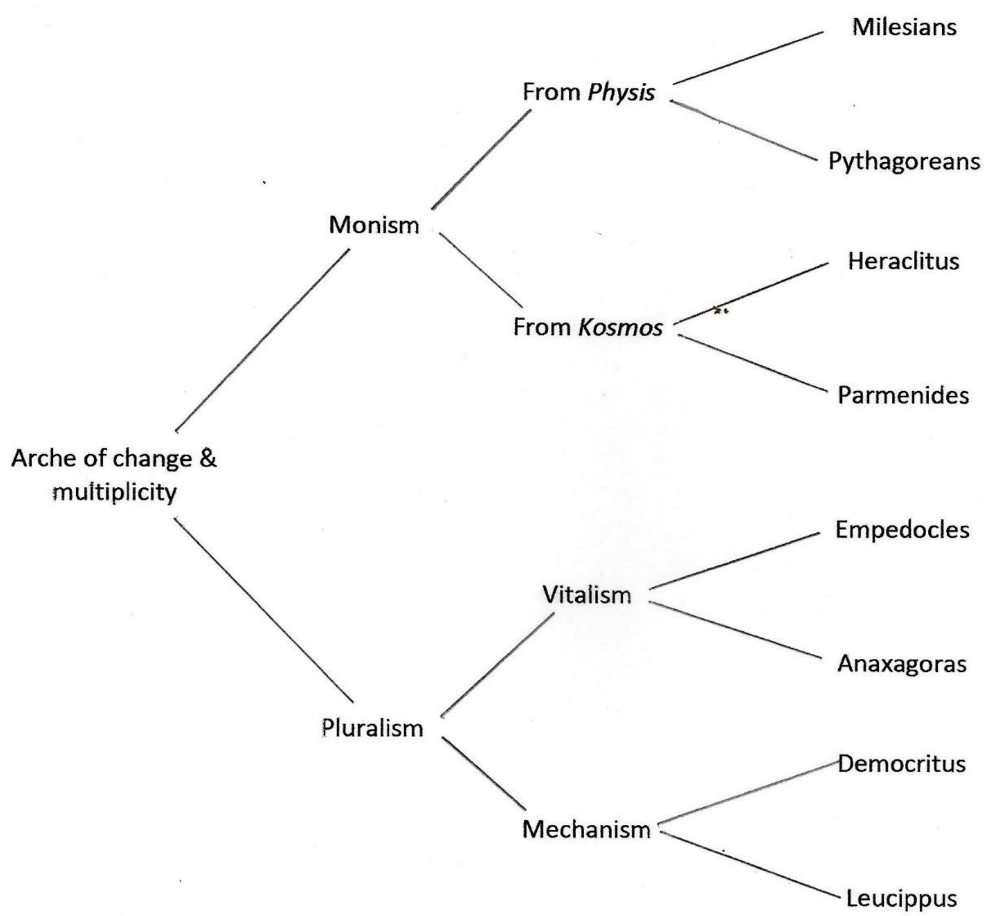
As we learned last week, the figure of the Milesian, Thales, is usually regarded as the first of the natural philosophers we're calling the *physikoi* (which is, after all, the term they used to characterize themselves). We also found last week that they were preoccupied with discovering a *logos* or explanatory account of the twin phenomena of change and multiplicity. It is convenient, therefore, to classify the *physikoi* according to the sorts of accounts they provided in their philosophical thinking. Those who supposed that *one fundamental thing* explains both change and multiplicity were the Monists (from the Greek, *monas*, meaning a unit, or singular), while those who believed that more than one thing was needed were the Pluralists.

Those given to monistic explanations also divided into two camps: the *materialists* or the thinkers who derived their accounts from the study of nature (or *physis*), on the one hand, and the *formalists* or thinkers who derived their accounts from the logical order of things. And those given to pluralistic explanations were also divided into two camps: their fundamental commitments were either to *vitalism* (whereby living forces were thought to animate the natural world) or to *mechanism* (where only mechanical forces were believed to be sufficient to account for everything that happens in the natural world.

The Milesians, Thales, Anaximander, and Anaximines, were looking for a single material principle that would explain the diversity of things and events we find in the world. We met Thales and Anaximander last week, Of Anaximines, let's just note here that he studied under Anaximander, but held that instead of the Boundless, the principle that explained the composition of things in the world was that of the condensation or rarefaction of air (his view comes very close to the way we understand the phases of matter today: tightly bound things, like ice, are solids, less tightly bound ones are fluids, even less tightly bound ones are gases, and for fire, think of plasmas.

We also met the Pythagoreans last week, so we'll next turn our attention to the figures of Heraclitus and Parmenides. Let's first take stock of the early period as a whole.

The following chart displays all of the above distinctions graphically.



(4) Heraclitus.

Heraclitus (540 – 480 BCE) hailed from the Ionian town of Ephesus. His writing style was epigrammatic, taking the form of short, often puzzling phrases, which earned him the moniker, The Riddler, The Obscure. Much of his philosophy was expressly contemptuous of traditional religion and poetry. He asserted that both traditional and popular beliefs wax fallacious from a failure to read the "signs" latent in the nature of things. He proposed to reveal these signs and their meanings. A simple example would be seeing clouds as a sign of impending rain; a more complex example might be seeing a drop in the fertility of bee populations as a sign of impending drought. He supposed that such reasoning was a matter of reading the *logos* of the world—the rational order of things: everything that happens is part of a great story. Most people, however, do not know how to see and read the signs that punctuate this story, and so fail to determine the meanings of what happens.

The quintessential view we associate with Heraclitus is that *change is the only constant*—that the world is in a state of constant flux. This view is expressed in what is probably his most famous phrase: “You cannot step in the same river twice.” In other words, your second step touches different water than the first. One of Heraclitus’ disciples, named Cratylus, went so far as to say that you can’t even step in the same river once (before you even take your first step, the water goes rushing by). It’s said that upon being questioned, Cratylus would make no reply, but would simply wag his finger so as to indicate that nothing in nature is stable enough for any answer to be true for long. In keeping with this doctrine of constant flux, Heraclitus maintained that there is always a unity of opposites in nature (for a very nice example, think of magnetic polarity: the magnetic field is a unity of the poles). In one of his epigrams Heraclitus says that the *archē* of the *cosmos* is fire. He didn’t mean one of the four elements, but rather the image of constant flux. He also held that the *cosmos* was not made, and had no beginning. What he was getting at in these cryptic phrases was a critique of the Milesians, who were looking for a fundamental material underlying change and multiplicity (for Thales it was water; for Anaximander, the boundless; and for Anaximines, rarefied air). Heraclitus observation was that building blocks (no matter how fundamental) are not enough to explain why anything *happens*. Matter, in other words is not enough of an *archē* to do the job of explaining the world; what’s also needed is a principle of agency.

If reality is indeed a condition of total flux, then, according to Heraclitus, the appearance of stability comes from language, from *logos*. Consider his claim that one cannot step in the same river twice. Why would you think otherwise? Because you give the river a name (like the Stones River here in Murfreesboro). Language imposes order on the chaos of the reality. In this we can see an underlying theme, however—a theme that unites all of the *phusikoi*—in our philosophical and scientific investigations, we must confront a distinction between *reality* and *appearance*. When you place a rigid rod like a pencil in a glass of water, the rod will appear bent, but in reality it is not. It might *seem* like liquid water, ice, and steam are different substances, different kinds of things, even. But of course, in reality there is just H_2O. We can read Heraclitus, then, as insisting that when we focus just on our immediate sense experience of the world, all we find is flux; reality, like fire, is constantly changing—it has no *logos-in-itself*.

(5) Parmenides.

Heraclitus was the last Ionian among the natural philosophers. Parmenides (515 – 440 BCE) was from a Greek colony in Italy: Elea. He and his followers, Zeno and Melissus, are known as the Eleatics. Like Heraclitus, Parmenides was concerned with the distinction between reality and appearance, but his view was more or less diametrically opposed to the Heraclitean notion that the Real is Flux. On the contrary, Parmenides taught that change and multiplicity are illusions—illusions imposed by language on the unchanging nature of things. He asserted, therefore, that we can consider the world from one of two perspectives: The Way of Truth or The Way of Seeming. Science falls into the Way of Seeming; science tells us about the appearances of things, but not how the world is in and of itself. We are, in effect, locked into supposing that there is change in the world, and that things are multiple, but this is an illusion. The source of this illusion, according to Parmenides, lies in the logic of possibility. We suppose that the world might have been otherwise than we find it, and we look to science to explain why things are the way they are and not some other way they might have been. This is the Way of Seeming, but not the Way of Truth, for Parmenides. The Way of Truth tells us logically that *whatever is, must be*; and that's an end on it. It is only within the Way of Seeming that we suppose that *what is not might be*. In other words, what Parmenides was getting at was that there are no *negative facts*. Suppose we ask: Is today's non-earthquake the same as yesterday's non-earthquake? Parmenides would say that this question is meaningless. The incoherence of the very idea of negative facts establishes, or so Parmenides held. That nothing can ever change at all—it just looks that way, somewhat in the same way that your cursor appears to move across your computer screen; the cursor is not really moving at all—it just looks that way. It is important to note that Parmenides was not saying that science is impossible; his claim was that science is encompassed by the Way of Seeming, which is to say, science is an assembly of mind-tools for predicting and controlling our experience, not for coming to know how the world is in itself. This view is often called *instrumentalism*. Think of the geocentric model of the solar system: we can use it to find our way at sea at night, and in this regard we don't have to think it gets at the *true* nature of the relation between the Earth and the Stars; it's just a good tool.

Parmenides had a disciple who left a lasting impression on subsequent philosophy by offering a series of paradoxes that challenged the idea that there is real change or multiplicity in nature of things. His name was Zeno of Elea. About multiplicity, he offered three paradoxes:

(i) If an object, *x*, has a given size, then it is an ensemble of smaller and smaller parts; but at root, then, it must be made from simples (like mathematical points), none of which has any size at all. But then *x* is nothing at all.

(ii) On the other hand, if an object has a given size, it must have a rind (inner and outer parts); but each of these parts has inner and outer parts (like the layers of an onion), and so on for each layer; so the object must be infinitely large, which is impossible.

(iii) Between any two things, if things are multiple, there must be a third (or they'd be the same thing), so there are infinitely many things; but this too is impossible; there must be a definite (that is finite) number of things.

About change, Zeno presented a series of paradoxes of motion. The first he called The Runner. Consider a runner running a race. In order to accomplish the feat of reaching the finish line, the runner must traverse half the distance between the starting line and the finish line. But to do this the runner must traverse a quarter of the distance, but to do this s/he must cross an eighth of the distance, and, of course, before crossing an eighth, she must cross a sixteenth. You see where this is going, no? There are infinitely many of these smaller and smaller distances, and since the runner is a finite being, s/he cannot cross an infinite number of intervals.

Similarly, Zeno imagined a race between Achilles (the Greek hero known as the fleetest of foot) and a tortoise. If Achilles gives the tortoise a head-start, however, he'll never be able to quite catch up to the tortoise. Just as in the case of the Runner, while the gap between the two is constantly shrinking, by some factor, there will always remain a smaller unit of separation between them. Both of these paradoxes can be resolved by summing the infinite series involved, as we do routinely in calculus. But another of Zeno's paradoxes, the Paradox of the Arrow, is a little trickier. It goes like this. You aim an arrow at a target, and let it fly. Now at any given instant, let us ask: Is the arrow in a definite place at that instant? If you answer, yes, then the arrow is not moving; in that instant it is stationary. But if you answer, no, then the arrow is not at a definite place but rather nowhere at all. Neither answer is acceptable, and so, Zeno concludes, motion must be an illusion (like your cursor moving across the screen) after all. What is of special interest here is that Zeno's reasoning approximates Heisenberg's Uncertainty Principle in quantum mechanics, which says that in the microphysical world, nothing can be observed to have both position and momentum to an arbitrary degree of precision, and that in fact, the more precision we have when measuring the position of, say, an electron, in its orbital around a nucleus, the less precision we have regarding its momentum (and vice versa). Zeno may have been on to something after all.

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Next time, we'll continue our attention to Chapter 3 – The Earliest Comprehensive and Rationalistic Syntheses. We'll look to the Pluralists and begin our introduction to the Golden Age of Athens. Be well everyone, and remember: social distancing saves lives, which is presumably why we are still not in JUB 202 presently.