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## Logical and illogical exegeses of hydrometeorological phenomena in ancient Greece

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## Mythological views

Attic red figure vase,  
**6th century BC**  
depicting the battle of  
Hercules against  
Achelous (Acheloos)



Achelous is the greatest in  
discharge river of Greece

As demystified by the historian **Diodorus Siculus (c. 90-30 BC)** and  
the geographer **Strabo (c. 64 BC-24 AD)**, the meaning of the victory  
is related to the channel excavation and the construction of dikes to  
confine the shifting bed of Achelous

## Mythological views (continued...)

Detail of the Wind Tower in Athens (**2nd or 1st century BC**) showing Kaikias, the northeast wind holding a shield with hail-stones



Even though science had been significantly advanced by 2<sup>nd</sup>-1<sup>st</sup> century BC (by the end of the Hellenistic period) and scientific views had gained ground, still mythological views are popular (and particularly inspiring in arts)

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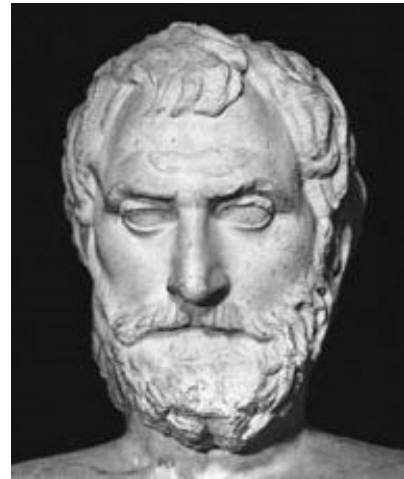
## The emergence and development of philosophy and science

- Around 600 BC a new approach to understanding nature emerged in Ionia, which went beyond the myths and searched for physical explanations
- Philosophy and science in classical Athens during the 5<sup>th</sup> and 4<sup>th</sup> centuries BC were developed further forming a body of knowledge that would be dominant for about 2000 years
- However, in the Hellenistic period (c. 4<sup>th</sup>-1<sup>st</sup> BC) the scientific views were more advanced and closer to modern science

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## Thales of Miletus (640-546 BC)

- Was the founder of the Ionic philosophy (according to many, the father of philosophy and of science)
- Proclaimed water as the fundamental substance of the world
- Accomplished the diversion of Ales river (thus emphasizing the link of technology and philosophy at the beginnings of the latter)
- Proposed an incorrect physical exegesis for the “Nile puzzle”\*, based on the regime of winds (thus emphasizing the importance of hydrology at the beginnings of science)



\* the fact that the Nile floods occur at the summertime when rainfall in Egypt is minimal

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## Anaximander (c. 610 BC – c. 547 BC)

- Understood the relationship of rainfall and evaporation:  
*“Rains are generated from the evaporation [atmis] that is sent up from the earth toward under the sun”*



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## Anaximenes of Miletus (585-525 BC)

Devised logical explanations for

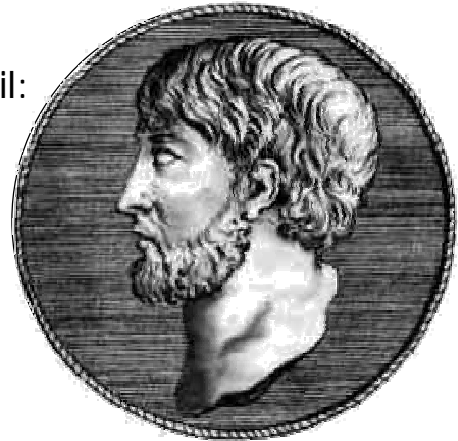
- the formation of clouds, rain and hail:

*"hail is produced when precipitating water from clouds freezes; snow is produced when the water in the clouds freezes"*

- the creation of winds:

*"they are caused when the air density is decreased, so the air becomes light and then starts to move"*

- the formation of the rainbow (iris)
- lightning (an attempt of an explanation without the intervention of Gods)



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## Xenophanes of Colophon (570-480 BC)

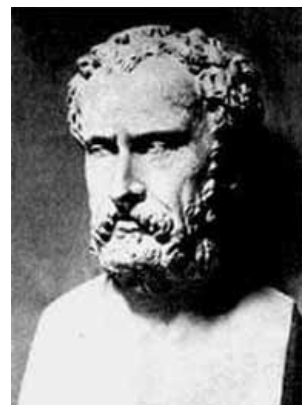
- Integrated the concept of **hydrological cycle**

*"The sea is the source of water and of wind,*

*For without the great sea, there would be no wind*

*Nor streams of rivers, nor rainwater from on high*

*But the great sea is the begetter of clouds, winds, and rivers"*



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## Anaxagoras of Clazomenae (500-428 BC)

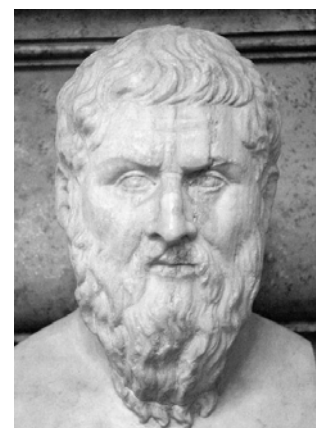
- Considered that the differences in the **air density**, caused by the **solar heat**, were responsible for the creation of **winds**
- Explained the rainbow (iris):  
*“iris is the **reflection** of the **solar light** incident to the clouds”*
- Attempted to explain the “Nile puzzle” maintaining that the snow melting in the mountains of Ethiopia in spring, causes summer floods in the regions of Delta of Nile, with time delay
- Transplanted the Ionic philosophy to Athenians (including his students Pericles, Euripides, Sophocles, and Herodotus)



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## Plato (c. 427–c. 347 BC)

- Despite his great contributions in metaphysics, epistemology, politics and ethics, his influence in natural philosophy/hydrology is a regression:  
*“**Homer** [...] says ‘Far off, the lowest abyss beneath the earth’ [...] which elsewhere he and many other poets have called **Tartarus**. For **all the rivers** flow together into this **chasm** and flow out of it again, and they have each the nature of the earth through which they flow. And the reason why all the streams flow in and out here is that this liquid matter has no bottom or foundation. [...] And when the water retires to the region which we call the lower, it flows into the rivers there and fills them up, as if it were **pumped** into them; and when it leaves that region and comes back to this side, it **fills the rivers** here; [...] Thence they go down again under the earth [...] and **flow again into Tartarus**”*



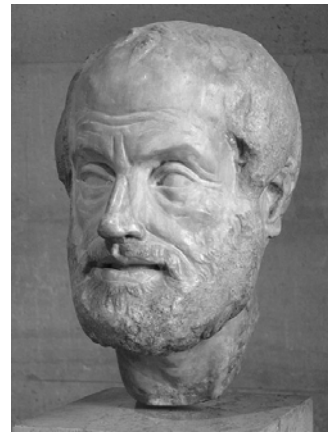
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## Aristotle (384-328 BC)

- Was a student of Plato but his theories were influenced by Ionic philosophers
- His treatise *Meteorologica* is a great contribution to the explanation of hydrometeorological phenomena:

*"the **sun** causes the **moisture to rise**; this is similar to what happens when water is heated by fire"*

*"the **vapour that is cooled**, because of lack of heat in the area where it lies, condenses and turns from air into water; and after the water has formed in this way it falls down again to the earth. The **exhalation** of water is **vapour**; air **condensing into water is cloud**."*



## Aristotle (continued...)

- Recognized the principle of mass conservation within hydrological cycle:

*"Thus, the **sea will never dry up**; for the **water that has gone up beforehand will return** to it; and if this has happened once we must admit its **recurrence**."*

*"Even if the same amount does not come back every year or in a given place, yet in a certain period **all quantity that has been abstracted is returned**."*
- Understood "change" perhaps better than we do today:

*"The same parts of the earth are not always wet or dry, but they change depending on the formation or the disappearance of rivers."*

*"But if **rivers are formed and disappear** and the same places were not always covered by water, the sea must change correspondingly. And if the sea is receding in one place and advancing in another it is clear that the **same parts of the whole earth are not always either sea or land**, but that **all changes in course of time**."*

## Theophrastus (372-287 BC)

- Was the successor of Aristotle in his Peripatetic school
- Corrected/completed Aristotle's theories:  
*"The movement of air is wind"*
- Understood the mechanisms of evaporation and particularly the influence of wind:

*"The reason that **winds**, which are cold, dry more quickly than the sun, which is warm, and the coldest winds most of all, must be that they **create a vapour and remove it** [...] while the sun leaves the vapour"*



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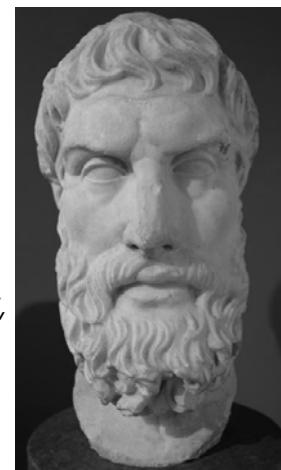
## Epicurus (341-270 BC)

- Was one of the most prominent opponents of superstition in history
- Studied, and attempted to explain hurricanes, hail, snow, dew, hoarfrost, rainbow, lightning and thunder, including the time lag between the last two:

*"... perhaps, the two phenomena being simultaneous, the **lightning arrives** among us **more rapidly** than the noise of the thunder-bolt, as is in fact remarked in other cases when we see at an instance the clash of two objects"*

- Developed epistemological views that could stand in a modern discussion:

*"It is not good to desire what is **impossible**, and to endeavour to enunciate a **uniform theory about everything** [...] Besides, it is **not** here a **question** about reasoning on new principles, and of laying down, **a priori, rules for the interpretation of nature**; the only guides for us to follow are the appearances themselves."*



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## Hero (Heron) of Alexandria (~ 150 BC)

- Mostly known as an engineer, but his conception of physics is very advanced, as evidenced from his treatise *Pneumatica*:

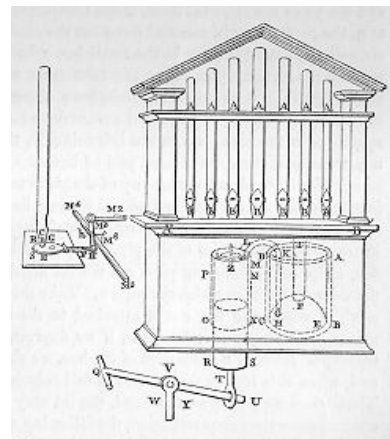
*“Vessels which seem to most men empty are not empty, as they suppose, but full of air. Now the **air**, as those who have treated of physics are agreed, is **composed of particles** minute and light, and for the most part invisible. If, then, we pour water into an apparently empty vessel, air will leave the vessel proportioned in quantity to the water which enters it. This may be seen from the following **experiment**. Let the vessel which seems to be empty be inverted, and, being carefully kept upright, pressed down into water; the water will not enter it even though it be entirely immersed: so that it is manifest that the **air, being matter**, and having itself **filled all the space** in the vessel, does not allow the water to enter. Now, if we bore the bottom of the vessel, the water will enter through the mouth, but the air will escape through the hole.”*



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## Hero's *Pneumatica* (continued...)

*“Hence it must be assumed that the air is matter. The air when set in motion becomes wind (for **wind** is nothing else but **air in motion**), and if, when the bottom of the vessel has been pierced and the water is entering, we place the hand over the hole, we shall **feel the wind** escaping from the vessel; and this is nothing else but the air which is being driven out by the water. It is not then to be supposed that there exists in nature a distinct and continuous **vacuum**, but that it is distributed in small measures through air and liquid and all other bodies. [...] Winds are produced from excessive exhalation, whereby the air is disturbed and rarefied, and sets in motion the air in immediate contact with it. This movement of the air, however, is not everywhere of **uniform velocity**: it is more violent in the neighbourhood of the exhalation, where the motion began.”*



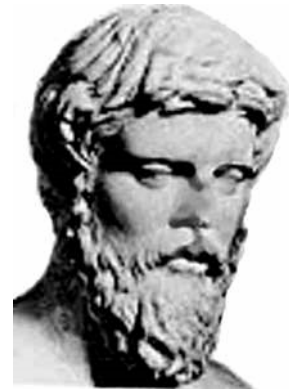
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## Formulation of scientific theories needs courage...

... as pointed out by **Plutarch** (c. 46- 127):

*"Anaxagoras was the first to put in writing, most clearly and most **courageously** of all men, the explanation of the moon's illumination and darkness ... His account was not common property, but was [still] a secret, current among only a few ... For in those days they **refused to tolerate the physicists** and stargazers, as they were called, who presumed to fritter away the deity into unreasoning causes, blind forces, and necessary properties. Thus **Protagoras was exiled**, and **Anaxagoras was imprisoned** and with difficulty saved by Pericles."*

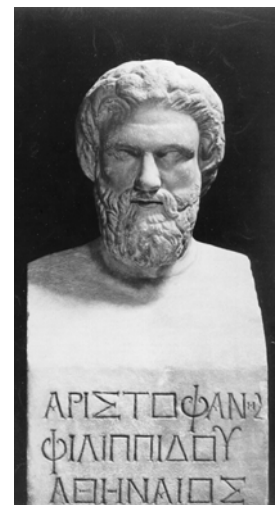


... and as indicated from Epicurus, against whom (and his theories) several accusations were leveled, some of which (among with misconceptions of his theories) survive even today – but his books have not survived

## Understanding and acceptance of scientific exegeses is not easy ...

... as satirized by **Aristophanes** (c. 448 - c. 385 BC) in his comedy *Clouds* :

- *Socrates: What Jupiter? Do not trifle. There is **no Jupiter**.*
- *Strepsiades: What do you say? Who rains then? For first of all explain this to me.*
- *Soc.: These to be sure. I will teach you it by powerful evidence. Come, where have you ever seen him raining at any time without **Clouds**? And yet he ought to rain in fine weather, and these be absent.*
- *Strep.: By Apollo, of a truth you have rightly confirmed this by your present argument. And yet, before this, I really thought that Jupiter caused the rain. But tell me **who** is it that **thunders**. This makes me **tremble**.*
- *Soc.: These, as they roll, thunder.*
- *Strep.: In what way? you all-daring man!*



## Aristophanes' *Clouds* (... continued)

- *Soc.:* When they are full of much water, and are compelled to be borne along, being necessarily precipitated when full of rain, then they fall heavily upon each other and burst and clap.
- *Strep.:* Who is it that compels them to borne along? **Is it not Jupiter?**
- *Soc.:* By no means, but **aethereal Vortex**.
- *Strep.:* Vortex? It had escaped my notice that Jupiter did not exist, and that **Vortex now reigned** in his stead. But you have taught me nothing as yet concerning the clap and the thunder.
- *Soc.:* Have you not heard me, that I said that the **Clouds**, when full of moisture, dash against each other and **clap by reason of their density?**

## Conclusions

- A phenomenon perhaps unique in history, which occurred in Ancient Greece, is that technological needs triggered physical explanations of natural phenomena, thus enabling the foundation of philosophy and science
- The study of hydrometeorological phenomena had a major role in the development of science
- Many of the theories are erroneous but there are many impressive elements in Greek exegeses of hydrometeorological processes such as the evaporation, the creation of clouds, rain, hail and snow, and the evolution of hydrological cycle
- During Hellenistic period the scientific theories were more advanced and closer to modern views

# Sources

## Images

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