GreatHearts Irving

Remote Learning Packet

NB: Please keep all work produced this week. Details regarding how to turn in this work will be forthcoming.

April 13 - 17, 2020

Course: 6 Nature of Science

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Weekly Plan:

Monday, April 13

☐ Read "Anaximenes" on pp. 91-92 of the *Nature of Science*
☐ Read Supplementary Material: Anaximenes (see below)
☐ Complete the day's reading worksheet questions

Tuesday, April 14

☐ Read "Pythagoras" on pg. 93 of the *Nature of Science*
☐ Read Supplementary Material: Pythagoras (see below)
☐ Complete the day's reading worksheet questions

Wednesday, April 15

☐ Read Supplementary Material: Heraclitus (see below) (Read the Supp. Material first)
☐ Read "Heraclitus" on pp. 94-95 of the *Nature of Science*
☐ Complete the day's reading worksheet questions

Thursday, April 16

☐ Read Supplementary Material: Parmenides (see below) (Read the Supp. Material first)
☐ Read "Parmenides" on pp. 96-97 of the *Nature of Science*
☐ Complete the day's reading worksheet questions

Friday, April 17

☐ Read Supplementary Material: Empedocles (see below)
☐ Read "Empedocles" on pg. 99 of the *Nature of Science*
☐ Complete the day's reading worksheet questions

Statement of Academic Honesty

I affirm that the work completed from the packet is mine and that I completed it independently.

I affirm that, to the best of my knowledge, my child completed this work independently

_____
Student Signature

_____
Parent Signature

This week we continue our study of the earliest of the natural scientists, the Pre-Socratics. These earliest of scientists show us what it means to ponder carefully the most fundamental questions about the natural world. We hope you enjoy! Remember that you (or your parents) can reach out to us with questions.

NB: Please note carefully which order you should complete the readings. Please do follow the order, but it is a good idea to have them side by side throughout so you can consult back and forth as questions and insights arise.

Monday, April 13

1. NoS pp. 91-92
2. Special Reading: Anaximenes
3. Worksheet

Tuesday, April 14

1. NoS p. 93
2. Special Reading: Pythagoras
3. Worksheet

Wednesday, April 15

1. Special Reading: Heraclitus (Read the Special Reading before the textbook)
2. NoS pp. 94-95
3. Worksheet

Thursday, April 16

1. Special Reading: Parmenides (Read the Special Reading before the textbook)
2. NoS pp. 96-97
3. Worksheet

Friday, April 17

1. NoS p. 99
2. Special Reading: Empedocles
3. Worksheet

Chapter Five: Anaximenes

Thales vs. Anaximander

Thales: Water, you see, is the perfect choice. It is abundant, it surrounds the land, it is basic, it can be in solid, liquid, or ga—

Anaximander: Yes, yes, but how do you explain the existence of *fire*? Water and fire are opposites, and opposites are continually at war with each other. If it was all water and no fire in the beginning, fire could never have come to be.

Thales: But that's true of *any* substance you choose, not just water. What else could it be?

Anaximander: The *indefinite.*

Thales: The what?

Anaximander: Material without any real, definite form to it, and so without any opposites.

Thales: Can you *show* me this "indefinite"?

Anaximander: Well, not exactly… It has turned into all of the substances we see.

Thales: How are you so sure it existed then?

Anaximander: I mean…what else could it be?

Thales: Hmmm…

Did you catch the problem that Thales is pointing out? The *indefinite* may solve the opposites problem, but it creates a new problem—that no one has any experience of the indefinite. While that does not mean it cannot exist, it makes us less certain.

Along Comes Anaximenes

There was a young man who lived at the same time as Thales and Anaximander, and in the same city too. His name was Anaximenes (an-ax-SIM-uh-nees). Anaximenes is thought to be 24 years younger than Anaximander, and—you guessed it—a student of his. He must have heard many arguments like the one above,[1] and he must have wondered about these questions a lot.

Have you ever had to make a choice between two options that *both* seem very good to you? If you have, you may have some idea of the dilemma that Anaximenes was in. Both arguments were really good—how could he choose? Well, Anaximenes did what many people do

[1] Ok, not *exactly* like the one above.

when faced with a decision like this—he tried to choose both. And the way he did so was one of the greatest strokes of scientific genius the world had ever seen.

Anaximenes' Solution

In order to choose what was great about both systems, Anaximenes proposed an entirely new idea. He said that the ultimate material principle of the universe was…

Air!

Why was this a stroke of genius? Why, because it captured the best things about both theories! Read on, and you shall see.

Back to the Basics

Anaximenes, like Thales, chose a substance that we all know and experience daily. It is one of those basic, fundamental substances that we find everywhere in our world. And it turns out, most of the good arguments for water also apply to air. Look:

Water	Air
Water is everywhere and in abundance.	Air is everywhere and in abundance.
Water surrounds the land on every side.	Air surrounds and covers the entire earth, like a blanket. Have you ever been anywhere where there wasn't any air?
Water is basic. That is, it seems that you cannot mix ingredients together to make water.	Air, in a similar way, is also basic. Air is just *there*. It does not seem to be *made of* other things.
Water is fluid and changeable. It takes on any shape, depending on the container it is in.	Air is also fluid and changeable. If you have ever seen someone make balloon animals, you are well aware of air's fluidity.
Water is essential for life.	Air is similarly essential for all living things. Both plant and animal life[2] depends on a steady supply of air.

As you can see, many of the arguments in favor of water can be applied equally well to air. At this point, air and water may seem to be about equal. But just wait to see how air handles Anaximander's objection.

[2] Yes, even fish! Their gills allow them to breathe in the air that is mixed into the water.

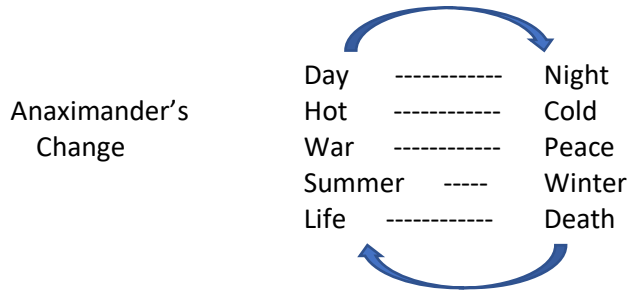
Answering Anaximander

Not only does air have the strengths of water, it also has some of the strengths of the indefinite—indeed, many of air's characteristics make it seem very much like the indefinite. Air has no visible size or shape, hardly any visible qualities at all. In general, it seems a little more neutral than water or fire, and does not seem to be intensely opposed to anything in the way that water and fire are. Really, if you were going to find a real-world material substitute for Anaximander's *indefinite*, you could not do better than air.

But these similarities, on their own, are not enough to answer Anaximander's challenge. To answer Anaximander's challenge, Anaximenes had to do some thinking about *change*.

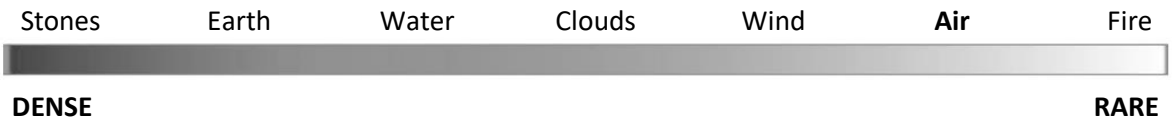
A Brand-New Pair of Opposites

Anaximander, as you will recall, saw all change as a kind of back-and-forth war between opposite forces. And there were tons of these forces everywhere in the world.



Anaximenes agreed, in part. He said yes, there were opposites—but not so many. In fact, he said, there were only *two opposites*: **density** and **rarity**.[3]

When something is changing, it is becoming either more or less dense. And what exactly is the "*it*" that is getting more or less dense? You got it—air! Anaximenes understood every material in the world as a denser or rarer form of air. He laid them out in this order:



Air could become water by becoming denser—a process called **condensation**. Water could become earth or stones by further condensation. Air could become fire by becoming rarer—a process called **rarefaction**. All the change that you see in the world, said Anaximenes, can be explained by changes in density.

Do you see how this solves Anaximander's challenge? Air is not the *opposite* of anything—it is just in a different place on a continuous spectrum between two opposites, rarity and density. Under this system, fire and water are also not opposites—they are just different densities of air.

[3] *Density*, as you'll recall from Chapter 1, is about how tightly packed together the matter is (lead is denser than feathers); *rarity* is about how spread out the matter is (feathers are rarer than lead).

Evidence for Air: Changes in Material
There is plenty of evidence to support Anaximenes' theory of change.

One of the most common and well-known examples is with the evaporation and condensation of water. We all know—and people at the time knew it too—that water is getting less dense when it evaporates or turns into steam. So water becomes "air"[4] through rarefaction. And then it becomes a cloud and, eventually, rain, through the process of condensation. Thus, condensation and rarefaction do a perfectly good job of explaining how water can become air, and air can become water.


It is easy to observe the rarefaction and condensation of water.

Other examples are easy enough to think of. Say you have a little pile of dirt in your hands and you throw it into the air and becomes a cloud of dust. This would be a process of rarefaction (the dust is becoming *less dense* by spreading out) and the resulting cloud would be something closer to air. But that same pile of dirt, as you can imagine, could be packed together so tightly into such a dense form that it becomes a rock.[5]

More Evidence for Air: Other Apparent Opposites
Condensation and rarefaction, the only true opposites, can also explain why there appear to be other opposites. Hard and soft, for example, seem to be opposites, but really, when a thing becomes harder, it is really just becoming denser, and when a thing becomes soft it is really just becoming rarer.

Condensation and rarefaction, however, could also explain opposites that were not so obvious. Demonstrating this was one of Anaximenes' great achievements. He managed to show that, although they may seem unrelated, condensation and rarefaction actually explain changes between *hot and cold*.

To show this, Anaximenes' appealed to an experience that everyone can have. Put your hand next to your mouth and exhale with your mouth wide open. Do you feel that it is warm? Now, purse your lips so that there is only a small opening, and blow through it. Do you feel that it is cold? Anaximenes explained that when your mouth is wide open, the air coming out is *rarer*; when you make the opening smaller, you *condense* the air—and that makes the air colder! This, said Anaximenes, proves that even pairs of opposites that you would not expect, like hot and cold, ultimately depend on density and rarity.

The Soul of the Cosmos
Thus, by explaining change in a different and very convincing way, Anaximenes has avoided the problem that Anaximander pointed out with Thales' water, and at the same time was able to choose a substance that is part of the world we experience. Well done, Anaximenes!

At this point, however, one might ask: when Anaximenes solved the problem of change, why didn't he simply go back to Thales' answer of water? Couldn't we just as easily say that everything is simply the condensation and rarefaction of *water*?

Anaximenes' reason may surprise you. He preferred air because our souls, he said, are made of air. This was a commonly held belief at the time, and not without good reason. After all, one of the first ways to

[4] Steam or water vapor can be thought of as water in air form.
[5] There is actually an entire class of rocks that are formed this way. They are called *sedimentary* rocks.

check if a person or an animal is alive is to check for *breathing*. While air is flowing in and out of us, we are alive; when air stops moving through us, we die. Furthermore, just as the soul is the unseen mover of the body, so air is an unseen mover of the world around us. Have you ever seen the branches and leaves of a tree stirred to life, or *animated,* by the wind? For these reasons, many of the ancients said that the soul is breath or air.[6]

Have We Done It?

Anaximenes seems to have done it—what better choice is there than air? How could anyone object to this? As you'll see, actually, many natural scientists following Anaximenes have disagreed with him and proposed new theories. His insights, nevertheless, had a lasting effect and shaped the way others after him—even those who disagreed with him—thought about change and the material causes of the natural world.

[6] The Latin word for soul, *"anima"* (from which we get words like animated and animal) itself comes from an earlier root meaning "breath."

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Teacher: _____
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The Pre-Socratic Philosophers: Anaximenes
***Nature of Science* textbook: pp. 91-92**
Supplementary Readings: pp. 1-5

1. Anaximenes was a student of _____.

2. Anaximenes said the ultimate material principles of the universe was _____.

3. Anaximenes' idea solved some of the concerns of the ideas of both _____ and _____.

4. Anaximenes did not think there were as many opposites as Anaximander. He said there were only _____ opposites:

   a. _____
   And
   b. _____

5. What does rarity mean? (see the side bar on p. 91) (Use a complete sentence, please.)

   _____
   _____

6. Put the following in order from dense to rare.

Water	Stones	Earth	Fire	Air	Clouds	Wind

Most Dense:
Most Rare:

(Worksheet continues onto the next page)

7. How does Anaximenes' insight solve Anaximander's challenge?
    a. By showing that fire can come out of its opposite, water
    b. By showing that the *indefinite* does not exist
    c. By showing that change is really just a series of opposite forces switching places
    d. By showing that air is not the opposite of anything and that water and fire are not opposites after all
    e. By showing that the indefinite is a visible substance (air) we all experience everyday

8. What was Anaximenes' trying to prove by having you experience the difference between blowing hot air when your mouth is open wide and cool air when it is closed?
    a. Condensation and rarefaction cause changes between hot and cold
    b. Air is on a spectrum between less dense and more dense
    c. Water and fire are not opposites after all
    d. The indefinite is made of matter
    e. Hot air is less dense than cold air

9. One of the main reasons Anaximenes chose air over water has to do with the fact that the ancients commonly held that a person's soul was made of _____.

Chapter Six: Pythagoras

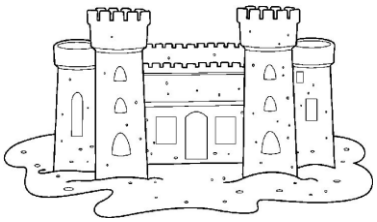
The "Milesians"

The thinkers that we have seen—Thales, Anaximander, and Anaximenes—were searching for an ultimate material principle—something out of which everything in the world is made—while at the same time trying to explain the change that they saw around them. These three thinkers were all from the same city of Miletus, in an Eastern region of the Greek world, called Ionia. These thinkers, since they all lived in *Miletus*, have come to be known as the "*Milesians*." Meanwhile there were thinkers in the western parts of the Greek world that were also beginning to think scientifically about the natural world. They, as you will see, had a somewhat different approach.

Harmony

When these western thinkers looked at the changing world around them, they wondered less about the *material* that made everything up, and wondered more about what *held it all together*.

If you were one of these western thinkers, you might look at a sandcastle, for example, and wonder less about what is made of, and wonder more about why all the sand is staying together to form *one, unified* sandcastle.

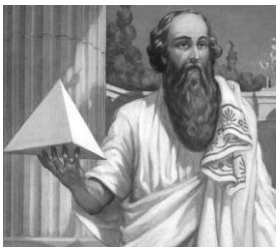


You might similarly look at a chicken, and think less about its material and more about why the materials are staying together to form *one*, *unified* chicken.

You might similarly look at *every individual thing* in the entire universe, and indeed the entire universe as a whole, and wonder why the materials are coming together to form *unified* wholes.

Pythagoras

The first to think these kinds of thoughts was a man named Pythagoras (pih-THAG-or-us). The life of Pythagoras is shrouded in mystery. We know very little about him. Even people who lived at the same time and in the same city hardly knew anything about him! He was intentionally secretive and silent. He shared his secrets only with his group of followers, a secret society or brotherhood of sorts, and they all believed the same things, followed the same rules, and observed the same rituals—and all were secretive and silent. If you were not part of this secret brotherhood, his thoughts and actions remained mostly a mystery to you.



There are, however, *some* things that we have managed to learn from some of his followers. Some are rather strange—for example, he is said to have commanded his followers never to eat beans. Other ideas of his were more important. Most important of all, it seems was his understanding of *mathematics.*

Mathematics

"Math? But what does math have to do with natural science?" you might ask. Quite a lot, in fact. Pythagoras might answer, it has *everything* to do with natural science. Indeed, Pythagoras said he knew what held everything in the world together: it was *number*.

Unity

Remember that Pythagoras is looking for the principle of harmony and *unity:* what holds things together and makes them *one*. The word unity itself comes from the Latin word meaning "*one*." And the thought of *one* is a mathematical thought—one is the basis for every number that there is.

The Tetractys

If you were a "Pythagorean," (that is, if you belonged to Pythagoras' secret society), one of your most beloved symbols was the *tetractys*. Followers of Pythagoras loved it so much that some historians say they actually *worshipped* it.

The Tetractys is the first four numbers, added together.

Take the first number, *one*. ◯

Then add the next number, *two*. ◯ ◯

And the next, *three*. ◯ ◯ ◯

And, lastly, *four*. ◯ ◯ ◯ ◯

And what do you get? Ten, a perfect number! You also get a perfect equilateral triangle,[7] which is one of the most perfect and beautiful shapes. (Do you see that you can count *four* on each side?).

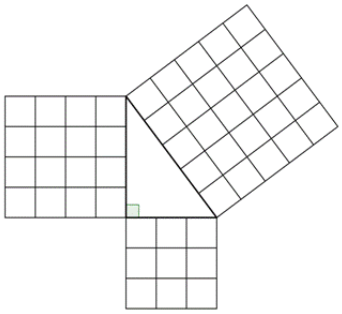
The number ten, such a perfect number, formed in such a perfect and harmonious way by the first four numbers! If such order, and harmony, and perfection, and unity could be found in number, perhaps number was the principle of such order and harmony in the whole cosmos.

The Pythagorean Theorem

Have you ever heard of the "Pythagorean Theorem"? Perhaps you have had to memorize it in a math class at some point in your education. It is usually written: $a^2 + b^2 = c^2$. You have now met the person it is named after!

The Pythagorean Theorem is a truth about right triangles (triangles with one right angle) and the squares built on the sides.

If you take any right triangle, like this one,



and build perfect squares on its sides,

the sum of the areas of the squares on the legs will *always* equal the area of the third square on the hypotenuse.

If you don't believe me, just count![8]

[7] A triangle with all three sides equal to each other.

[8] If you want to be *really* certain that this is true of *every* right triangle, just wait: you will learn the proof of it in 9th grade when you study Euclid's *Elements.*

If numbers and shapes could come together in such perfect harmony in this way, this is another good reason to believe that they were responsible for all the harmony and order in the universe.

Musical Ratios

Evidence that number was responsible for order and harmony in the material world is found again, in a special way, in *music.*

Say you have an instrument with strings, like a guitar. Pythagoras noticed that different lengths of strings, produced different pitches.

For example, a string of 10 inches 10 _____

makes a different pitch than a string of 5 inches. 5 _____

When these two strings are played together, they sound very good, or *harmonious*, together.

But only *some* lengths sounded harmonious; other combinations sounded jarring or harsh (dissonant). The important realization that Pythagoras had was that:

*the **number** of inches of the strings was responsible for the **harmony** in the sound.*

He played the following strings together, and found *they all produced the same harmony (or chord):*

A 10-inch and 5-inch string, 10 _____ 5 _____

8-inch and a 4-inch string, 8 _____ 4 _____

6-inch and a 3-inch string, 6 _____ 3 _____

2-inch and a 1-inch string. 2 _____ 1 ____

Do you see what is going on here? The ratios are all equal! As long as the string-lengths had the same *ratio*, they made the same harmony! You can tell, from your study of fractions, that all of these ratios of the strings shown above are equal:

$$\frac{10}{5} = \frac{8}{4} = \frac{6}{3} = \frac{4}{2} = \frac{2}{1}$$

It was by experimenting with these ratios that Pythagoras figured out the harmonies in the first musical scale (still called the Pythagorean scale to this day).

Indeed, it seemed that *number* was responsible for musical harmony. And music is such a perfect illustration of the harmony and discord found in the world: so many different sounds and pitches, all brought together to form a beautiful, harmonious, and ordered unity in the music. Just listen to a good piece of classical music and you will know exactly what I mean.

The fact that *number* was in some way responsible for harmony in music is a good indication that number is harmonizing not only music, but the entire universe.

Pythagorean Thoughts Today

As strange as the initial claim may have sounded—that everything is *number*—it turns out that we ourselves, to some degree, are still Pythagoreans.[9]

How do you explain that, if you drop a rock from a very tall cliff, you can describe the distance it falls (*d)* in a given time (*t*) with the equation $d = \frac{1}{2}gt^2$? When you study Physics in high school, you will see how mathematical equations like this can describe all sorts of motions and other natural phenomena. Other natural sciences too, use equations all of the time. Chemistry, as you will see, makes use of equations, and even Biology has some ways of using it.

Lastly, consider one of the most famous scientific discoveries of all time, made in more recent times by a natural scientist named Albert Einstein. His contribution to our understanding of the universe is an *equation:*

$$E = mc^2$$

Indeed, natural scientists today, in many ways, are still following Pythagoras' line of thinking. Truly, the more examples that you think of, the more reasonable it starts to seem that *number* is somehow an underlying principle controlling and harmonizing everything in the universe. Of course, we don't want to take it *too far*—we wouldn't want to *worship* number[10]—but it does seem that Pythagoras was really on to something when he said that number was the principle of harmony and order in the universe.

[9] Except that we can eat as many beans as we'd like to.

[10] Some scientists today, unfortunately, make the mistake of saying that you cannot truly know something unless you can describe it with numbers and equations. While not exactly number worship, it seems to be getting too close. Although number is so important for our knowledge of many things, there is much that we can know scientifically that cannot be described with number and equations.

Name: _____
Section & Course: _____
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The Pre-Socratic Philosophers: Pythagoras
***Nature of Science* textbook: p. 93**
Supplementary Readings: pp. 8-11

10. The Pythagoreans were the first to advance the study of _____.

11. The One is composed of both the _____ and the _____.

12. Complete this line from p. 93: "And indeed all things that are known have _____."

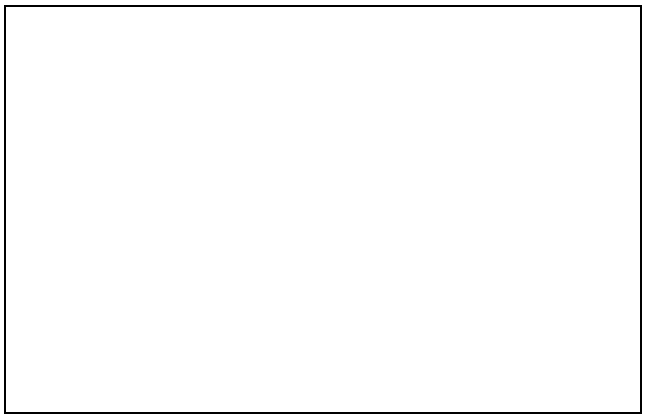
13. Thales, Anaximander, and Anaximenes were known as the _____, and they were from the Eastern part of the Greek world.

14. Pythagoras, however, was part of a group of thinkers from the _____ region of the Greek world.

15. What united the Eastern and Western thinkers was that *change* was a key point of reflection. A key difference, though, was that the Milesians were more concerned with the *material* making up the universe and the Western thinkers were more concerned with what _____ it [the universe] _____ _____.

16. Pythagoras said that what held everything in the world together was _____.

17. Draw the Tetractys and answer the following questions:
    a. What is 1+2+3+4 equal to? _____
    b. How many dots are there in the tetractys? _____
    c. What shape does the tetractys form? A perfect _____ _____



18. Pythagoras' reflection on musical ratios led him to realize that there was a crucial connection between:
    a. Matter and Harmonious Sound
    b. Musical Harmony and Light
    c. Number and Musical Harmony
    d. Math and Natural Science

19. What evidence is there that modern people like us are very much influenced by Pythagoras?
    a. Most people believe number is the fundamental structure of the universe.
    b. Natural scientists continue to explain fundamental things about the universe in terms of numbers and equations.
    c. Many current thinkers use ratios to explain harmony.
    d. We are not allowed to eat beans.

Chapter 7: Heraclitus

Hidden Wisdom

"We step into and we do not step into the same rivers.
We are and we are not."

"A dry soul is wisest and best."

"All things are an equal exchange for Fire
and Fire for all things."

These cryptic little passages are some of the few surviving writings of our next thinker, a man named Heraclitus (HAIR-uh-CLITE-us). If his words sound confusing to you, you are not alone! They are difficult to understand, because Heraclitus actually wrote with the *intention* of making his words hard to understand—that way, only the truly wise, who persevered in trying to figure out what he meant, could actually attain his wisdom.[11]

Unity of Opposites

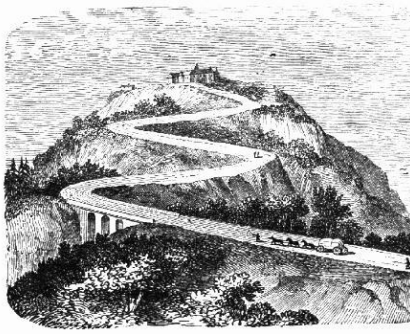
"The path up and down is one and the same."

Do you remember Anaximander's ideas about change—pairs of opposites, always at war with each other? Well, Heraclitus noticed these opposites too, and called the war between them "*strife."* But then he said something radically new and different. What we normally think of as <u>two</u> opposites, he said, are actually <u>*one*</u> *and the same reality*.

"What on earth does this mean?" you might ask. "*Opposites* are the *same*? But '*opposite'* and '*same'* are opposites!"

"That's right," responds Heraclitus with a little smile, "they *are* opposites. And they are *the same*."

Examples of the Unity of Opposites



How confusing! Luckily, Heraclitus gave many examples, like the one quoted above: *"The path up and down is one and the same."* People say that up and down are two different things, but they are failing to see the underlying reality: the path that leads *up* a hill is the *same exact path* that leads *down*. Up and down are really just two aspects of the same reality.

Similarly, people think that "pure" and "polluted" are opposites, but look:

"Sea is the most pure and the most polluted water;
for fishes it is drinkable and salutary [healthy],
but for men it is undrinkable and deleterious [harmful]."

Seawater is thus both opposites—pure and polluted—at the same time. What makes seawater pure and healthy for fish is the *same thing* that makes it polluted and unhealthy for us (the saltiness of it). What seems to be two opposites is actually just two aspects of the same thing—salty water.

[11] Heraclitus was generally disliked by people at the time, who thought he was arrogant and snobby for doing this.

"One man's trash is another man's treasure"[12] is a similar saying that is commonly used today. Trash and treasure, though opposites, are united in the same one object.

Logos: **The Unity and Harmony in All Things**

Wisdom, says Heraclitus, lies in seeing the underlying unity in things, especially the unity of opposites. To see the unity in all things, is to know what he calls the "*Logos*"[13], which is the principle of harmony and unity in the cosmos. Does this sound familiar? Pythagoras was in search of the same thing, and he said that it was *number*. Heraclitus here declares that the unifying principle is not number, but *Logos*.

To get a sense of what *Logos* is, take a look at these examples:

> When you see that the path up is the path down, you are seeing the *Logos* that unites them.
>
> When you see that pure and polluted are the same, you are seeing the *Logos* that unites them.
>
> Indeed, when you see that disease and health, weariness and rest, feast and famine, war and peace, waking and sleeping, yes even life and death—when you see that these are the same, then you have seen the *Logos* that unites them.

Balance and Strife

Are there really no opposites then? Was Anaximander wrong? Well, not exactly. Heraclitus, as you might expect by now, would reply: "There *are* opposites, and there *are not* opposites."

This again, can be confusing. Luckily, again, Heraclitus gave us an image to illustrate how opposites are related. The image is that of a bow:

Look at the opposite ends of the bow. Do you see how they are both pulling on the string, in *opposite* directions? If you are in archery club, or have ever used a bow, you have first-hand experience of the fact that these opposite ends are actually pulling very hard on the string.[14]

The constant pulling of the opposite ends of the bow is what Heraclitus would have described as constant ***strife*** (or war) between the two opposites.

Notice also, however, that neither side is winning—in the constant strife between opposites, the opposites are always perfectly ***balanced***.

Lastly, we should notice—are there really two opposites here? Well, yes in some sense there are: the two opposite ends of the bow. But those opposites ends are ends of ***one and the same*** bow, so in another sense these opposites are actually one and the same.

[12] This is not one of Heraclitus', but he said many things like it, such as: "Donkeys prefer rubbish to gold, [and men gold to rubbish]."

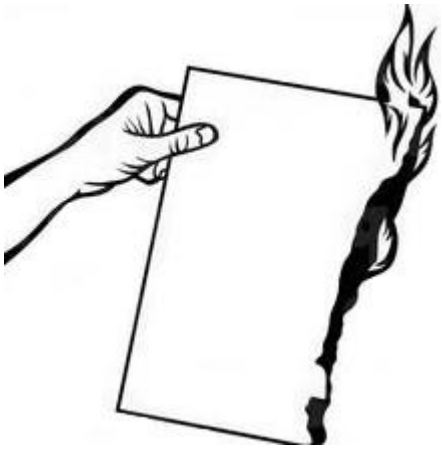
[13] Do you recognize this word? We saw earlier this year that it meant "study of." It actually has *many* meanings in Greek, and Heraclitus is using it to mean something a little different, as you will see.

[14] Earlier this year, Mr. Turner let me shoot an arrow with his bow, and I got to have this experience firsthand.

The Natural World
Heraclitus saw all of these principles in the natural world. The cosmos was unified and harmonious—there was some *logos* that was holding it all together. But there was also much *strife*, much war between opposites, that resulted in all of the change that we see. This strife, he said, always balanced out in the end.

Unity, harmony, *Logos*, strife, balance, change—to see how Heraclitus saw all of these things working together in the natural world, let's take a look at his favorite image: fire.

Fire
Let us imagine a fire, slowly burning a piece of paper, like the one pictured below.



Watch, in your imagination, as the fire consumes the paper.

Bit by bit, the paper turns to ashes and smoke.

We are already familiar with this as a good image of ***change***: paper changes into smoke and ash. It's also a good illustration of the ***strife*** or war that Heraclitus says is involved in all change.

In some sense the fire is raging—we see the strife. But look how slowly and evenly and steadily it is burning—is there not also here a sense of ***balance***?

And finally, what is at the heart of all of it, **bringing together** and **uniting** strife and balance, causing and directing the change from paper to smoke? That's right—*Fire*.

The Three World Masses, Governed by Fire
Fire, as we just saw, unites all of Heraclitus' ideas about the world into one. This had a profound effect on how Heraclitus saw the natural world.

Previous thinkers had said that all was water, or all was air; Heraclitus responds that no, everything is *fire*. But he goes even further than those thinkers went with their materials—it was not only the material out of which everything was made, it was also the *cause* of all changes and the *director* of those changes. Fire, in a very real way, was *in charge of the cosmos*.

The cosmos, he said, consists of three main substances: earth, water, and fire. These substances could all change back and forth between one another. Earth could change to water, water could change to fire, and so on. But, in all of this, fire is in charge, directing every change. All things can turn into fire, and fire can turn into all things.

"All things are an equal exchange for Fire and Fire for all things,
as goods are for gold and gold for goods."

.

He also says:

"This cosmos…always was, is, and shall be: an everlasting fire,
kindling in measures and going out in measures."

This is his explanation of the world that we see around us. The whole universe is an everlasting fire, though it is never all on fire at once: part of it is kindled, and another part goes out. Part of it (e.g. the sun) is on fire right now, while part of it (e.g. a mountain) is not currently aflame.

Do you see his central ideas coming through again here? There is change and strife, as parts of the world go up in flame. But there is also balance, for not all is burning at once. And underlying all of the things that we experience—earth, water, fire, and all the changes that we see—there is a single thing unifying them all, the *Logos* of the natural world: *fire*!

The Soul is Fire

Not only is the entire visible, material world made of fire and changed by fire, but even our very souls are fire.

The idea that the soul is fire actually has a long tradition and was indeed a common idea at the time. And it makes sense if you think about it. When you feel something very strongly, your heart is *burning*. When you feel full of life and energy, you feel like you're *on fire*. And conversely, when a person dies—and the soul has left the body—the body loses its heat and becomes cold.

So, Heraclitus says, the soul is fire. And look at how well this idea corresponds to the rest of his theory:

What unites all the material parts of the universe? → Fire!
What unites all the material parts of the human body? → Soul!

What directs and governs all action and change in the universe? → Fire!
What directs and governs all the actions and changes of a human being? → Soul!

Heraclitus said that every human soul is actually a little piece of the great cosmic fire, and would rejoin that great cosmic fire after death.

He also explained why wisdom is good for the soul, in this way. The soul, he said, is fire. And fire is the *Logos*. Therefore, when the soul (which is fire) comes in contact with the *Logos* (which is also fire), it is enflamed and burns brighter than ever. And this—when the soul unites with the *Logos*—is what we call wisdom.

Conclusion

Are you starting to get a sense for how Heraclitus thought about the world? It is hard to understand, to be sure—probably the most difficult theory we have seen yet. Indeed, Heraclitus *wanted* it that way. But hopefully you are at least by now getting some sense for the underlying unity—the *Logos*—that Heraclitus saw in all things.

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Wednesday: "Chapter 7: Heraclitus" on Special Reading pp. 13-17

1. The word Heraclitus uses to describe the change and opposition between elements is…
   a. Hatred
   b. Squabble
   c. Strife
   d. Animosity

2. Heraclitus argued that what we normally think of as opposites are actually _____ and the _____ _____.

3. *Logos* (which usually means reason, account, study, and is where we get the word "logic") is also being used here to mean the principle of _____ and _____ in the _____.

4. To explain how opposites can actually be in *balance* with one another, Heraclitus uses an image of…
   a. Two donkeys tied to opposite ends of a cart
   b. A see-saw
   c. Pushing a stone up a hill
   d. The tension of a bow-string

5. What element does Heraclitus argue is the governing principle of the natural world? What is one reason for his choice?

_____
_____
_____
_____
_____

6. According to page 16, how does fire burning up a piece of paper show both **strife** and **balance** at the same time?

_____
_____
_____
_____
_____

Next page→

Wednesday continued: "Heraclitus" on NoS pp. 94-95:

6. Read fragment 63 carefully. What do you suppose Heraclitus means when he says, "We step into and we do not step into the same rivers"? In other words, if the water in a river one day is technically different water than the water flowing in the same spot the next day, is it the same river?

_____
_____
_____
_____
_____

7. Choose one Fragment from either page and find a connection between that passage and any of our earlier readings.

_____
_____
_____
_____
_____
_____

Chapter Eight: Parmenides

Different Views of Change

Change, as you may have noticed, has been a very important part of every natural scientist's theory so far. Indeed, noticing change—for example, the change of grass to cow—was part of what got us started on this inquiry in the first place. Since then, several of the thinkers we've met have come up with an explanation for how or why change happens. See if you can remember who said what:

a) All change is the result of condensation and rarefaction.

b) All change is the result of balanced "strife" between opposites, overseen and moderated by fire.

c) All change is the result of warring opposites, who pay "penalty and retribution" to one another for their "injustice."

Answers are at the bottom of the page.[15]

Today we will meet someone new, who looked at change and said something astonishingly different.

Parmenides

This thinker's name was Parmenides (par-MEN-ih-dees).
Parmenides was born in the western Greek city of Elea, around 515 B.C. Plato tells the story of how one time, when Parmenides visited Athens, Socrates[16], who was still very young, went to hear him speak.

Parmenides had a style somewhat like that of Pythagoras and Heraclitus—shrouded in mystery. Rather than writing out his thoughts in a clear scientific explanation, Parmenides wrote them in the form of a poem, to give them the sound of wisdom coming from the gods.

The Poem

The poem begins with Parmenides in chariot, speeding down the "road of the god," being pulled along by "wise horses" and led by "maidens." The horses draw the chariot upward, into the sky, until they reach the Gates of Day and Night, which are alternately closed and locked by Justice. Parmenides worries that he will not make it through, but the maidens persuade Justice to open the gates for him, and he passes through them, out of the world.

Once past the Gates of Day and Night, he meets a goddess, who welcomes him and congratulates him on making it so far. Then the goddess says:

"There is need for you to learn all things—
both the unshaken heart of persuasive Truth
and the opinions of mortals, in which there is no true reliance."

And that is when she reveals the incredible and shocking Truth…

[15] a) Anaximenes, b) Heraclitus, c) Anaximander

[16] Socrates was the teacher of Plato, and Plato the teacher of Aristotle.

Two Possible Paths

*Everything either **is**, or **is not**.*

This is the truth that the goddess reveals to Parmenides. Either something *is*, or it *is not*: that is, it *exists*, or it *does not exist*. Actually, it seems fairly straightforward—do you agree with it?

Either this coffee exists, or it does not exist.

Either dumbo octopuses exist, or they do not exist.

There does not seem to be any third option, does there? There's no "kind of exists," because even that would be a type of existence.

Sounds reasonable to me!

The First Way is the True Way

Then the goddess continues. Although there are two paths—*is* and *is not*—only <u>one</u> is the true way:

It *is*.

Hmm, now this seems a little strange. I thought there were two options. Why can I only choose one of them? Why can't I say that something *is not*, or *does not exist*?

The goddess explains: *It is actually impossible to say that something does not exist*. If you try, you are uttering either 1) falsehood or 2) nonsense.

1) If you say, for example, that water does not exist, you are speaking falsehood. And falsehood is obviously not the true path.

2) But let's say you claim "Mr. Jingle does not exist." If he *does* exist, you are speaking falsehood, as we saw above. If he *does not* exist, then what are you actually talking about? Your subject, "Mr. Jingle," would be as nonsensical and meaningless as any other non-existing thing, like "glubbawump." Do you see? Saying "Glubbawump does not exist" is not really true or false—it simply doesn't mean anything, because "glubbawump" is meaningless.[17]

The Shocking Conclusion

Are you following so far? The goddess said there are two ways—*is* or *is not*. And then she pointed out that, of these, there is only one true way—*is*—because any time you say "is not" you are either speaking falsehood or nonsense.

Since there is only one way—that it *is*, or *exists*—it means that everything that you can think of *actually exists* and is in fact, already in existence. And from this bewildering statement, an even more bewildering conclusion follows:

There is no such thing as change.

That's right—all change is just an illusion. Our five senses do not present the world to us the way it really is. It only *appears* that things are changing and moving, coming-to-be, growing, and passing away.

[17] This is a very tricky philosophical argument, and I encourage you to give it some thought. Is it really *meaningless* nonsense to talk about leprechauns, for example, if they do not exist? Or am I still able to mean *something*?

In reality, however, we know that they are not. *Every kind of change and motion you can think of is absolutely impossible.*

Does the sun rise and set? No.

Does summer eventually turn to winter? No.

Do new plants and animals come into being, grow, and then pass away? No.

Can I go get a drink of water? No.

How is this possible? Though it seems impossible, says Parmenides, that is just because our senses are deceiving us. We can know by using our *reason*—the logical thinking that we just did—that no kind of change or motion is possible.

In case you're not convinced, let's repeat the argument:
Everything either *is*, or *is not*. But saying "is not" is nonsense or falsehood. The only true way, therefore, is to say "is." And that means that everything you can think of actually *already exists*.

"But why does this mean there is no change?" you ask. Great question! Let's try it out. Let's see if you can claim that something changed, that something new has come into existence.

You:	"I'm so excited, I went into my backyard yesterday and there is a new chicken!"
The goddess:	"A new chicken? What do you mean?"
You:	"Well, this chicken used to *not* exist, and now it *does* exist."
The goddess:	"Say that first part again?"
You:	"The chicken did not exist…"
The goddess:	"I thought I already told you that was impossible."
You:	"But…"

Another common way of expressing this idea is: ***being cannot come from non-being***. That is, something cannot come from nothing. A being, like a baby chicken, cannot suddenly come to be, because then you would have to say it came from non-being (that is, non-existence), which has been shown to be impossible.

The same argument applies for *every change*, even small ones—like changes in color. If an apple *is* red right now, it must have always been red; otherwise, you would have to say "The apple's redness did not exist," and Parmenides has shown that that is not possible.

Yes, indeed, this is a truly shocking idea about the natural world. Nothing changes or moves, and everything in existence always has existed and always will. Can we really accept this? Can we really

believe that everything our senses tell us is a lie? Well, says Parmenides, if you are going to follow reason and logical thinking, you are going to have to abandon your senses.

Parmenides' Contribution to Natural Science

Just in case you are worried right now—"Are my senses really deceiving me? Is everything I've ever thought about the world just one big lie??"—let me put your fears to rest. You *can* trust your senses to tell you truth about the world around you. Remember, as Aristotle showed us in the beginning of this school year, all knowledge begins in the senses.

Yes, Parmenides was wrong about change—change *is* possible—but that does not mean his ideas were worthless. Quite the contrary. When Parmenides started teaching his ideas, he caused quite a stir! People felt very troubled by it, especially because they did not know how to disprove Parmenides. Rather than worrying that change is impossible, however, they simply realized that their understanding of change just must not be good enough. Parmenides' paradox inspired them to seek a deeper understanding of what change really is.[18] The first person to give an excellent response to Parmenides was a natural scientist named Empedocles. It is his answer that we will be reading about in the next chapter.

[18] The problem was not fully settled until Aristotle showed how all change is truly possible in his book entitled *The Physics*. In the meantime, others made very good attempts.

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The Pre-Socratic Philosophers: Parmenides
***Nature of Science* textbook: pp. 96-97**
Supplementary Readings: pp. 20-23

1. Which of the following has been a very important part of every natural scientist's theory?
    a. Motion
    b. Opposites
    c. Water
    d. Change
    e. The Senses

2. Which foundational Greek philosopher heard Parmenides speak?
    a. Socrates
    b. Plato
    c. Aristotle
    d. Pythagoras
    e. None of the above

3. One particularly unique aspect of Parmenides' writing is that he wrote his theories in the form of a _____ rather than a direct explanation.

4. What are the two possible paths the goddess reveals to Parmenides?

    a. Path one: _____
    b. Path two: _____

5. According to Parmenides, it is impossible to say _____ _____ _____ _____ _____.

6. In the direct reading from Parmenides (p. 96 – parag. 4 at the bottom), the goddess describes "the way" or Being. List 4 attributes (characteristics) of "the way".
    a. _____
    b. _____
    c. _____
    d. _____

(Worksheet continues onto the next page)

7. What is the potential problem with saying that thing can come into being, or be generated?

   _____

   _____

   _____

8. According to Parmenides, what always deceive us?
   a. The gods
   b. The Earth
   c. The senses
   d. The elements

9. What shocking claim does Parmenides make?
   a. Air is truly the fundamental material of the universe
   b. Change and motion are impossible and do not exist
   c. Matter does not truly exist
   d. Air, water, and fire are actually the same thing

10. Consider your answer to question 9. Which Greek thinker finally showed that claim to be an error?

    _____ showed that claim to be an error in his book entitled _____.

Chapter Nine: Empedocles

Parmenides' Paradox

Recall from the last chapter how Parmenides proved—with a very powerful, logical argument—that change was impossible. This, as we discussed, is a terrifying thought, because it would mean that everything our five senses tell us is a lie. We want to reject the argument immediately, but there's a problem—Parmenides' argument is so good that it seems impossible to disprove.

Empedocles

Among those who were troubled by Parmenides' conclusion, was the gifted philosopher and natural scientist named Empedocles (em-PED-uh-klees). Empedocles is described by ancient authors as an "associate and emulator" of Parmenides—that is, they knew each other, and Empedocles sought to emulate (imitate) Parmenides in his science and philosophy. Empedocles, to be sure, respected Parmenides very much and was devoted to his teaching. He believed Parmenides was right—being cannot come from non-being. And yet, he could not accept what Parmenides claimed was the logical conclusion: that all change was impossible. Empedocles was determined to find a solution—some way to show that Parmenides was *right about being, but wrong about change.*

Empedocles eventually came up with a solution and wrote all of his ideas down in a poem (in imitation of Parmenides[19]). Let us examine this theory together and judge whether or not it met Empedocles' ambitious goal of proving that something cannot come from nothing, and yet change is still possible.

The Four Elements

Though he lived in the west, and was influenced by western thinkers like Pythagoras and Empedocles, he had an idea about the natural world that was in some ways more in line with the old Milesian thinkers in the East: Thales, Anaximander, and Anaximenes. You'll remember that each of these Eastern Greek thinkers was in search of the ultimate material principle that everything is made of. Thales said water, Anaximander said the indefinite, and Anaximenes said air.

A name commonly used to describe an ultimate material cause is "*element*." An element is an ultimate underlying material cause that everything is made of, but itself is not made of anything. When we described water and air as *basic* in this way, we could have also used the word *element*.

Empedocles took this Milesian idea of *elements*, but unlike those thinkers who each said that there was one element, Empedocles said that there were *four elements: fire, air, earth, and water.* These were the materials that everything else was made of, and which themselves were not made of anything. (Thus, contrary to Thales' idea, water could never become earth; or, contrary to Anaximenes' theory, air could never become water no matter how much you condensed it).


Fire


Air


Earth


Water

[19] Everyone—ancient and modern alike—agrees that Empedocles was the superior poet.

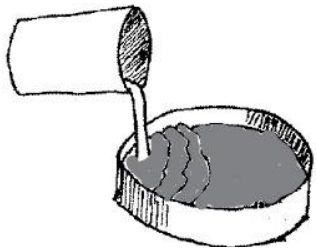
These four elements, he said, were *eternal*. They had always existed and always will exist and can never be changed at all in any way. Does this ring a bell? It sounds very much like Parmenides! It looks like he is following the "one true path" that the goddess points out, that everything *is* or *exists*, and always will. Let us see now what he says about change.

What about Change?

Water, he says, has always been and always will be. No new water is ever created, and no water is ever destroyed. All the existing water will never change even the slightest bit. And the same thing goes for fire, and for air, and for earth.

So far, this is a lot of *not changing*—how then did Empedocles explain all the change that he saw in the world? His solution lay in the idea of *mixtures*.

Let's think about Water and Earth—neither can be created or destroyed or changed in any way. *But* mix them together and voila! – you've "created" mud! And if you were somehow to separate the water and the earth once more, then you would have "destroyed" the mud.



This, Empedocles said, is really what is meant by coming-to-be and passing away. When something "new" is "created," it is not *really* creation—it is just those same elements that have always been around, coming together in a new mixture.

In this way, Empedocles has both affirmed Parmenides and affirmed our senses. Something cannot come from nothing—this is true. But our senses are not deceiving us. When it *looks* like something new has come into existence, we might call it "creation," but really it is more like *combination*. Nothing new ever comes into existence—it is just that the elements, which have always been around, are coming into a new combination.

Do you see the brilliance of this solution? And he does not stop there, but goes on to explain the entire system by which our whole world came to be the way that it is. Keep reading!

Love and Strife and the "Creation" of the World

In many of the theories we have encountered so far, change happens between opposites. And this is no different in Empedocles' theory. In this theory, the opposites are *Love* and *Strife*.

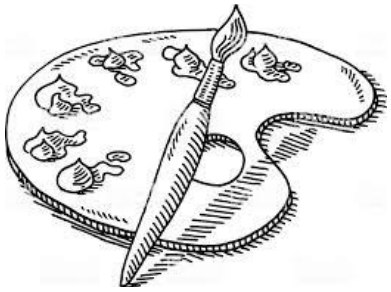
When elements come together in a mixture, they are brought together by Love. When they are separated out, they are being torn apart by Strife.

Love and Strife alternate, or "take turns," affecting the elements. At times, all things are being brought together by Love, and, at other times, torn apart by Strife. There was a time, says Empedocles, at which *all* the elements—everything that exists—were brought together in perfect harmony and they formed a perfect Sphere. But then it was Strife's turn, and Strife separated *everything,* leaving four distinct masses—earth, air, water, and fire—each completely separate. Then, it was Love's turn again, and Love began joining the elements back together again.

And this is where we are right now—in the middle of the process that Love has begun. Some of the elements have joined together through Love, making things like plants and animals. But a lot of the

elements are still separate, which is why we can easily see huge masses of earth, huge oceans of water, a whole sky of air, and all the balls of fire in the heavens (sun, stars, etc.).

The Painter Analogy



Can it really be that everything that we know of is really just a combination of four elements? Really, says Empedocles, it should not be that surprising. Just think of a painter. He begins with a blank canvas a few colors of paint—maybe red, blue, yellow, and white—and from there can paint anything and everything in the universe. So it is with the elements. Depending on how Love (the painter in the analogy) joins the elements together, any number of things can result.

Conclusion

What an incredible theory! Empedocles has succeeded in explaining just about everything[20]. He affirms our senses by showing that change is real, while yet upholding Parmenides' assertion that something cannot come from nothing. And then he even goes beyond that to explain how plants, animals, and human beings have come into existence, and indeed why the whole world as we know it appears the way it does. This is one powerful scientific theory!

Let's take a moment here, looking at Empedocles' incredible accomplishment, to appreciate how far we have come. Before Thales, no one had ever considered these questions. And now we have an entire system—with four elements and two opposite forces—that explains the entire universe and even answers a very difficult philosophical challenge about the possibility of change.

But do you see how we got here? You have probably, by now, caught on to the pattern—the pattern that makes this sort of theory possible. Each natural scientist that we have read about has responded to those that came before him, attempting to keep the strengths of their theories, and fix the weaknesses. These scientists were listening and responding to one another and are thus in *conversation* with one another. It is through being a part of a conversation like this that the best scientific discoveries can be made.

Keep in mind, as we continue reading, that we ourselves are *listening in* on that conversation. Indeed, our entire study of Chemistry will be listening to a great conversation, between some of the world's greatest natural scientists, about the ultimate material causes of the universe. As you read and study, you are listening—when it comes time for you to speak, what will you say?

[20] He actually wrote so many other things that also fit in with this theory—theories on the soul and the afterlife, on evolution, on how to live virtuously, on how to be healthy—but we do not have time to discuss them here.

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Friday: "Empedocles" on NoS pg. 99:

1. According to the second sentence, what does Empedocles say are the causes of materials "coming together" or being "borne apart" (meaning broken apart)?

_____
_____
_____
_____

2. What are the four most basic elements that Empedocles lists in the middle of the first paragraph?

_____
_____
_____
_____

3. If each element is "equal and of the same age" as the others, how many first principles does Empedocles believe there are? Does he believe that there is one first principle that the others come from, or four distinct first principles?

_____
_____
_____
_____
_____

Next page→

Friday continued: "Chapter 9: Empedocles" on Special Readings pp. 26-28

4. According to page 27, how does Empedocles explain changes that we can observe in substances?

_____
_____
_____
_____
_____

5. According to the third paragraph in the **"Conclusion"** section, what is the pattern that we've seen in all of the Pre-Socratic thinkers thus far?

_____
_____
_____
_____
_____