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The importance of water in the historical development of science

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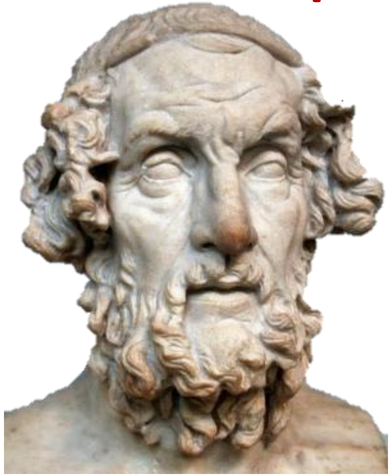
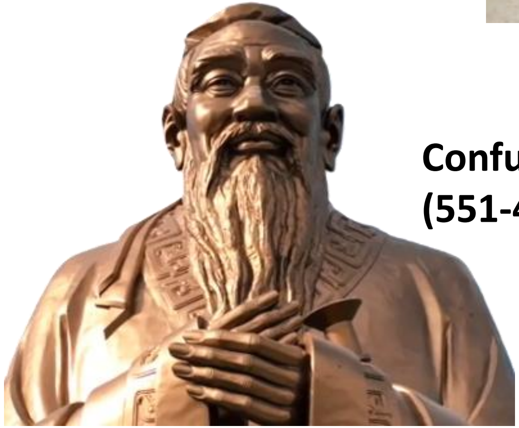
Presentation available online: http://www.itia.ntua.gr/2545/

China and Greece: Parallel evolution in philosophy

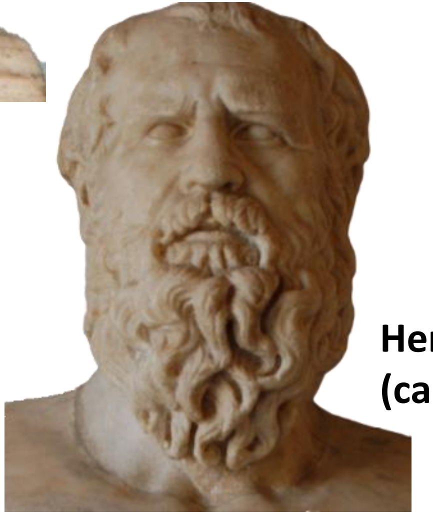
Lao Tzu
(6th century BC)



Homer
(8th Century BC)



Confucius
(551-479 BC)



Heraclitus
(ca. 540-480 BC)

Image sources:
Wikipedia,
https://news.cgtn.com/news/2022-09-29/Nishan-birthplace-of-great-Chinese-philosopher-Confucius-1dIXOx25IyY/index.html

The parallel cultural development in China and Greece

- There are striking similarities between ancient Greek and Chinese philosophies, which are most plausibly explained as independent development (coincidence rather than interaction).
- The absence of concrete evidence for direct or meaningful indirect contact during the 6th–5th centuries BC supports this view.
- However, the indirect interaction hypothesis (e.g. through Persians) cannot be entirely ruled out.
- It is useful to study the similarities to understand the analogous intellectual and social challenges faced by both cultures.

Yin and yang—or dialectical philosophy—in China and Greece

CHINA

According to the Chinese philosophy, the concept of yin-yang (阴阳; 陰陽), possibly introduced by the Chinese philosopher Zou Yan (305–240 BC), describes how seemingly contrary forces are interconnected and interdependent in the natural world, and how they give rise to each other in turn. Opposites thus only exist in relation to each other.

GREECE

Similar ideas had been proposed by ancient Greek philosophers—in particular Heraclitus (ca. 540-480 BC):

- *«Τὸ ἀντίξουν συμφέρον καὶ ἐκ τῶν διαφερόντων καλλίστην ἁρμονίαν καὶ πάντα κατ' ἔριν γίνεσθαι.»*
  (*"Opposition unites, the finest harmony springs from difference, and all comes about by strife."*)
- *«Ὁ θεὸς ἡμέρη εὐφρόνη, χειμὼν θέρος, πόλεμος εἰρήνη, κόρος λιμός* [τἀναντία ἅπαντα].»
  (*"God is day and night, winter and summer, war and peace, surfeit and hunger* [all the opposites]").

Basic epistemological principles in China and Greece

CHINA	GREECE

On knowledge, ignorance and intellectual humility: the limits of knowledge as a mark of true wisdom

- *"To know what you know and what you do not know, that is true knowledge."* (Confucius, 551-479 BC, Analects, 2:17)

- «[Σωκράτης ἔλεγεν] *εἰδέναι μὲν μηδὲν πλὴν αὐτὸ τοῦτο* [εἰδέναι μηδέν].»
("[Socrates used to say] *he knew nothing except just the fact of his ignorance*.") (Socrates, 470 – 399 BC; quoted by Diogenes Laertius, *Lives of the Philosophers*, 2.32.)

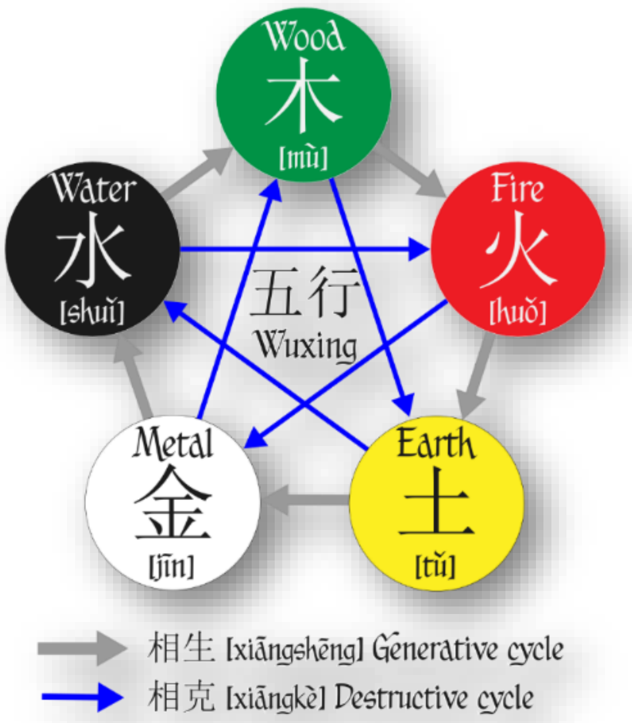
On the importance of terminology and clarity (sapheneia)

- *"If terms be incorrect, then statements do not accord with facts.* […] *Hence whatever a wise man denominates he can always definitely state, and what he so states he can put into practice, for the wise man will on no account have anything remiss in his definitions."* (Confucius, Analects, 13.3.2, 5-7).

- «*Ἀρχὴ παιδεύσεως ἡ τῶν ὀνομάτων ἐπίσκεψις*.»
("*The beginning of education is the inspection of names*.") (Attributed to Socrates by Epictetus, Discourses, I.17,12)
- «*Ἀεὶ διὰ τῶν ἀληθῶς μὲν λεγομένων οὐ σαφῶς δὲ πειρᾶσθαι λαβεῖν καὶ τὸ ἀληθῶς καὶ σαφῶς*.»
("*We must always endeavor, from statements that are true but not clearly expressed, to arrive at a result that is both true and clear*"; Aristotle, 384–322 BC, Eudemian Ethics 1220a).
- «*Εἰσὶ μὲν οὖν καὶ τούτων τὰ πλείω ἀνώνυμα, πειρατέον δ᾽* […] *αὐτοὺς ὀνοματοποιεῖν σαφηνείας ἕνεκα καὶ τοῦ εὐπαρακολουθήτου*.»
("*Now most of these* [concepts] *have no names, and we must try* […] *to invent names ourselves for the sake of clarity and ease to follow*"; Aristotle, Nicomachean Ethics, 985a).

Five elements in ancient Chinese and Greek cosmologies

CHINA



GREECE

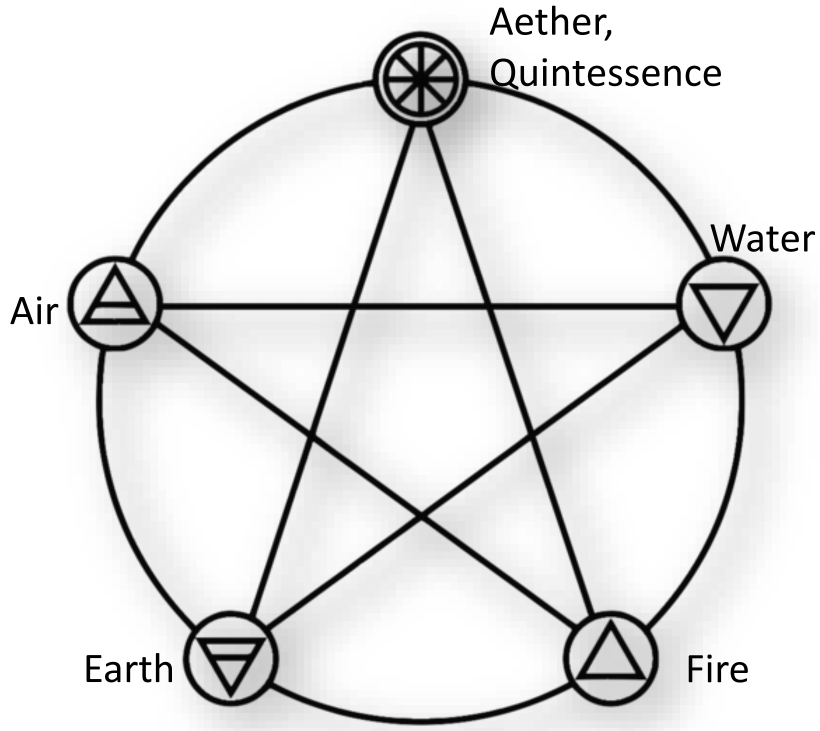
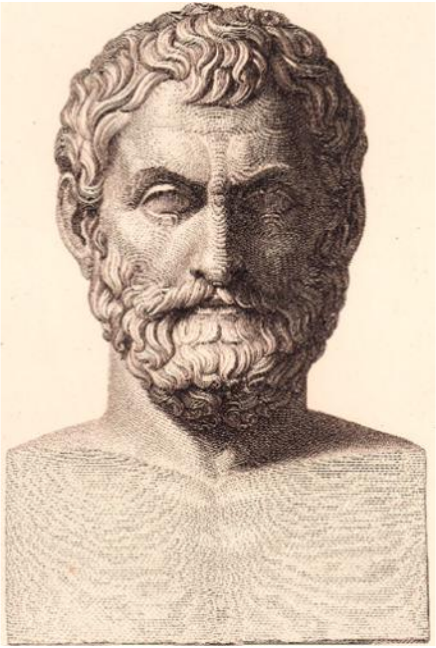


Image sources: https://en.wikipedia.org/wiki/Wuxing_(Chinese_philosophy); https://commons.wikimedia.org/wiki/File:Five_Elements_Pentacle.png

Thales, the four (out of five) elements, and the primacy of water



Thales (624–548 BC)
Image source: Visconti (1817)

- Four of the five elements of the Greek cosmology, i.e. the primordial elements from which everything was made, namely Earth, Water, Air and Fire, were introduced by Thales or even ealier.
- The aether was added later by Plato and Aristotle.
- Thales supported the primacy of one of them, Water:
  - *«τὰ μὲν οὖν πολυθρύλητα τέτταρα, ὧν τὸ πρῶτον εἶναι ὕδωρ φαμὲν καὶ ὡσανεὶ μόνον στοιχεῖον τίθεμεν, πρὸς σύγκρισίν τε καὶ πήγνυσιν καὶ σύστασιν τῶν ἐγκοσμίων πρὸς ἄλληλα συγκεράννυται.»*
  (“*Therefore the celebrated four, of which we say that the first is water and posit it as being as it were the only element, mix with one another for the combination, solidification, and composition of the things of this world*”; Thales, Testimonia, Part 3: Reception (R), LCL 525: 268-269).

See also: https://www.loebclassics.com/view/thales-reception/2016/pb_LCL525.269.xml

Thales and the birth of science

- **Thales of Miletus**, one of the Seven Sages of Greece, is regarded as the **father of natural philosophy and science**. His contributions cover several fields:
  - **Mathematics**. He introduced deduction through theorems; he proved several theorems in geometry, including those bearing his name: the Thales' angle theorem and intercept theorem.
  - **Astronomy**. He predicted the solar eclipse on 28 May 585 BC.
  - **Physics**. He studied static electricity by experimenting on amber (in Greek ήλεκτρον—electron) as well as magnetism.
  - **Surveying engineering**. He measured the heights of pyramids and the distance of ships from the shore.
  - **Hydraulic engineering**. He made a diversion of the river Halys for military purposes.
- In addition to his scientific achievements on geometry and astronomy, he dealt with the paradox of the Nile (will be examined below), thus highlighting the importance of water and **hydrology** in the birth of science.

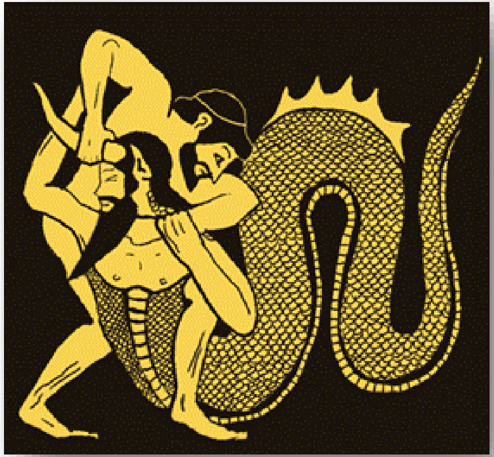
Hydrology (from the Greek words ύδωρ = water and λόγος = reason) is the science of the waters on Earth.

Before Thales: The Greek mythology

- Thinkers before Thales, such as Homer (8th century BC) and Hesiod (8th–7th century BC), used poetry for intellectual expression.
- Their explanations of water phenomena were mythological.
- Water was a crucial element in the Greek mythology. For example:
  - Zeus, known as “the king of gods” controlled rain, thunder and lightning, and was thus called “Zeus Ombrios” (Zeus of the Rain). The Greeks viewed rain as a divine gift from Zeus, reflecting their deep cultural reliance on water.
  - Poseidon, one of the major twelve gods, was ruler of seas and waters.
  - There was a diversity of water-related deities (Amphitrite, Nereus, Triton, Nereids and Nymphs), each with specific roles. In addition, rivers were personified as River Gods.
  - Primordial deities like Oceanus (Ocean) and Pontus (Sea) had significant roles in the creation of the world.
- The cultural significance of mythology was (and still is) enormous in literature (e.g. poetry, theater), rituals (offerings to water spirits) and art depictions.

Example of Greek mythological views: Hercules vs. Achelous fight

- Achelous is the most important river of Greece worshiped as a deity.
- Hercules (aka Heracles) is a Greek hero, also represented as a deity.
- The fight of the two symbolizes the struggle of humans against the destructive power of rivers.
- The victory of Hercules symbolizes the conversion of Achelous flooding area into a fertile plain.



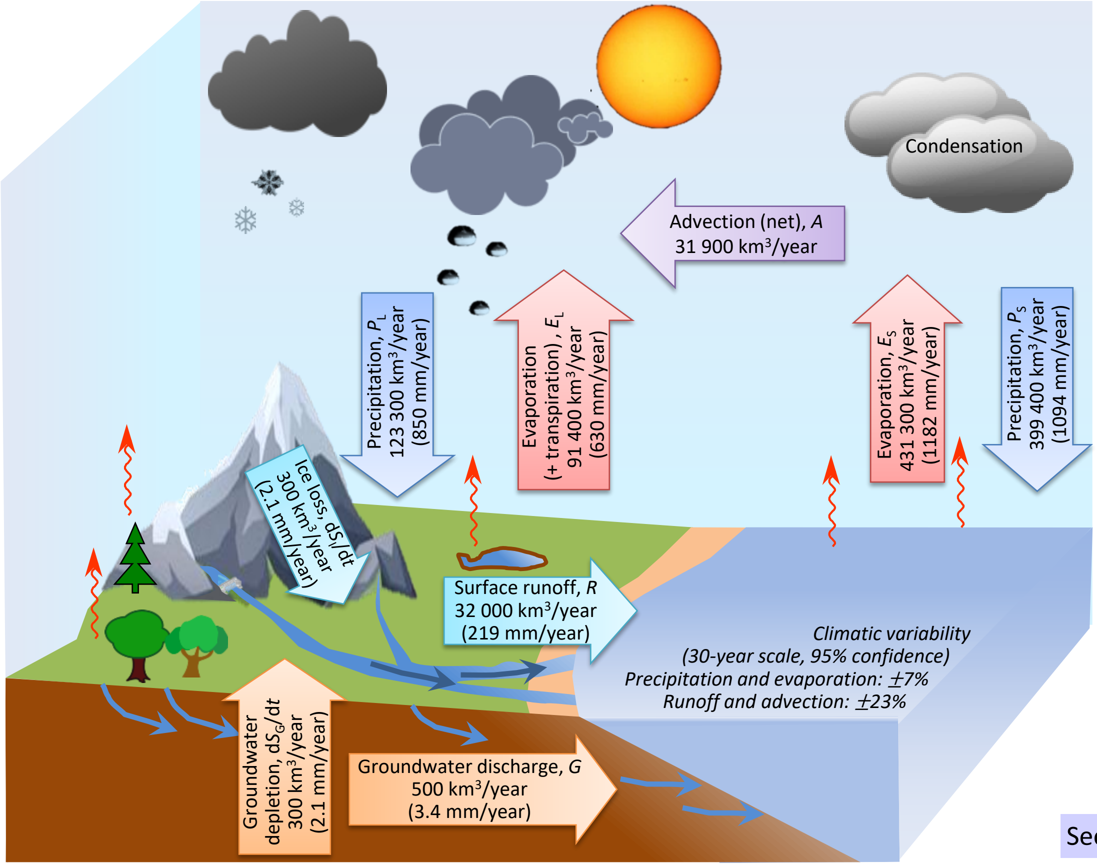
Depiction on an Attic red-figure vase (6th century BC), kept in the British Museum; Achelous is depicted as a snake.

Hercule combattant Achéloüs métamorphosé en serpent, exhibited at the Louvre; by François Joseph Bosio (1824)

Hercules fighting Achelous; wall painting (1937-39; with byzantine aesthetics) in the Athens City Hall by Fotis Kontoglou (writer, painter and hagiographer).

Image sources: Koutsoyiannis et al., 2007; https://commons.wikimedia.org/wiki/File:Hercule_Bosio_Louvre_LL325-1.jpg; Koutsoyiannis et al., 2012

The hydrological cycle as we know it today: When was it understood?

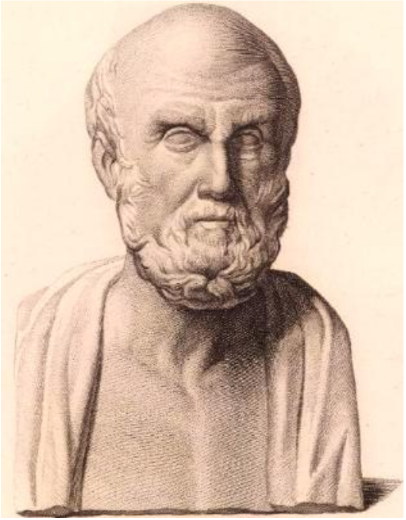


- The figure on the left depicts the current knowledge (with quantification) about the hydrological cycle.
- What did ancient Greeks think about the hydrological cycle and the hydrological processes?

See detailed calculations and results in Koutsoyiannis (2020)

Thales’ successors and the foundation of hydrological cycle

- **Anaximander of Miletus** (610–546 BC) understood the relationship or **rainfall and evaporation**.
- **Anaximenes of Miletus** (585–528 BC) devised logical explanations for the formation of **wind**, **clouds, rain and hail**.
- **Xenophanes of Colophon** (570–478 BC) understood the presence of fossilized marine organisms at three island locations and developed a theory of alternating periods of flood and drought. He proclaimed the **sea as the source of clouds, rain water and river flow**.
- **Heraclitus of Ephesus** (535 –475 BC), the father of dialectics, used water to symbolize change, while he related change with randomness:
  - «*Πάντα ῥεῖ*» (“*Everything flows*”; Heraclitus quoted in Plato’s Cratylus, 339-340).
  - «*Αἰών παῖς ἐστι παίζων πεσσεύων*» (“*Time is a child playing, throwing dice*”; Heraclitus; Fragment 52).
- **Hippocrates of Kos** (460 – c. 370 BC), the philosopher and most outstanding figure in the history of medicine, studied the relationship of **water and health**. He also contributed to hydrology through his treatise *Airs, Waters, Places*, where he **clearly described the hydrological cycle**, including the fact that the **salt contained in sea water is not evaporated**.

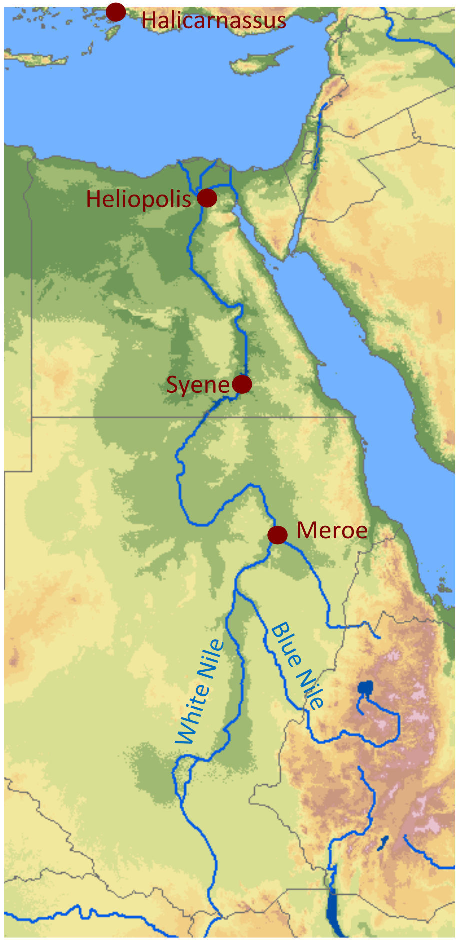


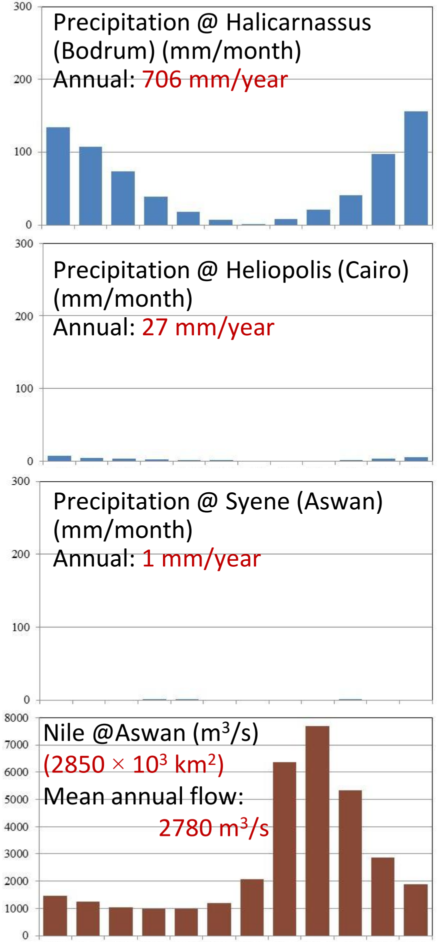
Hippocrates (460 – 370 BC)
Image source: Visconti (1817)

See details in Koutsoyiannis and Mamassis (2021)

Thales and the "Nile paradox"

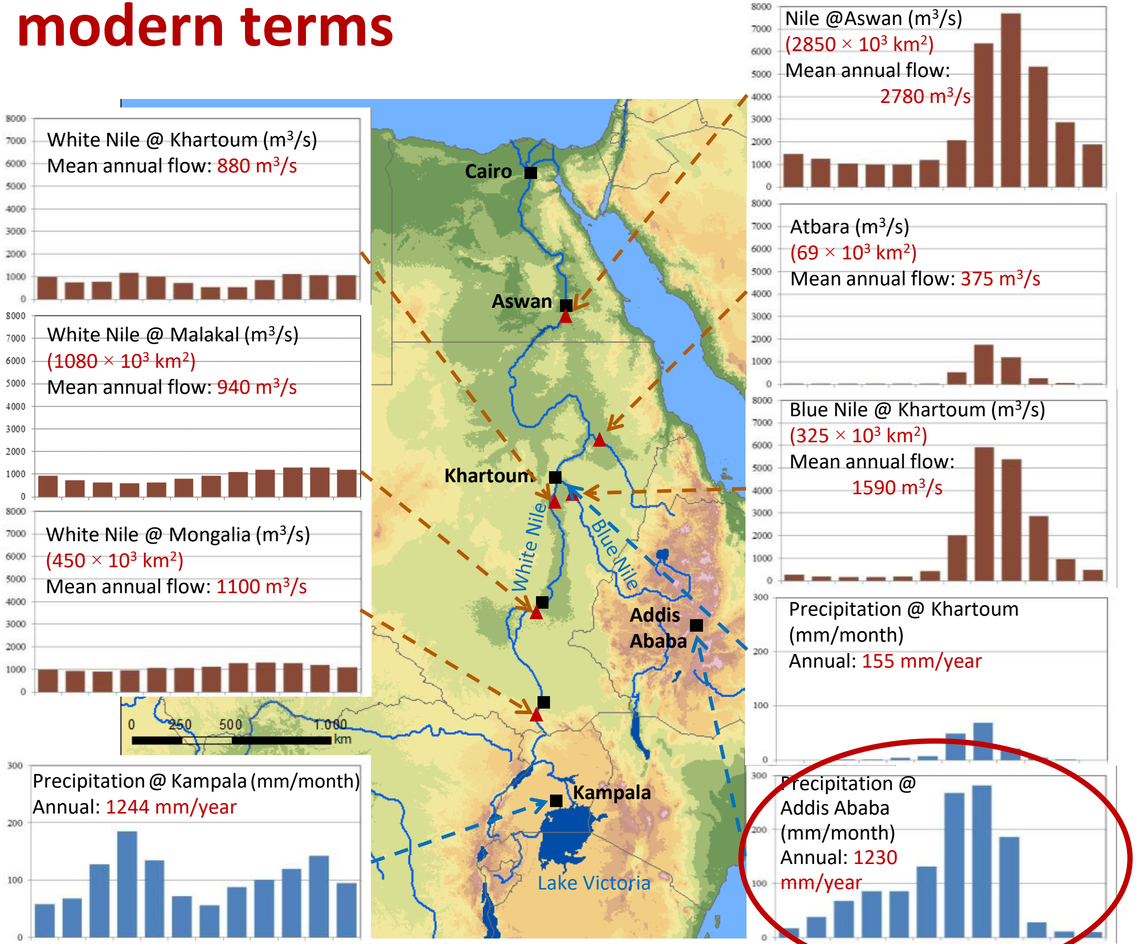
- The **first great problem related to a natural behaviour** and put in **scientific terms** was the **cause of the Nile floods**.
- What puzzled Greek thinkers was the different hydrological regime compared to other Mediterranean rivers: the **Nile floods occur in summer rather than during winter**.
- The so-called "Nile paradox" was posited by **Thales**, who removed all mythical elements in his explanations thus signifying the transition from mythology to science.
- The paradox was debated for almost **three centuries** (Burstein, 1976).
- The historian **Herodotus** cites **three different hypotheses** up to his time, rejecting them with some irony.
- He also presents his own (fourth) hypothesis.
- All hypotheses are wrong, but some are scientific, excluding divine actions.





The Nile (non)paradox in modern terms

- The measurements of the hydrological cycle components clearly show that it is the rainfall in Ethiopia that causes the Nile flooding.
- The rainfall pattern is characterized by high amount of rainfall in summer months, caused by monsoons.



Aristotle and the solution of the “Nile paradox”

«Ὅτι οἱ ἐτήσιαι πνέουσι κατὰ τὸν καιρὸν τοῦ ἀκμαιοτάτου θέρους δι΄ αἰτίαν τοιαύτην. Ὁ ἥλιος μετεωρότερος καὶ ἀπὸ τῶν μεσημβρινῶν τόπων ἀρκτικώτερος γινόμενος λύει τὰ ὑγρὰ τὰ ἐν ταῖς ἄρκτοις˙ λυόμενα δὲ ταῦτα ἐξαεροῦται, ἐξαερούμενα δὲ πνευματοῦται, καὶ ἐκ τούτων γίνονται οἱ ἐτήσιαι ἄνεμοι […]. *Ἐκεῖ δὴ ταῦτα ἐκφερόμενα προσπίπτει τοῖς ὑψηλοτάτοις ὄρεσι τῆς Αἰθιοπίας, καὶ πολλὰ καὶ ἀθρόα γινόμενα ἀπεργάζεται ὑετούς˙ καὶ ἐκ τῶν ὑετῶν τούτων ὁ Νεῖλος πλημμυρεῖ τοῦ θέρους, ἀπὸ τῶν μεσημβρινῶν καὶ ξηρῶν τόπων ῥέων. Καὶ τοῦτο Ἀριστοτέλης ἐπραγματεύσατο˙* ***αὐτὸς γὰρ ἀπὸ τῆς φύσεως ἔργῳ κατενόησεν, ἀξιώσας πέμψαι Ἀλέξανδρον τὸν Μακεδόνα εἰς ἐκείνους τοὺς τόπους καὶ ὄψει τὴν αἰτίαν τῆς τοῦ Νείλου αὐξήσεως παραλαβεῖν. Διό φησιν ὡς τοῦτο οὐκέτι πρόβλημά ἐστιν˙ ὤφθη γὰρ φανερῶς ὅτι ἐξ ὑετῶν αὔξει.*** *Καὶ <λύεται> τὸ παράδοξον, <ὅτι> ἐν τοῖς ξηροτάτοις τόποις τῆς Αἰθιοπίας, ἐν οἷς οὔτε χειμὼν οὔτε ὕδωρ ἐστί, ξυμβαίνει τοῦ θέρους πλείστους ὑετοὺς γίνεσθαι»* (Ανώνυμος, Βίος Πυθαγόρου, στο Φωτίου, *Μυριόβιβλον*, Anon, https://el.wikisource.org/wiki/Μαρτυρίαι_(Αριστοτέλης).

(“*The Etesian winds* [i.e., monsoons] *blow during the peak of the summer for this reason. The sun, at the zenith passing from south to north, disintegrates the moisture from the arctics and once this moisture is disintegrated, it evaporates and gives rise to monsoons* […] *When they reach the high mountains of Ethiopia and concentrate there, they produce rains. These rains in full summer cause the flood of the Nile and make it overflow, while it flows at the northern arid regions.* ***This was analysed by Aristotle, who, by the superiority of his mind, understood it. He demanded to send Alexander of Macedonia to these regions, and to find, by sight, the cause of the flooding of the Nile. That's why they say there is not a problem anymore.*** *It became apparent by sight that the flow is increased by these rains. And this solved the paradox that in the driest Ethiopian* [i.e. African] *places where there is no winter nor rain, it happens that in the summer strong rainfalls occur*”; Photios, *Bibliotheca*, Comments on Anonymus, *Life of Pythagoras*)

Aristotle (384 – 322 BC)

How do we know about Aristotle’s explanation?

- Aristotle wrote a book on the “paradox”, titled *Περὶ τῆς τοῦ Νείλου ἀναβάσεως* (*On the Inundation of the Nile*), which has not survived.
- Most of ancient Greek texts, including Aristotle’s book on the Nile, have been lost:
  - The Library of Alexandria was burned several times.
  - The Imperial Library in Constantinople was destroyed in 1204 by the Crusaders, and the remaining libraries in the city were destroyed by the Ottomans in 1453.
- Information on lost books is indirectly obtained from references in other books that were saved.
- An example is Patriarch Photius’s (c. 810/820 – 893) Myriobiblon or Biblioteheca, composed of 279 reviews of books which he had read.
- This book, perhaps **the first in history collection of book-reviews**, written in Greek, was printed in 1611 with Latin translation.
- This gives the information shown in the previous slide about **Aristotle’s decisive contribution in solving the Nile paradox**.
- In addition, there is a treatise in Latin titled Liber Aristotelis de Inundacione Nili (Aristotle’s Book on the Inundation of the Nile), in short De Nilo, which is presumably a Latin translation of Aristotle’s lost text.

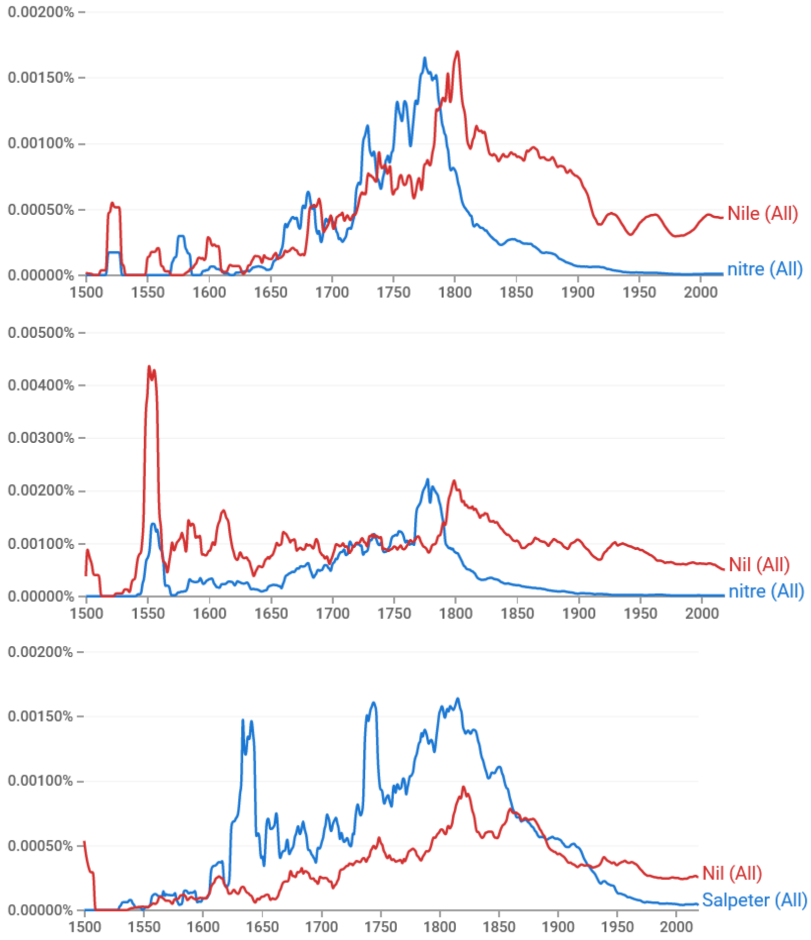
When was Aristotle’s theory accepted?

- The **mythological views are more charming than scientific** and, hence, they continued to be popular **during the Roman times**. The Roman epicurean philosopher **Lucretius** (c. 99 – c. 55 BC) and the stoic philosopher **Seneca** (4 BC –65 AD), both of whom wrote about Nile, did not adopt Aristotle’s scientific explanation.
- Rather, they **were fascinated by the Nile for its mystery, not its demystification**. An excellent summary of the reasons is contained in the following quotation by Merrills (2017):

  “The metaphysical qualities of the Nile—a river that replicated each year the origins of the world, and which overspilled its banks even into the bathhouses and taverns of Pompeii—were essential to its resonance in the Roman world.”
- The reference to Pompei encapsulates the archaeological evidence in Pompei of sacred objects and iconographies for Nile and its waters.
- **And what about modern times? Were the mythical views abandoned after the first quantification of the hydrological cycle in the 17th century?** This question is studied in detail in Koutsoyiannis and Mamassis (2021).
- In brief, **the surprising answer is that it took 2100 years** for Aristotle’s theory to be accepted or reinvented.

Why Aristotle's Nile theory was unpopular?

- It appears that mythology is preferred to science, even by scientists.
- **A new mythology was developed around a "theory" of the "nitre"** (a mythical element that presumably caused the flooding of the Nile), while rainfall in Ethiopia had a minor role, if any.
- This mythical theory was supported by famous European learned societies up to the 18th century.
- It took the visit to the origins of the Blue Nile of the Scottish traveller James Bruce and the publication of his book (Bruce, 1813) for the modern mythical theory to cease.
- **For comparison, notice that Aristotle's incorrect geocentric system was popular among scholars.**



Frequency of appearance of the indicated words in books hosted in the Google books platform in three languages: (upper) English; (middle) French; (lower) German.
Source: Koutsoyiannis and Mamassis (2021)

Aristotle and the phase change of water

Aristotle's treatise ***Meteorologica*** **offered a great contribution to the explanation of hydrometeorological phenomena**:

> *«ἔτι δ' ἡ ὑπὸ τοῦ ἡλίου ἀναγωγὴ τοῦ ὑγροῦ ὁμοία τοῖς θερμαινομένοις ἐστὶν ὕδασιν ὑπὸ πυρός.»* (Μετεωρολογικά, Β2)
>
> (*"the sun causes the moisture to rise; this is similar to what happens when water is heated by fire"*; Meteorologica, II.2, 355a 15)
>
> *«συνίσταται πάλιν ἡ ἀτμὶς ψυχομένη διά τε τὴν ἀπόλειψιν τοῦ θερμοῦ καὶ τὸν τόπον, καὶ γίγνεται ὕδωρ ἐξ ἀέρος· γενόμενον δὲ πάλιν φέρεται πρὸς τὴν γῆν. ἔστι δ' ἡ μὲν ἐξ ὕδατος ἀναθυμίασις ἀτμίς, ἡ δ' ἐξ ἀέρος εἰς ὕδωρ νέφος.»*
>
> (*"the vapour that is cooled, for 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*; ibid., I.9, 346b 30).

Aristotle (384 – 322 BC)
Image source: Visconti (1817)

Aristotle, change and mass conservation within change

- Aristotle penetrated into the concept of *change*. He was fully aware that the landscape changes through the ages and that **rivers are formed and disappear in the course of time**:

  «*ἀλλὰ μὴν εἴπερ καὶ οἱ ποταμοὶ γίγνονται καὶ φθείρονται καὶ μὴ ἀεὶ οἱ αὐτοὶ τόποι τῆς γῆς ἔνυδροι, καὶ τὴν θάλατταν ἀνάγκη μεταβάλλειν ὁμοίως. τῆς δὲ θαλάττης τὰ μὲν ἀπολειπούσης τὰ δ’ ἐπιούσης ἀεὶ φανερὸν ὅτι τῆς πάσης γῆς οὐκ ἀεὶ τὰ αὐτὰ τὰ μέν ἐστιν θάλαττα τὰ δ’ ἤπειρος, ἀλλὰ μεταβάλλει τῷ χρόνῳ πάντα*.»

  (“*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*”; ibid., I.14, 353a 16).

- Aristotle recognized **the principle of mass conservation** within the hydrological cycle:

  «*ὥστε* [τὴν θάλατταν] *οὐδέποτε ξηρανεῖται· πάλιν γὰρ ἐκεῖνο φθήσεται καταβὰν εἰς τὴν αὐτὴν τὸ προανελθόν*.»

  (“*Thus,* [the sea] *will never dry up; for* [the water] *that has gone up beforehand will return to it*”; ibid., II.3, 356b 26).

  «*κἂν μὴ κατ’ ἐνιαυτὸν ἀποδιδῷ καὶ καθ’ ἑκάστην ὁμοίως χώραν, ἀλλ’ ἔν γέ τισιν τεταγμένοις χρόνοις ἀποδίδωσι πᾶν τὸ ληφθέν*.»

  (“*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*”; ibid., II.2, 355a 26).

Aristotle and experimentation

- Aristotle also understood **by experiment that salt contained in water is not evaporated**:

  «ὅτι δὲ γίγνεται ἀτμίζουσα πότιμος καὶ οὐκ εἰς θάλατταν συγκρίνεται τὸ ἀτμίζον, ὅταν συνιστῆται πάλιν, πεπειραμένοι λέγωμεν.»

  (*"Salt water when it turns into vapour becomes drinkable* [freshwater] *and the vapour does not form salt water when it condenses again; **this I know by experiment**"*; ibid., II.3, 358b).

- This has certainly found technological application in desalination (removal of salt from sea water), useful in a country with scarcity of fresh water and many shores and islands. Thus, we learn from a commentary on Aristotle's Meteorologica II, written by Olympiodorus (the peripatetic philosopher, 495 – 570 AD), that:

  "Sailors, when they labour under a scarcity of fresh water at sea, boil the sea-water, and suspend large sponges from the mouth of a brazen vessel, to imbibe what is evaporated, and in drawing this off from the sponges, they find it to be sweet [fresh] *water"* (Morewood 1838; see also quotation by Alexander of Aphrodisias, peripatetic philosopher, fl. 200 AD, in Forbes, 1970).

Aristotle, Alexander and the Hellenistic World

- Aristotle, in addition to his many scholarly achievements, was tutor of **Alexander the Great**.
- Alexander, during his campaign, in which he conquered big parts of Asia and Africa, was exchanging letters with his tutor (and his mother Olympias), addressing him as professor (καθηγητὴν).
- The respect of the student to his mentor resulted in the **first scientific expedition in history in order to confirm a scientific hypothesis**.
- The Hellenistic period, which starts with the death of Alexander in 323 BC and ends with the emergence of the Roman Empire in 31 BC, is marked by the **wide dissemination of the Greek civilization and the flourishing of science**.

Aristotle (384 – 322 BC)

Alexander of Macedonia / the Great (356–323 BC)

Source of images: Visconti (1817)

Prominent scientists of the Hellenistic period: Archimedes

- **Archimedes** (287 – 212 BC) was the leading scientist (mathematician, physicist, engineer, inventor and astronomer) of the Hellenistic world, and is regarded to be the greatest mathematician of all time.
- The heliocentric system was earlier introduced by Aristarchus (c. 310 – c. 230 BC) but remained contrary to "consensus theory" for 1800 years. However, it is important to note that it was adopted by Archimedes. In fact, Archimedes provides the most precious information about Aristarchus's ideas:

  "*It is hypothesized* [by Aristarchus of Samos] *that the fixed stars and the Sun remain unmoved and the Earth revolves about the Sun in the circumference of a circle, with the Sun lying in the middle of the orbit and the sphere of the fixed stars, situated about the same centre as the Sun, is so great that the circle in which the Earth is hypothesized to revolve, bears such a proportion to the distance of the fixed stars as the centre of the sphere bears to its surface*" (Archimedes, The Sand Reckoner).
- It is well known that Archimedes offered several **important contributions in mathematics, including the concept of infinitesimals and a first version of integral calculus**.
- From the hydrological perspective, important is the principle named after him and the **foundation of hydrostatics**.
- From his inventions most relevant to hydrology is **Archimedes' screw, which is still in wide use for pumping**.

The Fields Medal (regarded as the highest honour for mathematicians) depicts Archimedes. The head of Archimedes in the medal is synthesized by the imagination of the artist (Tropp, 1976), as there is no original sign about it, neither in sculpture nor in coins.
Image source: https://en.wikipedia.org/wiki/Fields_Medal

Prominent scientists of the Hellenistic period: Heron

- The scientist of the Hellenistic period with the greatest contribution to hydrology is **Heron (Hero) of Alexandria** (mathematician and engineer who most likely lived in the 1st century BC or the 1st AD; see Woodcroft, 1851).
- He studied the notion of pressure and pneumatics and invented a steam machine.
- He introduced the term hydraulic (organ) for a musical instrument operated by hydraulics (ὑδραυλικὸν ὄργανον), which he describes in his book Pneumatica (Πνευματικὰ; Schmidt, 1899, p. 192, "Ὑδραυλικοῦ ὀργάνου κατασκευὴ"; Woodcroft, 1851, p. 105).
- **His contribution to hydrology is that he introduced the concept of discharge and its measurement**. Here is the relevant passage from his book Dioptra (Διόπτρα):

«Πηγῆς ὑπαρχούσης ἐπισκέψασθαι τὴν ἀπόρρυσιν αὐτῆς, τουτέστι τὴν ἀνάβλυσιν, ὅση ἐστίν. εἰδέναι μέντοι χρὴ ὅτι οὐκ ἀεὶ ἡ ἀνάβλυσις ἡ αὐτὴ διαμένει. ὄμβρων μὲν γὰρ ὄντων ἐπιτείνεται διὰ τὸ ἐπὶ τῶν ὀρῶν τὸ ὕδωρ πλεονάζον βιαιότερον ἐκθλίβεσθαι, αὐχμῶν δὲ ὄντων ἀπολήγει ἡ ῥύσις διὰ τὸ μὴ ἐπιφέρεσθαι πλέον ὕδωρ. αἱ μέντοι γενναῖαι πηγαὶ οὐ παρὰ πολὺ τὴν ἀνάβλυσιν ἴσχουσιν. δεῖ οὖν περιλαβόντα τὸ πᾶν τῆς πηγῆς ὕδωρ, ὥστε μηδαμόθεν ἀπορρεῖν, σωλῆνα τετράγωνον μολιβοῦν ποιῆσαι, στοχασάμενον μᾶλλον μείζονα πολλῷ τῆς ἀποθύσεως· εἶτα δι' ἑνὸς τόπου ἐναρμόσαι αὐτὸν ὥστε δι' αὐτοῦ τὸ ἐν τῇ πηγῇ ὕδωρ ἀπορρεῖν. δεῖ δὲ αὐτὸν κεῖσθαι εἰς τὸν ταπεινότερον τῆς πηγῆς τόπον, ὥστε ἔχειν αὐτὴν ἀπόρρυσιν. τὸν δὲ ταπεινότερον ἐπιγνωσόμεθα τῆς πηγῆς τόπον διὰ τῆς διόπτρας. ἀπολήψεται οὖν τὸ ἀπορρέον διὰ τοῦ σωλῆνος ὕδωρ ἐν τῷ περιστομίῳ τοῦ σωλῆνος· οἷον ἀπολαμβάνει[ν] δακτύλους β· ἐχέτω δὲ καὶ τὸ πλάτος τοῦ περιστομίου τοῦ σωλῆνος δακτύλους ς· ἑξάκις δύο γίνονται ιβ· <ἀποφανούμεθα δὴ τὴν ἀνάβλυσιν τῆς πηγῆς δακτύλων ιβ>. εἰδέναι δὲ χρὴ ὅτι οὐκ ἔστιν αὔταρκες πρὸς τὸ ἐπιγνῶναι, πόσον χορηγεῖ ὕδωρ ἡ πηγή, [ἢ] τὸ εὑρεῖν τὸν ὄγκον τοῦ ῥεύματος, ὃν λέγομεν εἶναι δακτύλων ιβ, ἀλλὰ καὶ τὸ τάχος αὐτοῦ· ταχυτέρας μὲν γὰρ οὔσης τῆς ῥύσεως πλέον ἐπιχορηγεῖ τὸ ὕδωρ, βραδυτέρας δὲ μεῖον. διὸ δεῖ ὑπὸ τὴν τῆς πηγῆς ῥύσιν ὀρύξαντα τάφρον τηρῆσαι ἐξ ἡλιακοῦ ὡροσκοπίου, ἐν τινὶ ὥρᾳ πόσον ἀπορρεῖ ὕδωρ ἐν τῇ τάφρῳ, καὶ οὕτως στοχάσασθαι τὸ ἐπιχορηγούμενον ὕδωρ ἐν τῇ ἡμέρᾳ πόσον ἐστὶν, ὥστ᾽ οὐδὲ ἀναγκαῖόν ἐστι τὸν ὄγκον τῆς ῥύσεως τηρεῖν· διὰ γὰρ τοῦ χρόνου δήλη ἐστὶν ἡ χορηγία.» (Ἥρων ο Αλεξανδρεύς, Διόπτρα, Schoenne, 1976)

(See translation to English in next slide).

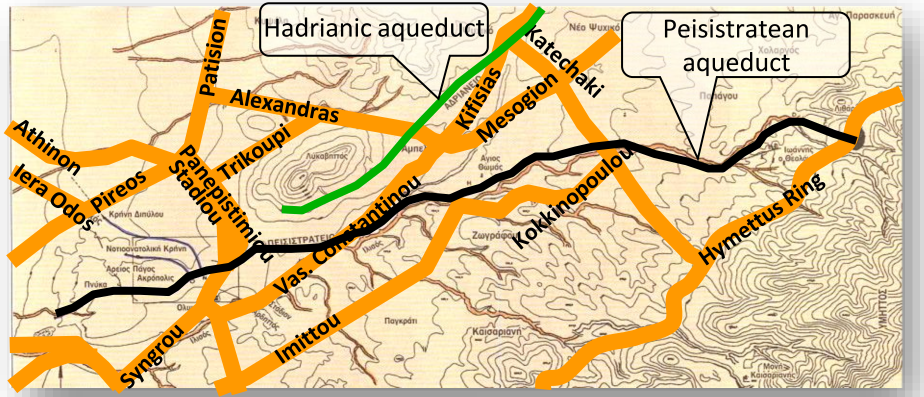
Prominent scientists of the Hellenistic period: Heron (2)

Translation of the Greek text:

"Given a spring, to determine its flow, that is, the quantity of water which it delivers. One must, however, note that the flow does not always remain the same. Thus, when there are rains the flow is increased, for the water on the hills being in excess is more violently squeezed out. But in times of dryness the flow subsides because no additional supply of water comes to the spring. In the case of the best springs, however, the amount of flow does not contract very much. Now it is necessary to block in all the water of the spring so that none of it runs of at any point, and to construct a lead pipe of rectangular cross section. Care should be taken to make the dimensions of the pipe considerably greater than those of the stream of water. The pipe should then be inserted at a place such that the water in the spring will flow out through it. That is, the pipe should be placed at a point below the spring so that it will receive the entire flow of water. Such a place below the spring will be determined by means of the dioptra. Now the water that flows through the pipe will cover a portion of the cross-section of the pipe at its mouth. Let this portion be, for example, 2 digits [in height]. *Now suppose that the width of the opening of the pipe is 6 digits. 6 × 2=12. Thus, the flow of the spring is 12* [square] *digits.* ***It is to be noted that in order to know how much water the spring supplies it does not suffice to find the area of the cross section of the flow*** *which in this case we say is 12 square digits.* ***It is necessary also to find the speed of flow, for the swifter is the flow, the more water the spring supplies, and the slower it is, the less.*** *One should therefore dig a reservoir under the stream and note with the help of a sundial how much water flows into the reservoir in a given time, and thus calculate how much will flow in a day. It is therefore unnecessary to measure the arca of the cross section of the stream. For the amount of water delivered will be clear from the measure of the time."* (Hero, Dioptra, 31, English translation by Cohen, 1958)

Water technology preceded the development of science: aqueducts

- The first major hydraulic project in Athens was constructed under the tyrant Peisistratos (in power between 546-527 BC) and his sons.
- The largest part of the aqueduct was carved as a tunnel at depth reaching 14 m.
- Other aqueducts were also constructed in several phases forming a network of pipelines.
- One of them is still in use today, while another is being rehabilitated.
- Greek hydraulic constructions were mostly underground for security reasons (e.g. in case of war; Koutsoyiannis et al., 2008).



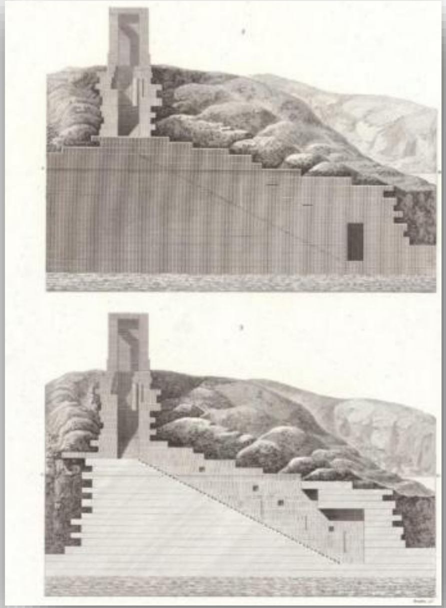
For cleaning and maintenance, in their upper part the pipes had elliptic openings covered by ceramic covers.

Water measurement also preceded science: the Nile c. 3050 BC

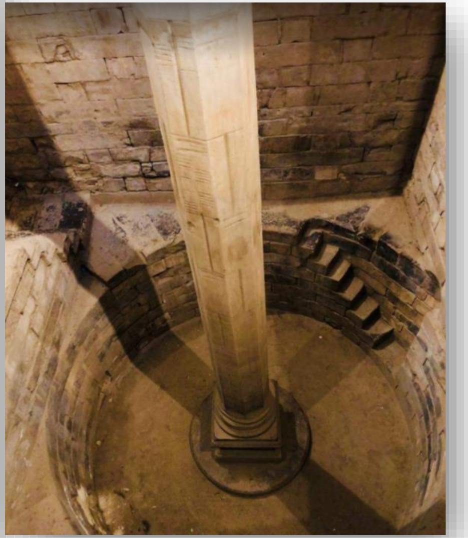
The measurement of Earth and water was essential for the agricultural management in the Nile's valley, as well as the administration of the country, including taxation, and dates back to c. 3050 BC. This triggered developments in metrology.

Palermo stone with inscriptions of the Nile flood level (c. 2686 – c. 2181 BC).

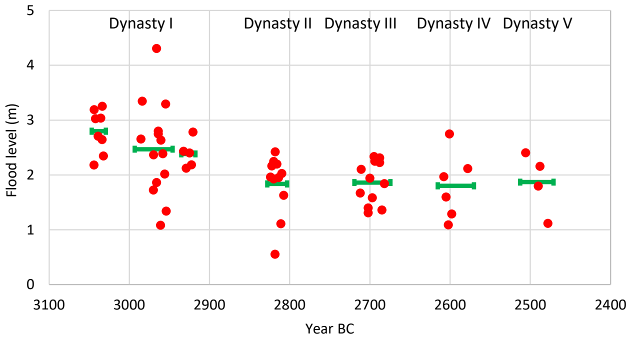
Nilometers installed in the Hellenistic period (332 BC – 30 AD).

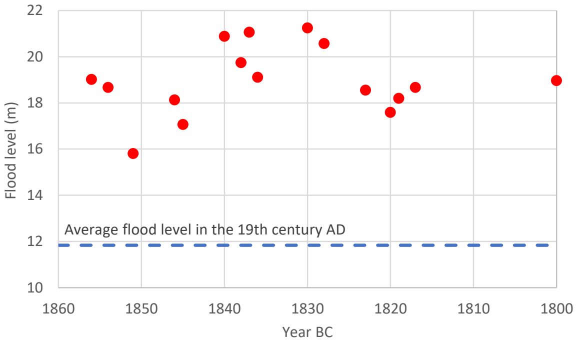


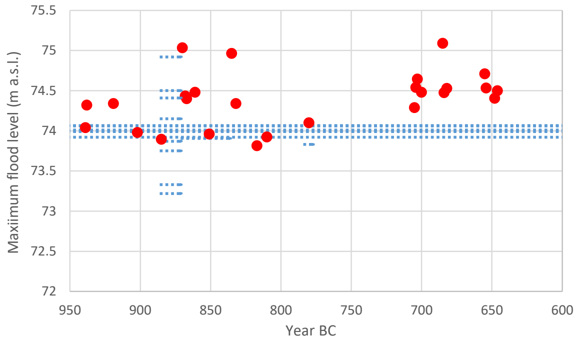
The nilometer at the Roda Island built in 715 AD and continued to the end of the 19th century, measuring annual maxima and minima.



A collection of prehistoric measurements of the Nile floods







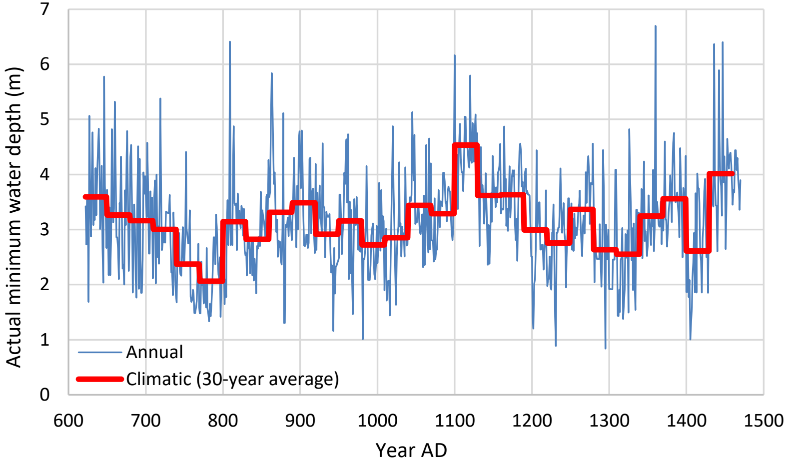
Maximum annual flood levels during the Dynasty I (c. 3100 – c. 2900 BC) and the Old Kingdom of Egypt (Dynasties II-V; c. 2686 – c. 2181 BC) from the Palermo Stone and other related fragments, believed to have been measured at Memphis. The green straight lines represent the average of the indicated period for each group of measurements.

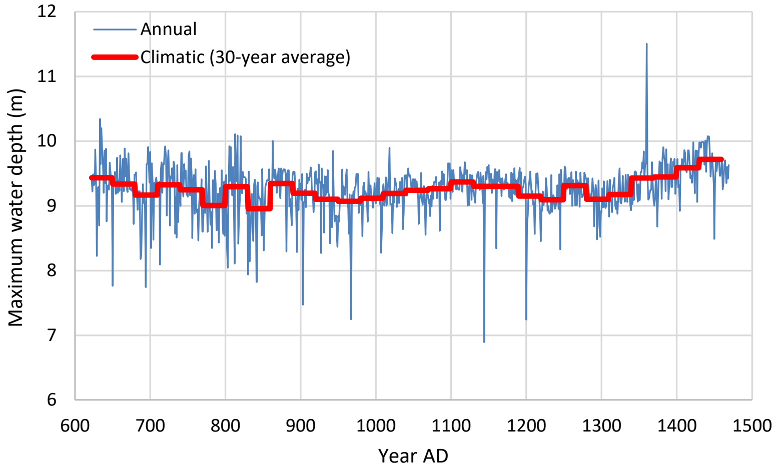
Maximum annual flood levels as inscribed on the bordering cliffs of a constricted part of the Nile at Semna – Kumma in Nubia (about 350 km south of Aswan) during the Middle Kingdom of Egypt (c. 2055 BC–c. 1650 BC) and specifically during the reign of pharaoh Amenemhat III (or Amenemhet III; regnal c. 1860 – c. 1814 BC; Dynasty XII).

Maximum annual flood levels as inscribed on the quay of Karnak during the Third Intermediate Period of Egypt (c. 1069 BC–c. 672 BC)

See details in Koutsoyiannis and Iliopoulou (2024)

Nilometer’s uninterrupted record: a landmark for climatology





- Nile integrates climatic behaviors over tropical and subtropical zones. The case of the Nile, for which instrumental data exist for many centuries, offers a unique opportunity to understand climate and, more specifically, its perpetual change.
- Toussoun (1925) published the annual minimum and maximum water levels from 622 to 1921 AD. During 622–1470, the record is almost uninterrupted, but later there are large gaps.
- This instrumental record of measurements surviving to date is the longest in world history (849 years).
- All Nile records, spanning over a period from the 31st century BC to the 21st century AD, attest to the case that climate always changed. The records allow quantification of climatic changes.

Water legislation: Wisdom in archaic Athens

- Solon (c. 630 – c. 560 BC) was an Athenian statesman, lawmaker, political philosopher and poet, and one of the Seven Sages of Greece.
- He laid the foundation for Athenian democracy by legislating against political, economic and moral decline of his era. Among his laws, one dealt with water management:

  «ἐπεὶ δὲ πρὸς ὕδωρ οὔτε ποταμοῖς ἐστιν ἀενάοις οὔτε λίμναις τισὶν οὔτ᾽ ἀφθόνοις πηγαῖς ἡ χώρα διαρκής, ἀλλ᾽ οἱ πλεῖστοι φρέασι ποιητοῖς ἐχρῶντο, νόμον ἔγραψεν, ὅπου μέν ἐστι δημόσιον φρέαρ ἐντὸς ἱππικοῦ, χρῆσθαι τούτῳ: τὸ δ᾽ ἱππικὸν διάστημα τεσσάρων ἦν σταδίων: ὅπου δὲ πλεῖον ἀπέχει, ζητεῖν ὕδωρ ἴδιον: ἐὰν δὲ ὀρύξαντες ὀργυιῶν δέκα βάθος παρ᾽ ἑαυτοῖς μὴ εὕρωσι, τότε λαμβάνειν παρὰ τοῦ γείτονος ἑξάχουν ὑδρίαν δὶς ἑκάστης ἡμέρας πληροῦντας: ἀπορίᾳ γὰρ ᾤετο δεῖν βοηθεῖν, οὐκ ἀργίαν ἐφοδιάζειν.»

  (“*Since the area is not sufficiently supplied with water, either from continuous flow rivers, or lakes or rich springs, but most people used artificial wells, Solon made a law, that, where there was a public well within a hippicon, that is, four stadia* [710 m], *all should use that; but when it was farther off, they should try and procure water of their own; and if they had dug ten fathoms* [18.3 m] *deep and could find no water, they had liberty to fetch a hydria (pitcher) of six choae* [20 L] *twice a day from their neighbours; for he thought it prudent to make provision against need, but not to supply laziness*”; Plutarch, Solon, 23)
- Important elements of this law are:
  - the priority of public wells and their protection;
  - the balance of the public and private interests for the construction and operation of wells;
  - the regulation of relationships among individuals in order to cover water needs of all citizens;
  - the provision against need, while discouraging laziness.

Water institutions in classical Athens

- In ancient Athens, a distinguished public administrator, called **«κρουνῶν ἐπιμελητής» (Superintendent of Fountains)**, was appointed to operate and maintain the city's water system, to monitor enforcement of the regulations and to ensure the fair distribution of water.
- This officer was one of the few that were elected by vote whereas other officers were chosen by lot:

  «*τὰς δ᾽ ἀρχὰς τὰς περὶ τὴν ἐγκύκλιον διοίκησιν ἁπάσας ποιοῦσι κληρωτάς, πλὴν ταμίου στρατιωτικῶν καὶ τῶν ἐπὶ τὸ θεωρικὸν καὶ τοῦ τῶν* ***κρηνῶν ἐπιμελητοῦ. ταύτας δὲ χειροτονοῦσιν****, καὶ οἱ χειροτονηθέντες ἄρχουσιν ἐκ Παναθηναίων εἰς Παναθήναια.* ***χειροτονοῦσι δὲ καὶ τὰς πρὸς τὸν πόλεμον ἁπάσας***.»

  (“*All the officials concerned with the regular administration are appointed by lot, except a Treasurer of Military Funds, the Controllers of the Spectacle Fund, and the* ***Superintendent of Fountains; these officers are elected by show of hands****, and their term of office runs from one Panathenaic Festival to the next.* ***All military officers also are elected by show of hands***”; Aristotle, Athenaion Politeia, 43.1).

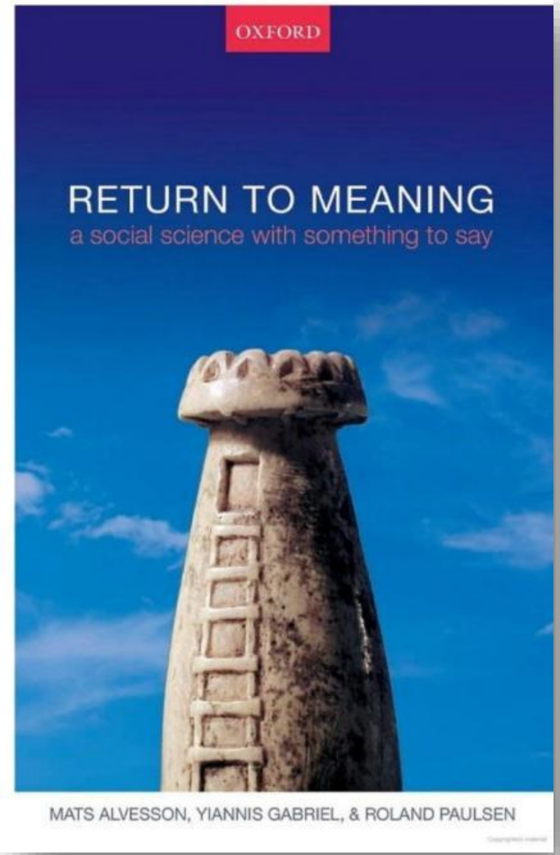
- This must be related to the high importance of this particular position, in which even Themistocles (c. 524 – c. 459 BC; an Athenian politician and general, credited for the victory in the Battle of Marathon in 490 BC) had served.
- Generally, private sponsoring of public hydraulic systems was encouraged; e.g. in 333 BC the Athenians awarded a gold wreath to the Superintendent of Fountains Pytheus because he restored and maintained several fountains and aqueducts.

From ancient wisdom to modern nonsense in academic research

- According to Alvesson et al. (2017), currently academic careers lack an intrinsic meaning and value, as well as social utility.

  *"We argue that we are currently witnessing not merely a decline in the quality of scientific research, but a **proliferation of meaningless research** of no value to society and of only modest value to its authors—apart from in the context of securing employment and promotion.* […] *Publishing comes to be seen as a game of hit and miss, of targets and rankings, crucial for the fashioning of academic careers and institutional prestige but devoid of intrinsic meaning and value, and of no wider social uses whatsoever. This is what we view as the **rise of nonsense in academic research.**"*

- My hypothesis is that these developments are deliberate, which is supported by the fact that research proposals in Europe are only funded if they conform to the dominant politico-ideological narrative.



Modern nonsense continued…

Circular Economy and Sustainability
https://doi.org/10.1007/s43615-022-00175-9

OPINION PAPER

Check for updates

Bullshit in the Sustainability and Transitions Literature: a Provocation

Julian Kirchherr[1]

Received: 15 November 2021 / Accepted: 1 May 2022

Abstract

Research on sustainability and transitions is burgeoning. Some of this research is helping to solve humankind's most pressing problems. However, as this provocation argues, up to 50% of the articles that are now being published in many interdisciplinary sustainability and transitions journals may be categorized as "scholarly bullshit." These are articles that

Essay

Why Most Published Research Findings Are False

PLoS Medicine | www.plosmedicine.org 0696 August 2005 | Volume 2 | Issue 8 | e124

John P. A. Ioannidis

Summary

There is increasing concern that most current published research findings are false. The probability that a research claim is true may depend on study power and

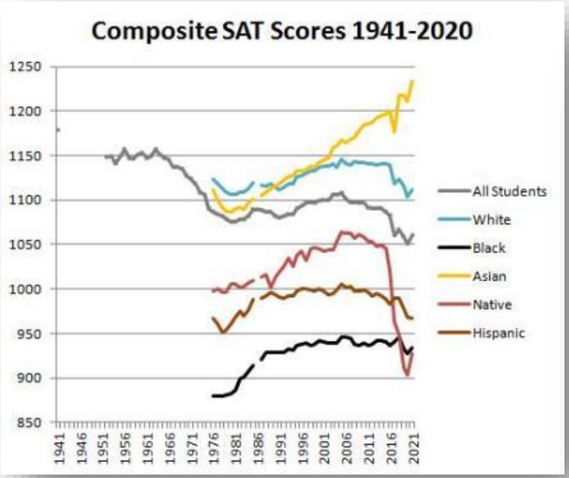
factors that influence this problem and some corollaries thereof.

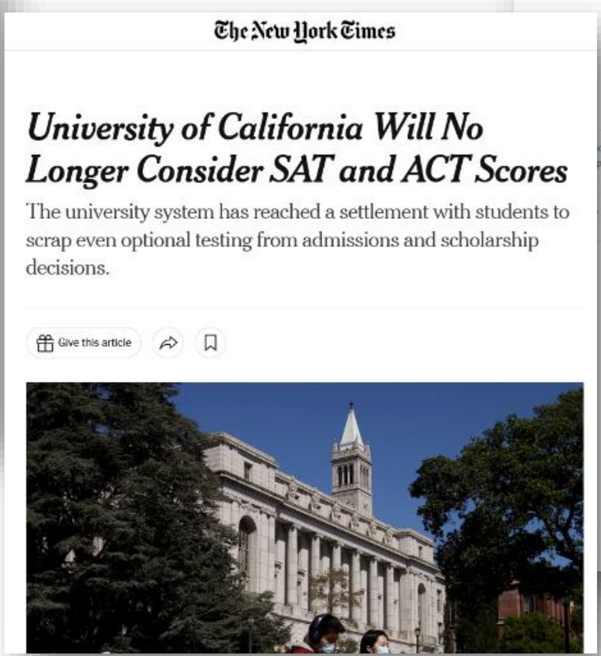
Modeling the Framework for False Positive Findings

Several methodologists have

is characteristic of the field and can vary a lot depending on whether the field targets highly likely relationships or searches for only one or a few true relationships among thousands and millions of hypotheses that may

“Political correctness”: incompatible with meritocracy



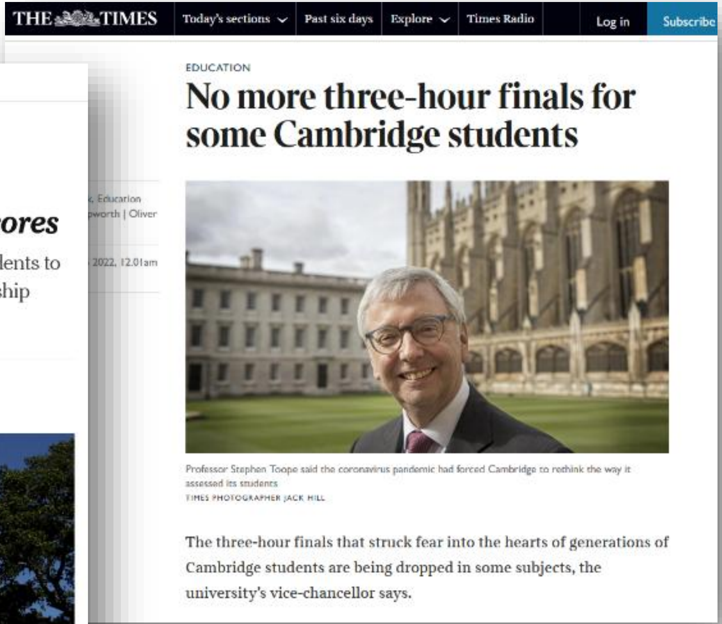


The New York Times

University of California Will No Longer Consider SAT and ACT Scores

The university system has reached a settlement with students to scrap even optional testing from admissions and scholarship decisions.

Give this article



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EDUCATION

No more three-hour finals for some Cambridge students

Professor Stephen Toope said the coronavirus pandemic had forced Cambridge to rethink the way it assessed its students

TIMES PHOTOGRAPHER JACK HILL

The three-hour finals that struck fear into the hearts of generations of Cambridge students are being dropped in some subjects, the university's vice-chancellor says.

SAT (Scholastic Assessment Test) is used for admission to American universities.

The chart shows that Asians are advancing while others are falling.

Sources: https://www.thetimes.co.uk/article/no-more-three-hour-finals-for-some-cambridge-students-9tmr8b2fx
https://twitter.com/UnsilencedSci/status/1446464463926792194
https://www.nytimes.com/2021/05/15/us/SAT-scores-uc-university-of-california.html

The scientific process then and now

Ancient Greece	Current situation in Western countries
Science (initially called natural philosophy) was born along with philosophy. It was rigorously defined, and its meaning was clarified: the genuine search for truth, independent of other (e.g. economic) interests. Science (the search for truth) was distinguished from sophistry (the misuse of knowledge to serve interests).	From a truth-seeking process, science has become institutional, analogous to the priesthood (often serving interests – cf. saving the planet, promoting bioweapons). Research is dependent on funding and its directions are predetermined by politico-economic power. Researchers' careers depend on their success in raising money. The linking of science with political and economic interests is touted as a positive development. But in terms of ancient Greek ideals, it is a negative development leading to decline.

The scientific process then and now (2)

Ancient Greece	Current situation in Western countries
Science (natural philosophy) was developed as a **part of philosophy**, alongside other branches of philosophy, namely metaphysics, epistemology, logic and axiology (ethics, aesthetics). The development of (Aristotelian) **logic** provided science with a powerful tool to distinguish meaning from nonsense, as well as deduction from induction, distinguishing the relative validity of the conclusion for each of the methods. The gradual development of the **scientific method**, which is part of philosophy, incorporating observation, experience and, at a later stage, experiment, provided the firm basis for science.	The fragmentation of knowledge and the departure of science from philosophy prevailed. The connection between science and axiology – especially ethics– has weakened, while its connection with interests has intensified. While the tradition has persisted that the highest degree in education is called a Doctorate of Philosophy–PhD, in fact little "Ph" (if any) is actually contained in doctoral research and most doctoral students are not aware of the philosophical presuppositions of the scientific method (see Gauch, 2003).

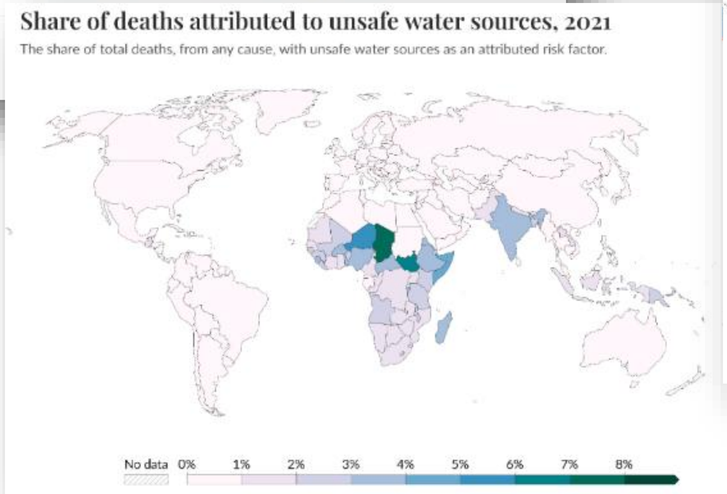
The scientific process then and now (3)

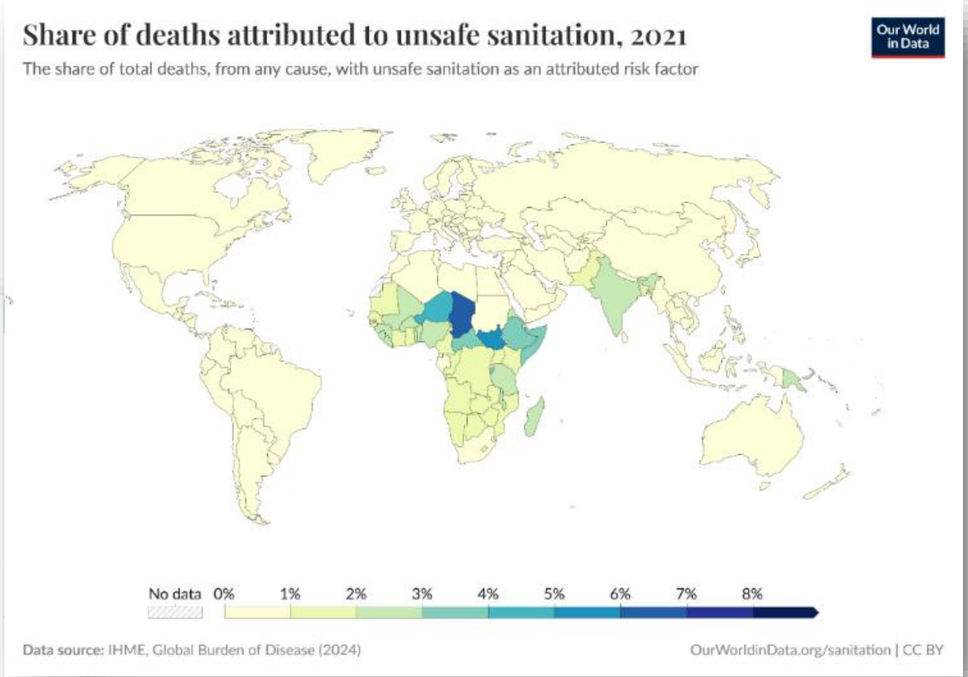
Ancient Greece	Current situation in Western countries
Sapheneia (σαφήνεια; clarity with accurate scientific knowledge) had been set as a strong requirement, so much so that Aristotle identified it with truth. The introduction of **terminology**, that is, sophisticated terms whose meaning may not be identical with the colloquial one, and the **definitions** of terms (by Socrates, Plato, Aristotle), is another reflection of the pursuit of sapheneia.	Sapheneia is no longer a desideratum in some disciplines, a development possibly influenced by politics (which is often better served by ambiguity). Cases of ambiguity are common in climatology (Koutsoyiannis, 2021, 2024), but extend even to mathematics (Koutsoyiannis et al., 2018).

The scientific process then and now (4)

Ancient Greece	Current situation in Western countries
The formulation of a **multitude of diverse ideas** by different scholars and the ensuing **clash of ideas** was vital to the development of science. Ancient Greek scholars quoted and discussed each other's ideas and theories, usually with due respect (and sometimes with irony). Thanks to these discussions, we now know the views of philosophers whose original works have been completely lost. The pluralism of ideas and the diversity of opinions, some of which were necessarily better than others, led to an evolutionary process that in turn allowed scientific progress.	In theory, the ancient practices of quoting others' ideas and dialogue have been incorporated into today's scientific practices. However, anti-scientific ideas have prevailed, such as those of 'consensus' –rather than debate– and 'settled science', which are not allowed to be challenged. While diversity is promoted in various social functions, diversity of opinion on scientific issues is often discouraged and scientific debate on politically sensitive issues is effectively banned (e.g. criticism is labelled 'conspiracy theory').

Water problems still exist today—and will not be solved with “political correctness”, nor with military conflicts and weapons





Sources: https://ourworldindata.org/what-no-safe-water-means; https://ourworldindata.org/sanitation

Epilogue: measures against decline

- 2500 years ago, parallel cultural developments occurred in China and Greece.
- Science (originally called “natural philosophy”) was born in Archaic Greece, in which water had a prominent position. It was established and clarified in classical Greece and made spectacular progress during the Hellenistic period.
- It is likely that the regression after the Hellenistic and classical Roman periods was due to intellectual decline, as evidenced by the closure of philosophical schools in the sixth century AD.
- Signs of similar regression and decline are present in our own time, particularly in the Western world, where ideas are being replaced by ideologies and logic by stereotypes of euphemistic ‘correctness’.
- The restoration of the values developed in antiquity is the most appropriate measure against modern decadence.

«*φίλος μέν Σωκράτης, ἀλλά φιλτάτη ή ἀλήθεια*.» (Latin version: “*Amicus Socrates, sed magis amica veritas*”; “*Socrates is dear* (friend)*, but truth is dearest*”; Ammonius, Life of Aristotle).

«*δόξειε δ᾽ ἂν ἴσως βέλτιον εἶναι καὶ δεῖν ἐπὶ σωτηρίᾳ γε τῆς ἀληθείας καὶ τὰ οἰκεῖα ἀναιρεῖν, ἄλλως τε καὶ φιλοσόφους ὄντας: ἀμφοῖν γὰρ ὄντοιν φίλοιν ὅσιον προτιμᾶν τὴν ἀλήθειαν.*»
(“*Still perhaps it would appear desirable, and indeed it would seem to be obligatory, especially for a philosopher, to sacrifice even one’s closest personal ties in defense of the truth. Both are dear to us, yet it is our duty to prefer the truth*”; Aristotle, Nicomachean Ethics 1096a11).

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