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The development of science (with emphasis on hydrology) from the Greek antiquity to the early modern period

Demetris Koutsoyiannis & Nikos Mamassis

Department of Water Resources and Environmental Engineering
School of Civil Engineering
National Technical University of Athens, Greece
(dk@ntua.gr)

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Hydrology is the science of the water on Earth: its occurrence, circulation, distribution, physical and chemical properties, and interaction with the environment and the biosphere (cf. UNESCO, 1963, 1964).

Nile River

Aswan Dam

Lake Nasser

Images from
earthobservatory.nasa.gov/IOTD/view.php?id=2416
earthobservatory.nasa.gov/images/imagerecords/46000/46209/earth_pacific_lrg.jpg
earthobservatory.nasa.gov/images/imagerecords/1000/1234/PIA02647_lrg.jpg
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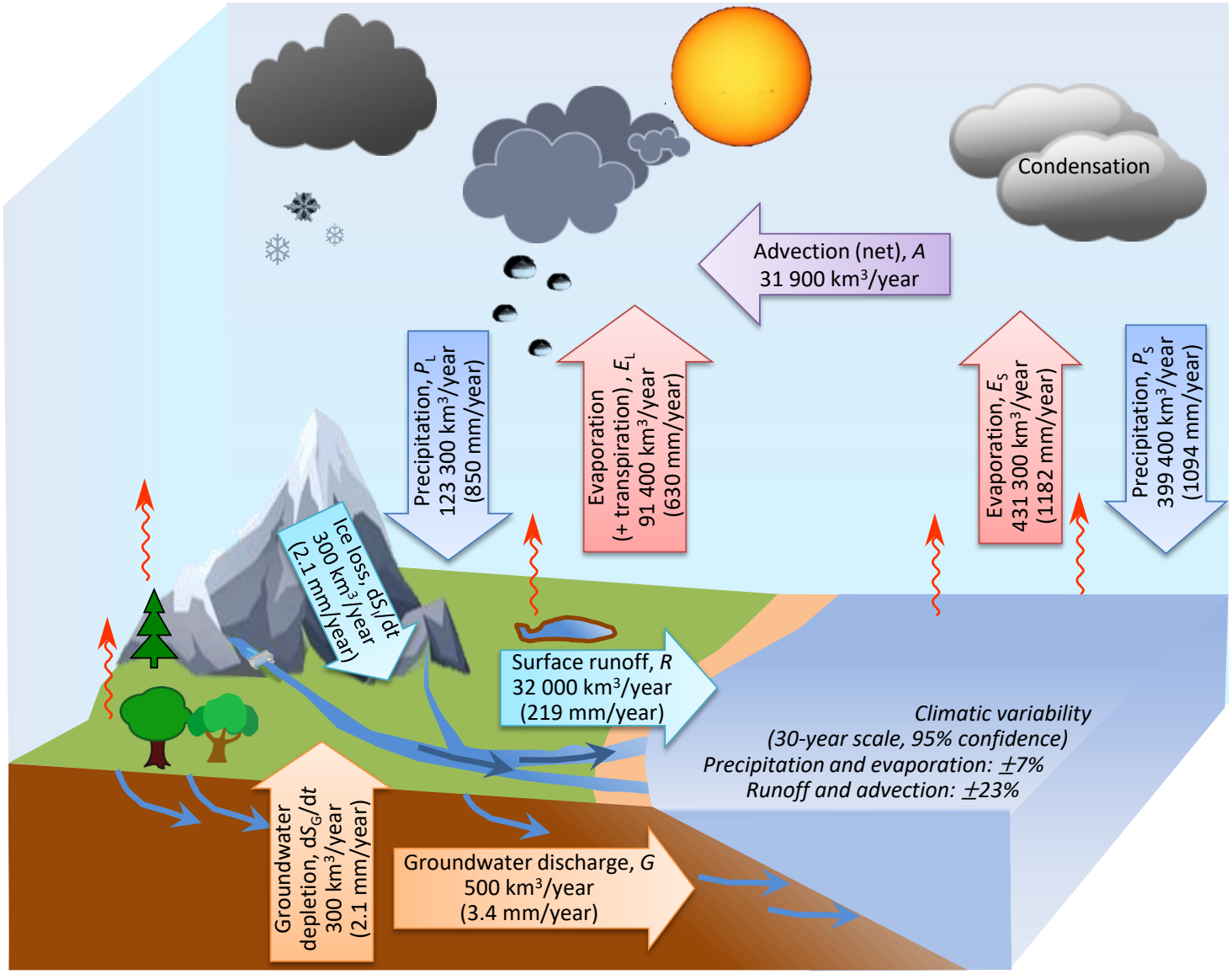
The hydrological cycle



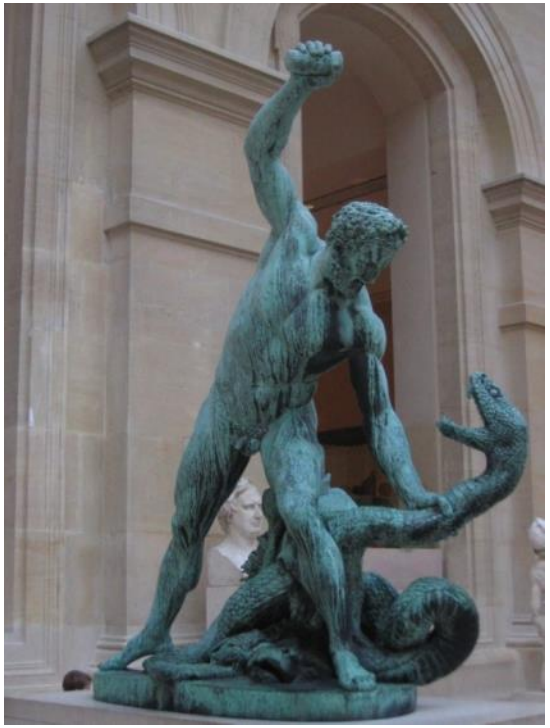
This is the current knowledge (with quantification) about the hydrological cycle (see detailed calculations and results in Koutsoyiannis, 2020).

What did the ancients think about the hydrological cycle and the hydrological processes?

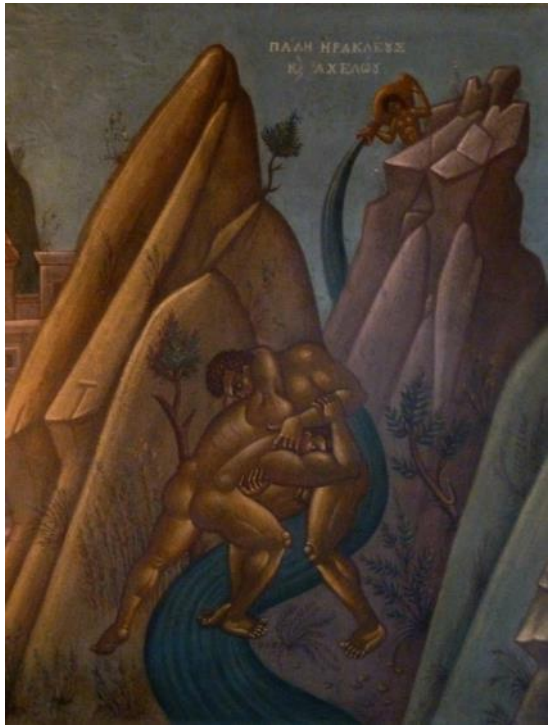
Starting from ancient Greek mythological views — inspiring even in modern times

The myth of Hercules fighting Achelous, a deity personifying the most important river of Greece, symbolizes the fight of men against the destructive power of rivers.

Depiction on an Attic red-figure vase (6th century BC), kept in the British Museum (reproduced from Koutsoyiannis et al., 2007).

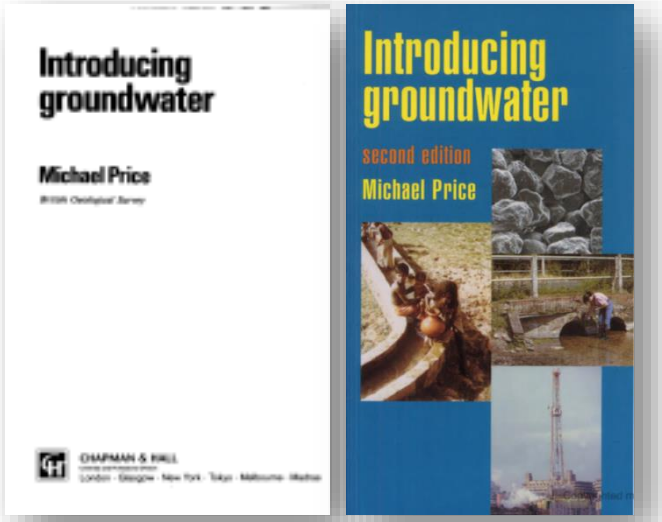


Hercule combattant Achéloüs métamorphosé en serpent, exhibited at the Louvre; by François Joseph Bosio (1824; https://commons.wikimedia.org/wiki/File:Hercule_Bosio_Louvre_LL325-1.jpg).



Hercules fighting Achelous; wall painting (1937-39; with byzantine aesthetics) in the Athens City Hall by Fotis Kontoglou, (writer, painter and hagiographer) (reproduced from Koutsoyiannis et al., 2012).

Modern mythology about past knowledge is also inspiring

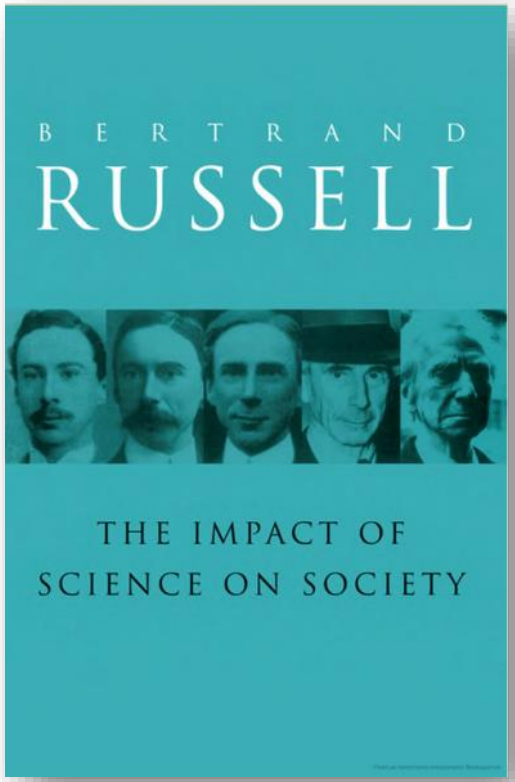


An inspiring extract from Price (1989):

"Today, our version of the ***hydrological cycle*** *seems so logical and obvious that* ***it is difficult to believe that it did not gain widespread acceptance until the 17th century****. This was caused in large part by the* ***tendency of the philosophers of Ancient Greece to distrust observations*** *and by the tendency of later philosophers to accept the opinions of the Greeks almost without question.* ***Plato advocated the search for truth by reasoning****.* ***He and his followers appear to have attached little importance to observations and measurements****. Thus* ***Aristotle****, Plato's most famous pupil,* ***was reportedly able to teach that men have more teeth than women, when simple observation would have dispelled this idea****. From a hydrological viewpoint, however, he had a more serious misconception – he believed that rainfall alone was inadequate to sustain the flow of rivers."*

Tracing back the succession of inspirations regarding Aristotle and women's teeth

"***Observation versus Authority***: *To modern educated people, it seems obvious that matters of fact are to be ascertained by observation, not by consulting ancient authorities. But this is an entirely modern conception, which hardly existed before the seventeenth century.* ***Aristotle maintained that women have fewer teeth than men; although he was twice married, it never occurred to him to verify this statement by examining his wives' mouths***" (Russell, 1952).



The original text by Aristotle

«Ἔχουσι δὲ πλείους οἱ ἄρρενες τῶν θηλειῶν ὀδόντας καὶ ἐν ἀνθρώποις καὶ ἐπὶ προβάτων καὶ αἰγῶν καὶ ὑῶν· ***ἐπὶ δὲ τῶν ἄλλων οὐ τεθεώρηταί πω****.* […] *Φύονται δ' οἱ τελευταῖοι τοῖς ἀνθρώποις γόμφιοι, οὓς καλοῦσι κραντῆρας, περὶ τὰ εἴκοσιν ἔτη καὶ ἀνδράσι καὶ γυναιξίν. Ἤδη δέ τισι γυναιξὶ καὶ ὀγδοήκοντα ἐτῶν οὔσαις ἔφυσαν γόμφιοι ἐν τοῖς ἐσχάτοις* […]»
(Των περί τα ζώα ιστοριών, Β).

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

"Males have more teeth than females in the case of men, sheep, goats, and swine; ***in the case of other animals observations have not yet been made*** […] *The last teeth to come in man are molars called 'wisdom-teeth', which come at the age of about twenty years, in the case of both men and women. Cases have been known in women of eighty years old where at the very close of life the wisdom-teeth have come up* […]"
(History of Animals/Book II).

Some epistemological questions

- What do we mean by *observation*? Does information from school teachers, professors, books, TV, internet, climate projections for the year 3000 AD, etc., classify as *observation*?
- Is the number of teeth:
  - A constant for all individuals? (and irrespective of sex?)
  - Varying among individuals
  - Varying among individuals and also varying in time for each individual? (like in a stochastic process?)
- How did Russell know whether or not Aristotle examined his two wives' teeth?
- And did Russell's himself examine his own four wives' teeth?

What do modern statistical data say?

Table 46. Mean number of permanent teeth among dentate adults 20–64 years of age, by selected characteristics: United States, National Health and Nutrition Examination Survey, 1988–1994 and 1999–2004

Characteristic	1988–1994		1999–2004	
	Mean	Standard error	Mean	Standard error
Age				
20–34 years	26.44	0.07	26.90	0.05
35–49 years	24.14	0.16	25.05	0.11
50–64 years	20.39	0.22	22.30	0.22
Sex				
Male	24.10	0.11	25.06	0.13
Female	23.86	0.14	24.90	0.08
Race and ethnicity				
White, non-Hispanic	24.28	0.14	25.23	0.13
Black, non-Hispanic	22.03	0.14	23.68	0.13
Mexican American	24.81	0.09	25.32	0.08

Official USA statistical data; Dye et al. (2007)

A first and second reason for the difference

(1) The number of teeth decreases with increasing age and women's life expectancy is longer by several years than men's.

(2) Women's teeth seem to be more fragile than men's.

Official USA statistical data: Harvey (1981).

Average number of decayed (D), missing (M), and filled (F) permanent teeth per person, among adults 35-74 years of age, by sex and age: United States, 1960-62 and 1971-74.

Sex and age	DMF teeth	
	1960-62	1971-74
Both sexes, 35-74 years	19.1	20.2
Men		
35-74 years	18.5	19.5
35-44 years	17.2	18.4
45-54 years	18.0	19.2
55-64 years	20.4	20.7
65-74 years	22.3	21.8
Women		
35-74 years	19.7	20.8
35-44 years	18.8	20.0
45-54 years	19.6	20.5
55-64 years	21.9	21.5
65-74 years	22.8	22.5

A third and fourth reason for the difference

(3) "***Sex Disparities***. *Table 2 represents the distribution and prevalence of third molar* ***agenesis*** [congenital lack of one or more teeth] *according to sex. Frequency of third molar agenesis was higher in females than males*" (Sujon et al., 2016).

Table 2. The frequency of agenesis according to sex.

Sex	n	Agenesis	Prevalence	X^2	*p* value
Male	2136	785	36.8%	5.02	.025*
Female	2092	839	40.1%		

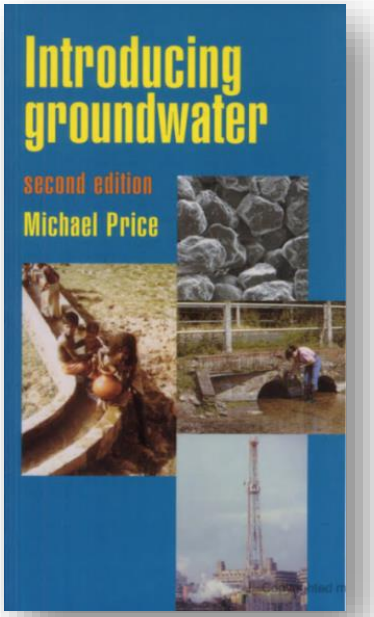
* *p* value <0.05 is significant

doi:10.1371/journal.pone.0162070.t002

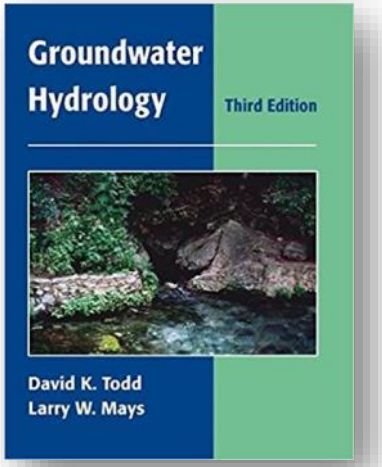
(4)"***Hyperdontia*** [increase in number of teeth in relation to the normal dental formula] *is more common in males, and the degree of sex difference is greater in blacks*" and "*The number of extra teeth per person ranged from 1 to 8*" (Harris and Clark, 2008).

Modern mythology about past knowledge (contd.)

Another inspiring extract from Price (1989):
"The first person to make a forthright and unequivocal statement that rivers and springs originate entirely from rainfall appears to have been a Frenchman called Bernard Palissy, who put forward this proposition in 1580. Despite this, in the early 17th century many workers were still in essence ***following the Greeks in believing that sea water was drawn into vast caverns in the interior of the Earth, and raised up to the level of the mountains by fanciful processes*** *usually involving evaporation and condensation. The water was then released through crevices in the rocks to flow into the rivers and so back to the sea."*

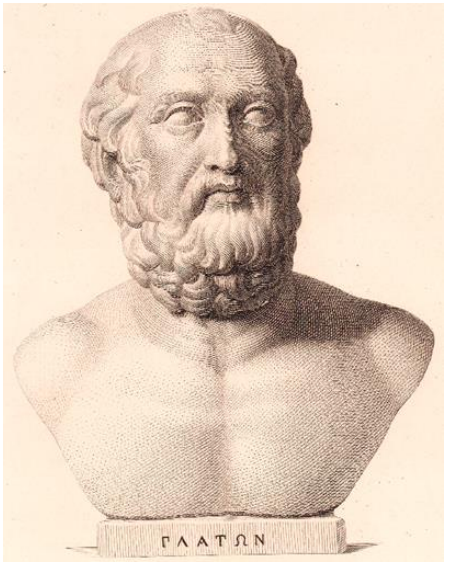


A similar extract from Todd & Mays (2005)
"As late as the seventeenth century it was generally assumed that ***water emerging from springs could not be derived from rainfall, for it was believed that the quantity was inadequate*** *and the earth too impervious to permit penetration of rainwater far below the surface. Thus, early Greek philosophers such as Homer, Thales, and Plato hypothesized that springs were formed by seawater conducted through subterranean channels below the mountains, then purified and raised to the surface. Aristotle suggested that air enters cold dark caverns under the mountains where it condenses into water and contributes to springs."*



Finding the culprit: Plato

[Σωκράτης:] «[…] *τοῦτο* [το χάσμα] *ὅπερ Ὅμηρος εἶπε, λέγων αὐτό "τῆλε μάλ᾽, ᾗχι βάθιστον ὑπὸ χθονός ἐστι βέρεθρον ὃ καὶ ἄλλοθι καὶ ἐκεῖνος καὶ ἄλλοι πολλοὶ τῶν ποιητῶν Τάρταρον κεκλήκασιν. εἰς γὰρ τοῦτο τὸ χάσμα συρρέουσί τε πάντες οἱ ποταμοὶ καὶ ἐκ τούτου πάλιν ἐκρέουσιν: γίγνονται δὲ ἕκαστοι τοιοῦτοι δι᾽ οἵας ἂν καὶ τῆς γῆς ῥέωσιν.* […] *ὅταν τε οὖν ὑποχωρήσῃ τὸ ὕδωρ εἰς τὸν τόπον τὸν δὴ κάτω καλούμενον, τοῖς κατ᾽ ἐκεῖνα τὰ ῥεύματα διὰ τῆς γῆς εἰσρεῖ τε καὶ πληροῖ αὐτὰ ὥσπερ οἱ ἐπαντλοῦντες: ὅταν τε αὖ ἐκεῖθεν μὲν ἀπολίπῃ, δεῦρο δὲ ὁρμήσῃ, τὰ ἐνθάδε πληροῖ αὖθις*» (Φαίδων, 14.112α).



Plato (428 - 348 BC)

Image source: Visconti (1817

[Socrates:] "[…] *One of the chasms of the earth is greater than the rest, and is bored right through the whole earth; this* [chasm] *is the one which Homer means when he says 'Far off, the lowest abyss beneath the earth' and 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 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*" (Phaedo, 14.112a).

Is this extract from Phaedo what the Greek philosophers said about the hydrological cycle?

While the view expressed in Phaedo was adopted by many thinkers and scientists from Seneca (*ca.* 4 BC–65 AD) to Descartes (1596-1650), **it is a just a poetic metaphor**, as indicated by the reference to Homer. It has a **symbolic meaning** as the philosophical subject of the dialogue Phaedo is the **immortality of the soul.** It is not representative of Greek philosophers' views on Nature, not even Plato's. In other dialogs Plato offers more consistent theories:

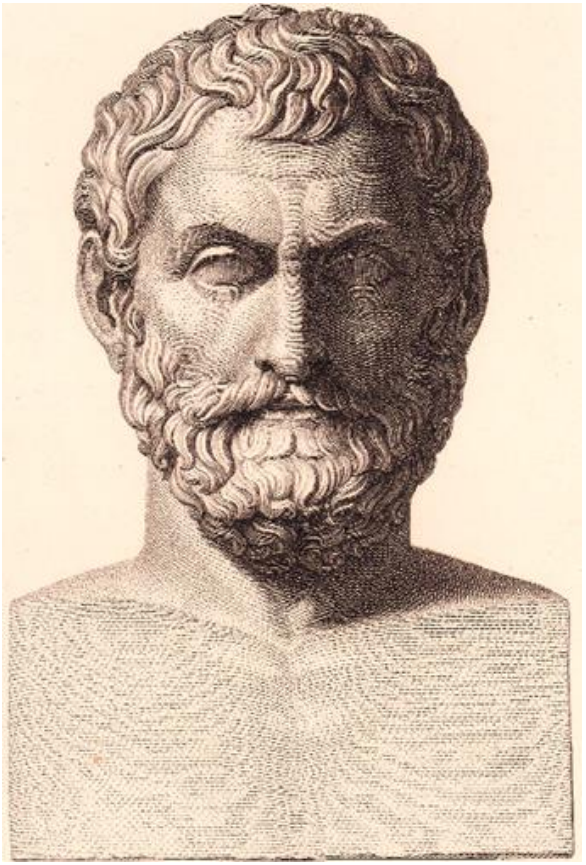
«*τὸ κατ᾽* ***ἐνιαυτὸν ὕδωρ*** *ἐκαρποῦτ᾽ ἐκ Διός, οὐχ ὡς νῦν ἀπολλῦσα ῥέον ἀπὸ ψιλῆς τῆς γῆς εἰς θάλατταν, ἀλλὰ πολλὴν ἔχουσα καὶ εἰς αὐτὴν καταδεχομένη, τῇ κεραμίδι στεγούσῃ γῇ* ***διαταμιευομένη****, τὸ* ***καταποθὲν ἐκ τῶν ὑψηλῶν ὕδωρ εἰς τὰ κοῖλα ἀφιεῖσα κατὰ πάντας τοὺς τόπους παρείχετο ἄφθονα κρηνῶν καὶ ποταμῶν νάματα***» (Πλάτων, Κριτίας, 111δ).

"*Moreover, it was enriched by the* ***yearly rains*** *from Zeus, which were not lost to it, as now, by flowing from the bare land into the sea; but the* ***soil*** *it had was deep, and therein it received the water,* ***storing it up in the retentive loamy soil*** *and by drawing off into the hollows from the heights the* ***water that was there absorbed, it provided all the various districts with abundant supplies of springwaters and rivers***" (Plato, Critias, 111d).

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 in 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.



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

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 hydrology in the birth of science.

Anaximander, Anaximenes and atmospheric processes

Thales's successor Anaximander(610–546 BC) is the first to dear write a book «Περί Φύσεως» ("On Nature"; lost), rejecting mythological and religious views. He understood the relationship or rainfall and evaporation:

«*ὑετούς δὲ* [γίγνεσθαι] *ἐκ τῆς ἀτμίδος τῆς ἐκ γῆς ὑφ' ἥλιον ἀναδιδομένης*» (Ιππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἱρέσεων Ἔλεγχος, I, 5).

"*Rain is created from the vapours which rise from earth by the sun*" (Hippolytus of Rome, Refutation of All Heresies, I, 5; https://books.google.gr/books?id=9HCOCwAAQBAJ).

Anaximenes was another philosopher from Miletus, who proclaimed Air as the "Arche" (origin) of the universe; naturally, thus, he devised logical explanations for the formation of wind, clouds, rain and hail:

«[…] *ἀνέμους δὲ γεννᾶσθαι, ὅταν ἐκ <μέρους> πεπυκνωμένος ὁ ἀὴρ καὶ ἀρθεὶς φέρηται· συνελθόντα δὲ καὶ ἐπὶ πλεῖον παχυνθέντα νέφη γεννᾶσθαι καὶ οὕτως εἰς ὕδωρ μεταβάλλειν. χάλαζαν δὲ γίνεσθαι, ὅταν ἀπὸ τῶν νεφῶν τὸ ὕδωρ καταφερόμενον παγῇ· χιόνα δέ, ὅταν αὐτὰ ταῦτα ἐνυγρότερα ὄντα πῆξιν λάβῃ. ἀστραπὴν δ' ὅταν τὰ νέφη διιστῆται βίαι πνευμάτων·* […]. *ἶριν δὲ γεννᾶσθαι τῶν ἡλιακῶν αὐγῶν εἰς ἀέρα συνεστῶτα πιπτουσῶν*» (Ιππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἱρέσεων Ἔλεγχος, I, 6)

"[…] *the winds arise when the air becomes partially condensed and is lifted up; and when it comes together and more condensed, clouds are generated, and thus a change is made into water. And hail is produced when the water precipitating from the clouds freezes; and snow is generated when these clouds, being more moist, acquire congelation; and lightning is caused when the clouds are parted by force of the winds;* […]. *And a rainbow is produced from solar rays falling on condensed air*" (Hippolytus, Refutation of All Heresies, I, 6).

The entire hydrological cycle and Xenophanes

Xenophanes (570–478 BC), another Ionian philosopher, supported his theory by the discovery of fossilized marine organisms at three island locations. Hippolitus (c. 170–235 AD; Christian theologian) attributes to him a theory of alternating periods of flood and drought.

Xenophanes expressed his philosophy in poetic form (hexameters, elegies, iambics), as in the following fragment:

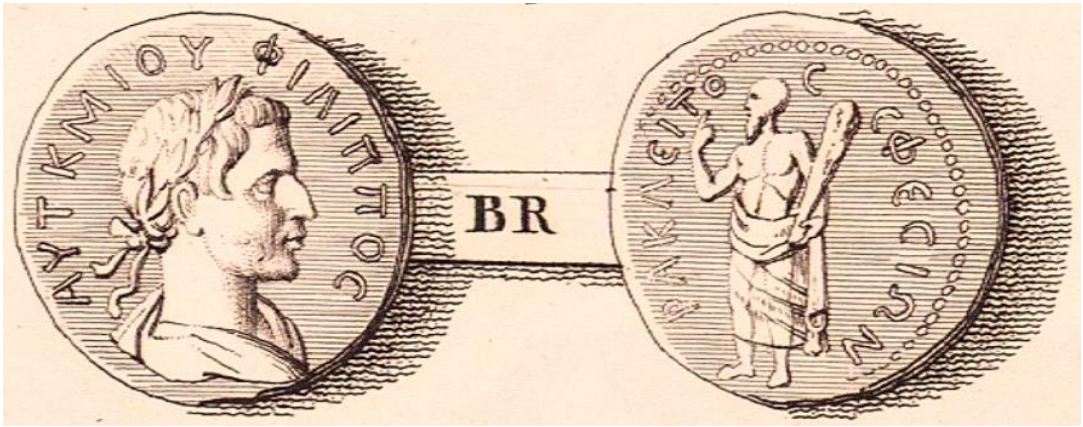
«*πηγὴ δ᾽ ἐστὶ θάλασσ᾽ ὕδατος, πηγὴ δ᾽ ἀνέμοιο·*
οὔτε γὰρ ἐν νέφεσιν <γίνοιτό κε ἴς ἀνέμοιο
ἐκπνείοντος> ἔσωθεν ἄνευ πόντου μεγάλοιο
οὔτε ῥοαὶ ποταμῶν οὔτ᾽ αἰ<θέρος> ὄμβριον ὕδωρ,
ἀλλὰ μέγας πόντος γενέτωρ νεφέων ἀνέμων τε καὶ ποταμῶν»
(Ξενοφάνης ἐν τῷ Περὶ φύσεως· Απόσπασμα Β 30·
http://www.poesialatina.it/_ns/Greek/testi/Xenophanes/Fragmenta.html)

"*The sea is the source of water and the source of wind;*
for neither in the clouds <would there be nor any blasts of wind
blowing forth> from within, ***without the mighty sea,***
nor river flows nor rain water from the sky*.*
The mighty sea is father of clouds and of winds and of rivers" (Fragment B 30, recovered from Geneva Scholia on Homer;
https://en.wikisource.org/wiki/Fragments_of_Xenophanes)

Hydrology is the science of change and randomness; Heraclitus described the nature of each in a few words

Heraclitus of Ephesus was another Ionian philosopher, father of dialectics.

He emphasized the dominance of change and randomness in Nature.



Heraclitus of Ephesus (535 –475 BC) depicted in the back facet of a coin whose front facet shows Philip

Image source: Visconti (1817)

«Πάντα ῥεῖ»
"Everything flows"

(Heraclitus; quoted in Plato's Cratylus, 339-340)

«Αἰών παῖς ἐστι παίζων πεσσεύων»
"Time is a child playing, throwing dice"

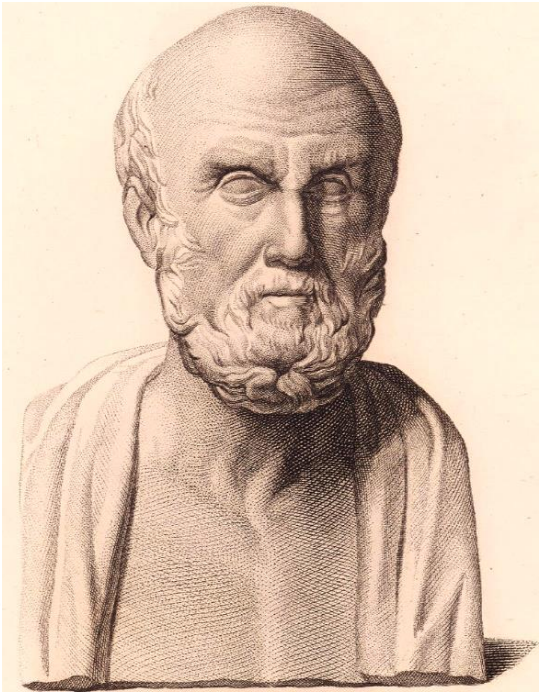
(Heraclitus; Fragment 52)

«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"
(Heraclitus, Fragment B 8)

Hippocrates and the strong relationship of hydrology with health

Hippocrates of Kos (460 – c. 370 BC), the philosopher and physician, is one of the most outstanding figures in the history of medicine. He also contributed to hydrology through his treatise Airs, Waters, Places:

τήν τε γὰρ ἀρχὴν ὁ ἥλιος ἀνάγει καὶ ἀναρπάζει τοῦ ὕδατος τό τε λεπτότατον καὶ κουφότατον. δῆλον δὲ οἱ ἅλες ποιέουσι. τὸ μὲν γὰρ ἁλμυρὸν λείπεται αὐτοῦ ὑπὸ πάχεος καὶ βάρεος καὶ γίνεται ἅλες, τὸ δὲ λεπτότατον ὁ ἥλιος ἀναρπάζει ὑπὸ κουφότητος· ἀνάγει δὲ τὸ τοιοῦτο οὐκ ἀπὸ τῶν ὑδάτων μοῦνον τῶν λιμναίων, ἀλλὰ καὶ ἀπὸ τῆς θαλάσσης καὶ ἐξ ἁπάντων ἐν ὁκόσοισι ὑγρόν τι ἔνεστιν. ἔνεστι δὲ ἐν παντὶ χρήματι. καὶ ἐξ αὐτῶν τῶν ἀνθρώπων ἄγει τὸ λεπτότατον τῆς ἰκμάδος καὶ κουφότατον (Ιπποκράτης, Περὶ Ἀέρων, Ὑδάτων, Τόπων, 8).



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

Rain waters, then, are the lightest, the sweetest, the thinnest, and the clearest; for originally the sun raises and attracts the thinnest and lightest part of the water, as is obvious from the nature of salts; for the saltish part is left behind owing to its thickness and weight, and forms salts; but the sun attracts the thinnest part, owing to its lightness, and he abstracts this not only from the lakes, but also from the sea, and from all things which contain humidity, and there is humidity in everything; and from man himself the sun draws off the thinnest and lightest part of the juices (Hippocrates, De Aere Aquis et Locis, 8).

Anaxagoras and the conveyance of science to Athens

Anaxagoras of Clazomenae lived and taught in Athens for ~30 years and transplanted the ideas of Ionic philosophers to Athenians, having prominent students such as Pericles, Euripides, Sophocles, and Herodotus. He proposed a theory of "everything-in-everything," and was the first to give a correct explanation of eclipses.

Anaxagoras (510 – c. 428 BC) depicted in the back facet of a coin whose front facet shows a ribbed head of a woman representing the personified city of Clazomenae (Image source: Visconti, 1817)

While his scientific theories were mostly related to astronomy, including the claims that the sun is a mass of red-hot metal and the moon is earthy, they also include hydrology:

«***τοὺς δὲ ποταμοὺς καὶ ἀπὸ τῶν ὄμβρων λαμβάνειν τὴν ὑπόστασιν*** *καὶ ἐξ ὑδάτων τῶν ἐν τῇ γῇ· εἶναι γὰρ αυτὴν κοίλην καὶ ἔχειν ὕδωρ ἐν τοῖς κοιλώμασιν*» (Ιππόλυτος, Φιλοσοφούμενα ἢ Κατὰ Πασῶν Αἱρέσεων Ἔλεγχος, I, 7).

"***The rivers receive their contents from the rains*** *and from the waters in the earth; for the earth is hollow and has water in its hollow portions*" (Hippolytus, Refutation of All Heresies, I, 7).

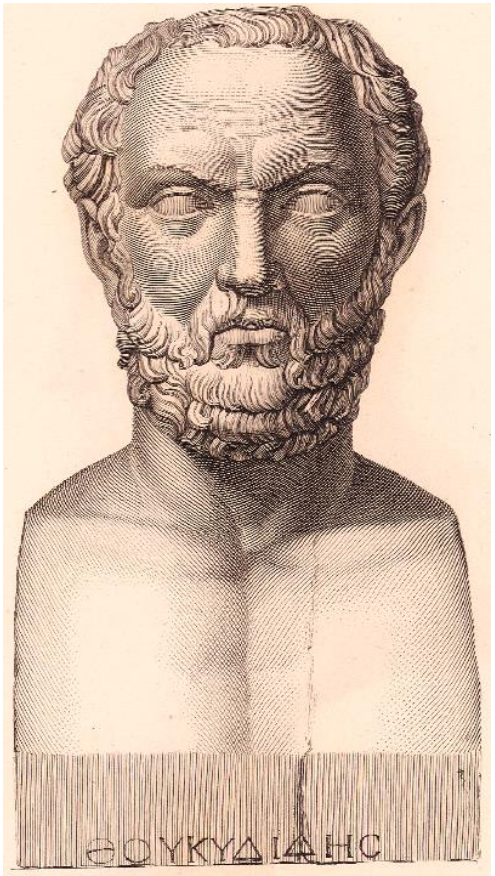
Why Athens became centre of the entire world for centuries?

The fact that Athens was the philosophical, scientific and political centre of the entire world for many centuries may seem as an historical paradox because it is a dry and infertile place.

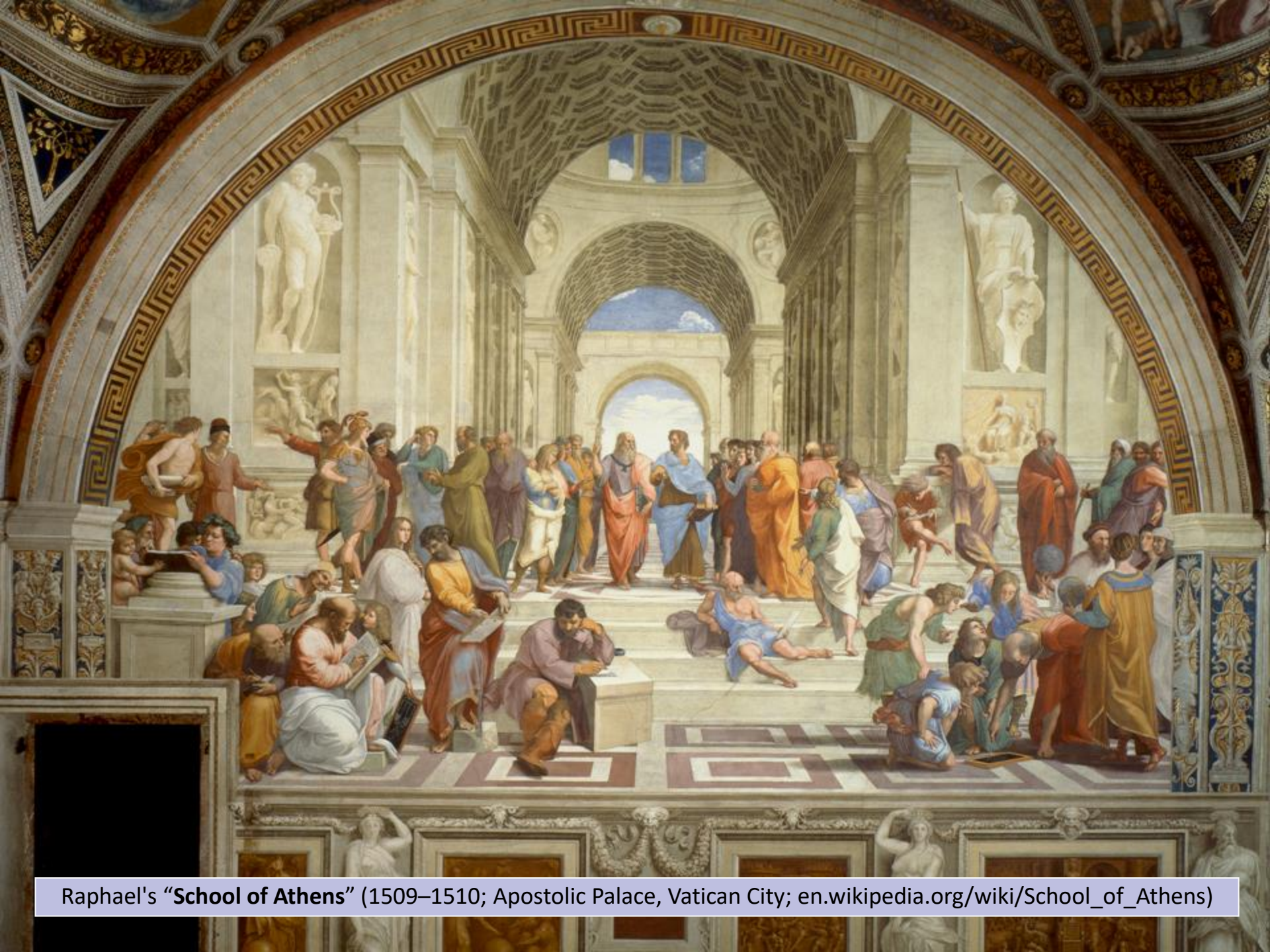
The paradox have been explained by the Athenian Thucydides, father of scientific history, who observed that infertility has also a good side and scarcity may be preferable to abundance:

μάλιστα δὲ τῆς γῆς ἡ ἀρίστη αἰεὶ τὰς μεταβολὰς τῶν οἰκητόρων εἶχεν […] διὰ γὰρ ***ἀρετὴν γῆς*** *αἵ τε δυνάμεις τισὶ μείζους ἐγγιγνόμεναι* ***στάσεις ἐνεποίουν ἐξ ὧν ἐφθείροντο, καὶ ἅμα ὑπὸ ἀλλοφύλων μᾶλλον ἐπεβουλεύοντο****.* ***τὴν γοῦν Ἀττικὴν ἐκ τοῦ ἐπὶ πλεῖστον διὰ τὸ λεπτόγεων ἀστασίαστον οὖσαν ἄνθρωποι ᾤκουν οἱ αὐτοὶ αἰεί****. καὶ παράδειγμα τόδε τοῦ λόγου οὐκ ἐλάχιστόν ἐστι διὰ τὰς μετοικίας ἐς τὰ ἄλλα μὴ ὁμοίως αὐξηθῆναι· ἐκ γὰρ τῆς ἄλλης Ἑλλάδος οἱ πολέμῳ ἢ στάσει ἐκπίπτοντες παρ᾽ Ἀθηναίους οἱ δυνατώτατοι ὡς βέβαιον ὂν ἀνεχώρουν, καὶ πολῖται γιγνόμενοι εὐθὺς ἀπὸ παλαιοῦ μείζω ἔτι ἐποίησαν πλήθει ἀνθρώπων τὴν πόλιν.*
(Θουκυδίδης, Ἱστορία τοῦ Πελοποννησιακοῦ Πολέμου, 1.2.3-6.)

The richest soils were always most subject to this change of masters; […]. The **goodness of the land** favoured the aggrandizement of particular individuals, and thus **created faction which proved a fertile source of ruin. It also invited invasion**. Accordingly Attica, from the **poverty of its soil enjoying from a very remote period freedom from faction, never changed its inhabitants**. And here is no inconsiderable exemplification of my assertion that the migrations were the cause of there being no correspondent growth in other parts. The most powerful victims of war or faction from the rest of Hellas took refuge with the Athenians as a safe retreat; and at an early period, becoming naturalized, swelled the already large population of the city[…]
(Thucydides, The Peloponnesian War, 1.2.3-6.)



Thucydides (460 – 400 BC) dubbed the father of scientific history
Image source: Visconti (1817)



Raphael's "**School of Athens**" (1509–1510; Apostolic Palace, Vatican City; en.wikipedia.org/wiki/School_of_Athens)

Aristotle and the phase change of water

Aristotle was student of Plato, but his theories were influenced by Ionic philosophers. His theories expand to all aspects of knowledge; in particular his treatise *Meteorologica* offers a great contribution to the explanation of hydrometeorogical phenomena:

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

«*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 and mass conservation

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 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 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:

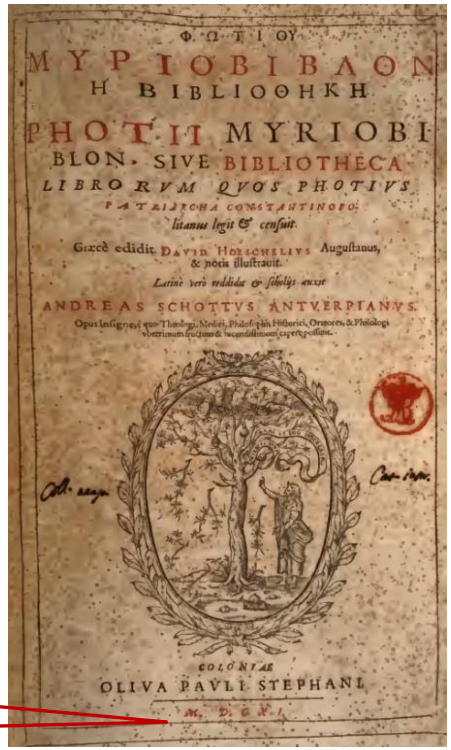
"Sailors, when they labour under a scarcity of fresh water at sea, boil the sea-water, and suspend large sponges from the mouth of a brazen vessel, to imbibe what is evaporated, and in drawing this off from the sponges, they find it to be sweet [fresh] *water"* (Morewood 1838; see also quotation by Alexander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

Aristotle and the solution of the Nile paradox

Most of ancient Greek texts have been lost and information on them is indirectly obtained from references in other books.

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 important information about Aristotle's decisive contribution in solving the Nile paradox.



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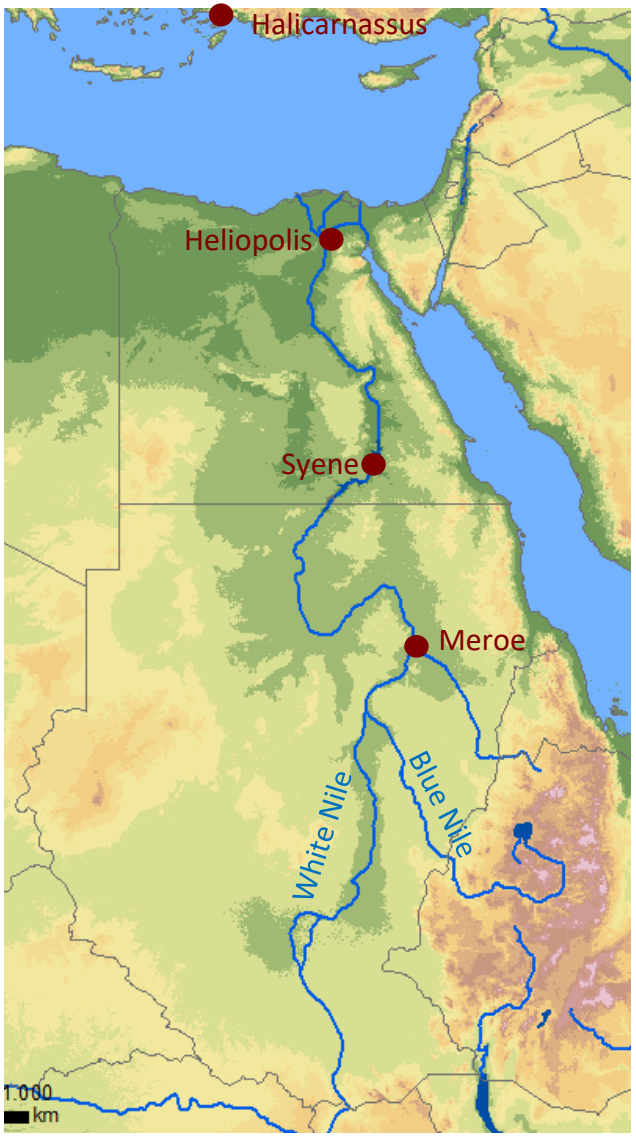
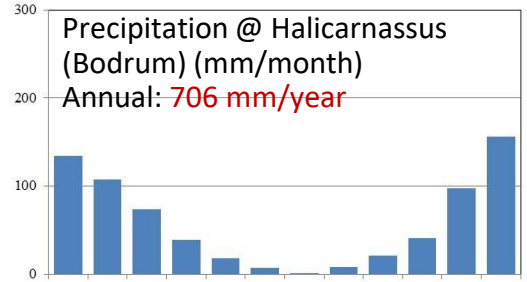
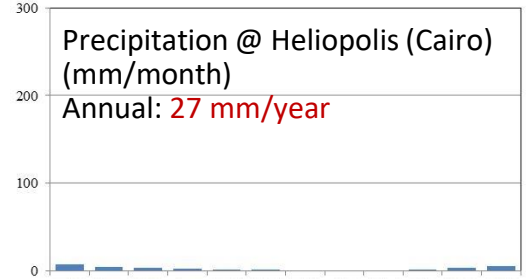
What was the Nile paradox?

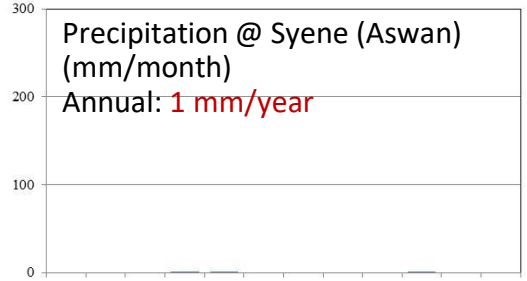
The first great problem related to a natural behaviour and put in scientific terms was the cause of the Nile floods. It was debated for almost three centuries (Burstein, 1976).

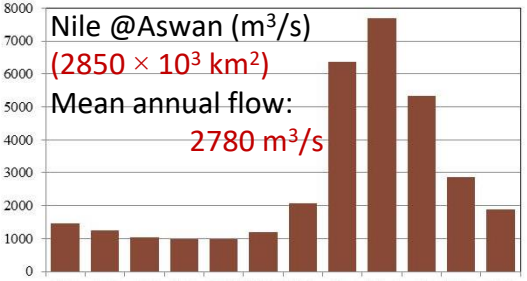
What puzzled Greek thinkers was the different hydrological regime compared to other Mediterranean rivers: the Nile floods occur in summer rather than during winter.



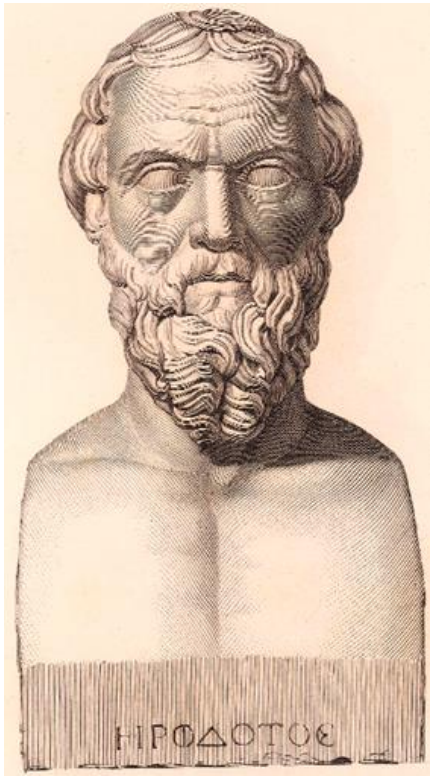








Problem statement by Herodotus



Herodotus (484–425 BC)
Image source: Visconti (1817)

«*τοῦ ποταμοῦ δὲ φύσιος πέρι οὔτε τι τῶν ἱρέων οὔτε ἄλλου οὐδενὸς παραλαβεῖν ἐδυνάσθην. πρόθυμος δὲ ἔα τάδε παρ᾽ αὐτῶν πυθέσθαι, ὅ τι κατέρχεται μὲν ὁ Νεῖλος πληθύων ἀπὸ τροπέων τῶν θερινέων ἀρξάμενος ἐπὶ ἑκατὸν ἡμέρας, πελάσας δὲ ἐς τὸν ἀριθμὸν τουτέων τῶν ἡμερέων ὀπίσω ἀπέρχεται ἀπολείπων τὸ ῥέεθρον, ὥστε βραχὺς τὸν χειμῶνα ἅπαντα διατελέει ἐὼν μέχρι οὗ αὖτις τροπέων τῶν θερινέων. τούτων ὧν πέρι οὐδενὸς οὐδὲν οἷός τε ἐγενόμην παραλαβεῖν παρὰ τῶν Αἰγυπτίων, ἱστορέων αὐτοὺς* ***ἥντινα δύναμιν ἔχει ὁ Νεῖλος τὰ ἔμπαλιν πεφυκέναι τῶν ἄλλων ποταμῶν****: ταῦτά τε δὴ τὰ λελεγμένα βουλόμενος εἰδέναι ἱστόρεον καὶ ὅ τι αὔρας ἀποπνεούσας μοῦνος ποταμῶν πάντων οὐ παρέχεται*» (Ηροδότου Ιστορίαι, 2, 19).

"*Concerning the nature of the river, I was not able to gain any information either from the priests or from others. I was particularly anxious to learn from them why the Nile, at the commencement of the summer solstice, begins to rise, and continues to increase for a hundred days—and why, as soon as that number is past, it forthwith retires and contracts its stream, continuing low during the whole of the winter until the summer solstice comes round again. On none of these points could I obtain any explanation from the inhabitants, though I made every inquiry, wishing to know what was commonly reported—* ***they could neither tell me what special virtue the Nile has which makes it so opposite in its nature to all other streams****, nor why, unlike every other river, it gives forth no breezes from its surface*" (Herodotus, The Histories, 2, 19).

First explanation described by Herodotus

«*ἀλλὰ* ***Ἑλλήνων μὲν τινὲς ἐπίσημοι βουλόμενοι γενέσθαι σοφίην*** *ἔλεξαν περὶ τοῦ ὕδατος τούτου τριφασίας ὁδούς: τῶν τὰς μὲν δύο τῶν ὁδῶν οὐδ᾽ ἀξιῶ μνησθῆναι εἰ μὴ ὅσον σημῆναι βουλόμενος μοῦνον*».

"*Some of the* ***prominent Greeks, however, wishing to get a reputation for wisdom****, have offered explanations of the phenomena of the river, for which they have accounted in three different ways. Two of these I do not think it worth while to speak of, further than simply to mention what they are*" (ibid. 2, 20).

«*τῶν ἡ ἑτέρη μὲν λέγει τοὺς ἐτησίας ἀνέμους εἶναι αἰτίους πληθύειν τὸν ποταμόν, κωλύοντας ἐς θάλασσαν ἐκρέειν τὸν Νεῖλον. πολλάκις δὲ ἐτησίαι μὲν οὔκων ἔπνευσαν, ὁ δὲ Νεῖλος τὠυτὸ ἐργάζεται. πρὸς δέ, εἰ ἐτησίαι αἴτιοι ἦσαν, χρῆν καὶ τοὺς ἄλλους ποταμούς, ὅσοι τοῖσι ἐτησίῃσι ἀντίοι ῥέουσι, ὁμοίως πάσχειν καὶ κατὰ τὰ αὐτὰ τῷ Νείλῳ, καὶ μᾶλλον ἔτι τοσούτῳ ὅσῳ ἐλάσσονες ἐόντες ἀσθενέστερα τὰ ῥεύματα παρέχονται. εἰσὶ δὲ πολλοὶ μὲν ἐν τῇ Συρίῃ ποταμοὶ πολλοὶ δὲ ἐν τῇ Λιβύῃ, οἳ οὐδὲν τοιοῦτο πάσχουσι οἷόν τι καὶ ὁ Νεῖλος.*»

"***One says that the Etesian [i.e. monsoon] winds cause the rise of the river by preventing the Nile-water from running off into the sea****. But in the first place it has often happened, when the Etesian winds did not blow, that the Nile has risen according to its usual wont; and further, if the Etesian winds produced the effect, the other rivers which flow in a direction opposite to those winds ought to present the same phenomena as the Nile, and the more so as they are all smaller streams, and have a weaker current. But these rivers, of which there are many both in Syria and Libya, are entirely unlike the Nile in this respect*" (ibid. 2, 20).

Second explanation described by Herodotus

«ἡ δ᾽ ἑτέρη ἀνεπιστημονεστέρη μὲν ἐστὶ τῆς λελεγμένης, λόγῳ δὲ εἰπεῖν θωμασιωτέρη: ἢ λέγει ἀπὸ τοῦ Ὠκεανοῦ ῥέοντα αὐτὸν ταῦτα μηχανᾶσθαι, τὸν δὲ Ὠκεανὸν γῆν περὶ πᾶσαν ῥέειν. […] ὁ δὲ περὶ τοῦ Ὠκεανοῦ λέξας ἐς ἀφανὲς τὸν μῦθον ἀνενείκας οὐκ ἔχει ἔλεγχον: οὐ γὰρ τινὰ ἔγωγε οἶδα ποταμὸν Ὠκεανὸν ἐόντα, Ὅμηρον δὲ ἢ τινὰ τῶν πρότερον γενομένων ποιητέων δοκέω τὸ οὔνομα εὑρόντα ἐς ποίησιν ἐσενείκασθαι.»

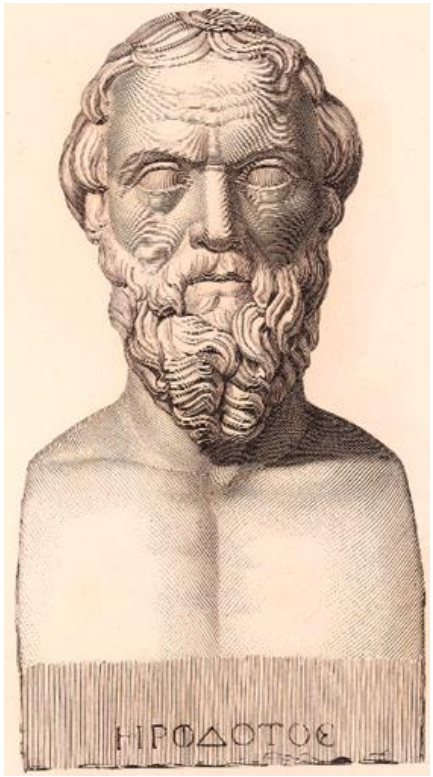
"The second opinion is even more unscientific than the one just mentioned, and also, if I may so say, more marvellous. ***It is that the Nile acts so strangely, because it flows from the ocean, and that the ocean flows all round the earth.*** *[…] As for the writer who attributes the phenomenon to the ocean, his account is involved in such obscurity that it is impossible to disprove it by argument. For my part I know of no river called Ocean, and I think that Homer, or one of the earlier poets, invented the name, and introduced it into his poetry"* (ibid. 2, 21&23).

Third explanation described by Herodotus

«*ἡ δὲ τρίτη τῶν ὁδῶν πολλὸν ἐπιεικεστάτη ἐοῦσα μάλιστα ἔψευσται: λέγει γὰρ δὴ οὐδ᾽ αὕτη οὐδέν, φαμένη τὸν Νεῖλον ῥέειν ἀπὸ τηκομένης χιόνος: ὃς ῥέει μὲν ἐκ Λιβύης διὰ μέσων Αἰθιόπων, ἐκδιδοῖ δὲ ἐς Αἴγυπτον. κῶς ὦν δῆτα ῥέοι ἂν ἀπὸ χιόνος, ἀπὸ τῶν θερμοτάτων ῥέων ἐς τὰ ψυχρότερα τὰ πολλά ἐστι; ἀνδρί γε λογίζεσθαι τοιούτων πέρι οἵῳ τε ἐόντι, ὡς οὐδὲ οἰκὸς ἀπὸ χιόνος μιν ῥέειν, πρῶτον μὲν καὶ μέγιστον μαρτύριον οἱ ἄνεμοι παρέχονται πνέοντες ἀπὸ τῶν χωρέων τουτέων θερμοί: δεύτερον δὲ ὅτι ἄνομβρος ἡ χώρη καὶ ἀκρύσταλλος διατελέει ἐοῦσα, ἐπὶ δὲ χιόνι πεσούσῃ πᾶσα ἀνάγκη ἐστὶ ὗσαι ἐν πέντε ἡμέρῃσι, ὥστε, εἰ ἐχιόνιζε, ὕετο ἂν ταῦτα τὰ χωρία: τρίτα δὲ οἱ ἄνθρωποι ὑπὸ τοῦ καύματος μέλανες ἐόντες. ἰκτῖνοι δὲ καὶ χελιδόνες δι᾽ ἔτεος ἐόντες οὐκ ἀπολείπουσι, γέρανοι δὲ φεύγουσαι τὸν χειμῶνα τὸν ἐν τῇ Σκυθικῇ χώρῃ γινόμενον φοιτῶσι ἐς χειμασίην ἐς τοὺς τόπους τούτους. εἰ τοίνυν ἐχιόνιζε καὶ ὅσον ὦν ταύτην τὴν χώρην δι᾽ ἧς τε ῥέει καὶ ἐκ τῆς ἄρχεται ῥέων ὁ Νεῖλος, ἦν ἂν τούτων οὐδέν, ὡς ἡ ἀνάγκη ἐλέγχει.*»

"*The third explanation, which is very much more plausible than either of the others, is positively the furthest from the truth; for there is really nothing in what it says, any more than in the other theories.* ***It is, that the inundation of the Nile is caused by the melting of snows.*** *Now, as the Nile flows out of Libya, through Ethiopia, into Egypt, how is it possible that it can be formed of melted snow, running, as it does, from the hottest regions of the world into cooler countries? Many are the proofs whereby any one capable of reasoning on the subject may be convinced that it is most unlikely this should be the case. The first and strongest argument is furnished by the winds, which always blow hot from these regions. The second is that rain and frost are unknown there. Now whenever snow falls, it must of necessity rain within five days, so that, if there were snow, there must be rain also in those parts. Thirdly, it is certain that the natives of the country are black with the heat, that the kites and the swallows remain there the whole year, and that the cranes, when they fly from the rigors of a Scythian winter, flock thither to pass the cold season. If then, in the country whence the Nile has its source, or in that through which it flows, there fell ever so little snow, it is absolutely impossible that any of these circumstances could take place*" (ibid. 2, 22).

Herodotus' own explanation



Herodotus (484–425 BC)
Image source: Visconti (1817)

«*εἰ δὲ δεῖ μεμψάμενον γνώμας τὰς προκειμένας αὐτὸν περὶ τῶν ἀφανέων γνώμην ἀποδέξασθαι, φράσω δι᾽ ὅ τι μοι δοκέει πληθύνεσθαι ὁ Νεῖλος τοῦ θέρεος: τὴν χειμερινὴν ὥρην ἀπελαυνόμενος ὁ ἥλιος ἐκ τῆς ἀρχαίης διεξόδου ὑπὸ τῶν χειμώνων ἔρχεται τῆς Λιβύης τὰ ἄνω. ὡς μέν νυν ἐν ἐλαχίστῳ δηλῶσαι, πᾶν εἴρηται: τῆς γὰρ ἂν ἀγχοτάτω τε ᾖ χώρης ο***ὗτος ὁ θεὸς καὶ κατὰ ἤντινα, ταύτην οἰκὸς διψῆν τε ὑδάτων μάλιστα καὶ τὰ ἐγχώρια ῥεύματα μαραίνεσθαι τῶν ποταμῶν***.*»

"*Perhaps, after censuring all the opinions that have been put forward on this obscure subject, one ought to propose some theory of one's own. I will therefore proceed to explain what I think to be the reason of the Nile's swelling in the summer time. During the winter, the sun is driven out of his usual course by the storms, and removes to the upper parts of Libya. This is the whole secret in the fewest possible words; for it stands to reason that the country to which* ***the Sun-god approaches the nearest, and which he passes most directly over, will be scantest of water, and that there the streams which feed the rivers will shrink the most***" (ibid. 2, 24).

Who supported the three explanations discussed by Herodotus?

Aetius, the 1st- or 2nd-century AD doxographer and Eclectic philosopher, reveals the supporters of the three explanations.

Interestingly, **the first explanation is attributed to Thales**, which highlights the strong link of hydrology with science (or natural philosophy), at the dawn of the latter:

«*Θαλῆς τοὺς ἐτησίας ἀνέμους οἴεται πνέοντας τῇ Αἰγύπτῳ ἀντιπροσώπους ἐπαίρειν τοῦ Νείλου τὸν ὄγκον διὰ τὸ τὰς ἐκροὰς αὐτοῦ τῇ παροιδήσει τοῦ ἀντιπαρήκοντος πελάγους ἀνακόπτεσθαι*» (Αέτιος IV, 1, 1).

"*Thales thinks that the Etesian winds (monsoons), blowing straight on to Egypt, raise up the mass of the Nile's water through cutting off the outflow by the swelling of the sea coming against it*" (Aetius IV, 1, 1).

The second was supported by Euthymenes of Massalia (Εὐθυμένης ὁ Μασσαλιώτης; fl. early 6thcentury BC), a Greek explorer from Massilia (Marseille), who explored the coast of West Africa.

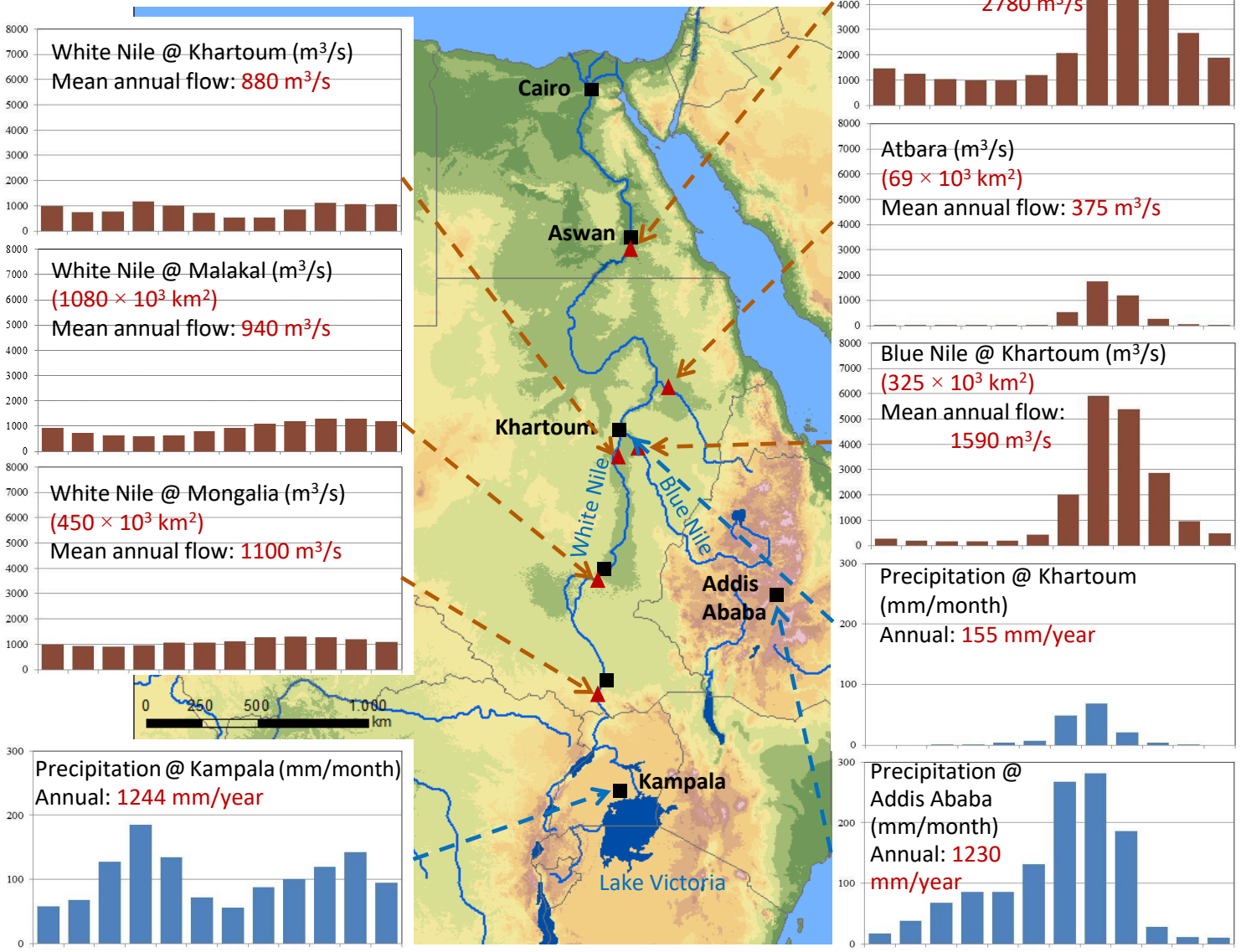
The third seems to have been supported by Anaxagoras and in another version by Democritus (460–370 BC).

The solution of the paradox by Aristotle

«*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,* http://remacle.org/bloodwolf/erudits/photius/pythagore.htm)

The Nile (non)paradox in modern terms



Verification of the story by other philosophers

«*Ἐρατοσθένης δὲ οὐκέτι φησὶν <πρόβλημα εἶναι> οὐδὲ ζητεῖν χρῆναι περὶ τῆς αὐξήσεως τοῦ Νείλου, σαφῶς καὶ ἀφικομένων τινῶν εἰς τὰς τοῦ Νείλου πηγὰς καὶ τοὺς ὄμβρους τοὺς γιγνομένους ἑωρακότων, ὥστε κρατύνεσθαι τὴν Ἀριστοτέλους ἀπόδοσιν*» (Πρόκλος ο Λύκιος, Σχόλια, Πλάτωνος Τίμαιος, 22 E—I 121, 8 Diehl).

"*Eratosthenes, however, says, it is no longer requisite to investigate the cause of the increase of the Nile, once some have reached at the springs of the Nile and saw the rains that occur there, so as to corroborate what is said by Aristotle*" (Proclus, Commentary on Plato's Timaeus, 22 E—I 121, 8 Diehl)

«*τῆς γὰρ Αἰθιοπίας ὑψηλοῖς παρὰ τὰ καθ' ἡμᾶς ὄρεσι διεζωσμένης ὑποδεχομένης τε τὰς νεφέλας πρὸς τῶν ἐτησίων ὠθουμένας, ἐκδιδόναι τὸν Νεῖλον. ὡς καὶ <Καλλισθένης> ὁ Περιπατητικὸς ἐν τῶι τετάρτωι βιβλίωι τῶν Ἑλληνικῶν (124 F 12) <φησιν ἑαυτὸν συστρατεύσασθαι Ἀλεξάνδρωι τῶι Μακεδόνι, καὶ γενόμενον ἐπὶ τῆς Αἰθιοπίας εὑρεῖν τὸν Νεῖλον ἐξ ἀπείρων ὄμβρων κατ' ἐκείνην γενομένων> καταφερόμενον*» (Ἰωάννης Λαυρέντιος ὁ Λυδός, De mensibus, 4, 107).

"*For since Ethiopia is girdled by mountains higher than ours, as it receives the clouds that are driven by the Etesian [winds], the Nile swells. As Callisthenes the Peripatetic also says in the fourth book of his Hellenica that he campaigned with Alexander the Macedonian, and when he was in Ethiopia he found that the Nile is driven down by the endless rain-storms that take place in that* [area]" (John the Lydian, On the Months, 4, 107).

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 rely on 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 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 a new mythology was developed around a "theory" of the "nitre" which was a mythical element that presumably caused the flooding of the Nile, while rainfall in Ethiopia had a minor role, if any.

When was Aristotle's theory accepted?

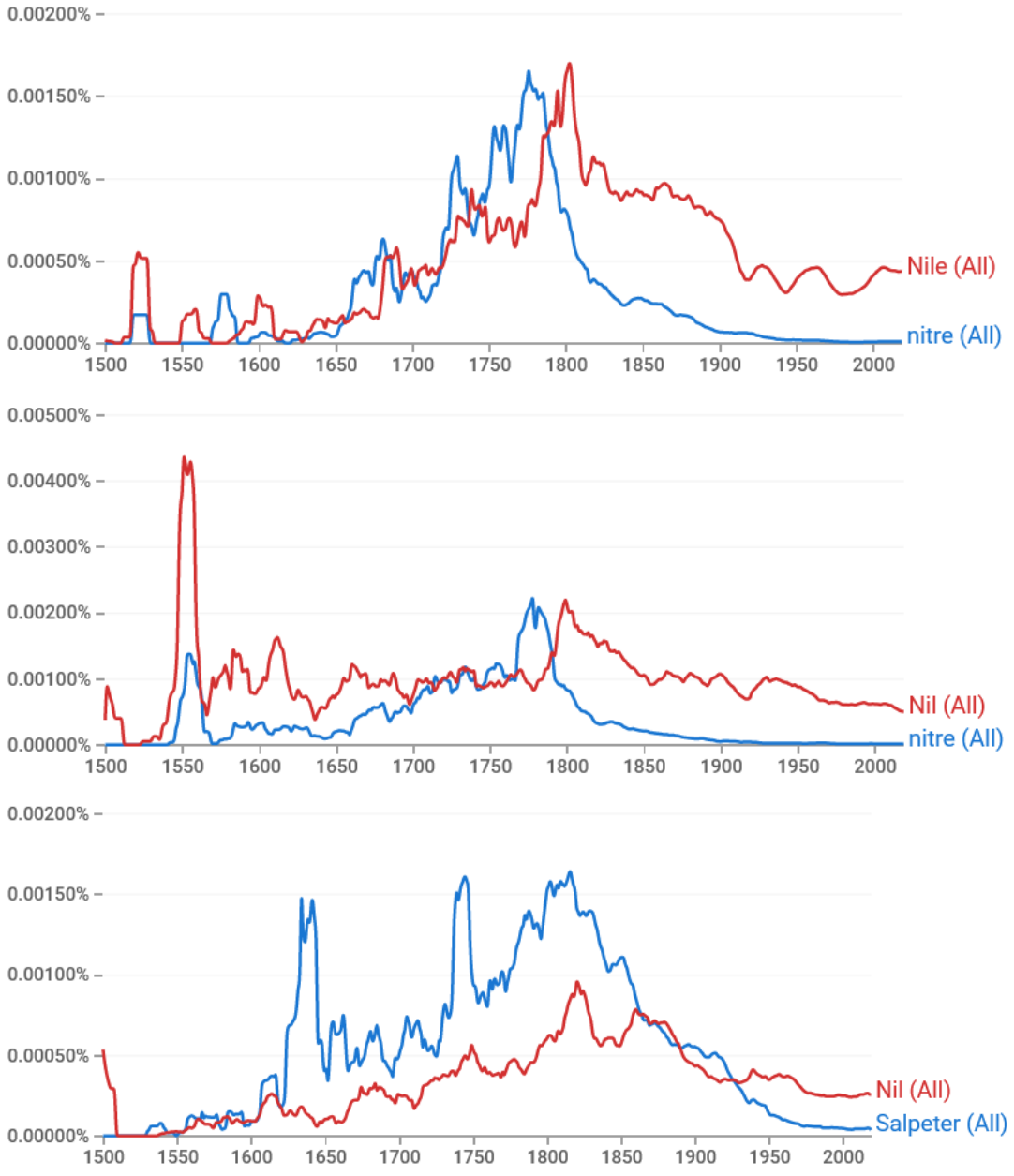
It took the visit to the origins of the Blue Nile of the Scottish traveller James Bruce and the publication of his book (Bruce, 1813) for the modern mythical theory to cease.

Question (food for thought):

Why Aristotle's incorrect geocentric system was so popular while his correct explanation of the Nile was unpopular?

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, 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 his 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.

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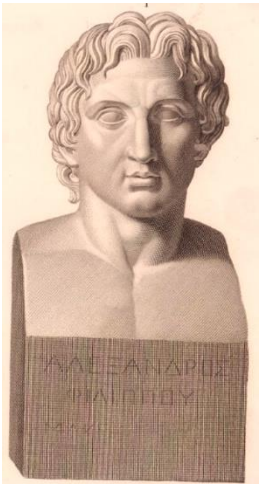
*Note that such respect is not the rule in history: Remarkable counterexample is the conspiration of Kolmogorov, Alexandrov and other students of Luzin, to convict their mentor likely to death—an attempt which was prevented by intervention of Kapitsa and ultimately by a decision of Stalin (Graham and Kantor, 2009).

Aristotle (384 – 322 BC)



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

Source of images: Visconti (1817)

Prominent scientists of the Hellenistic period: Aristarchus

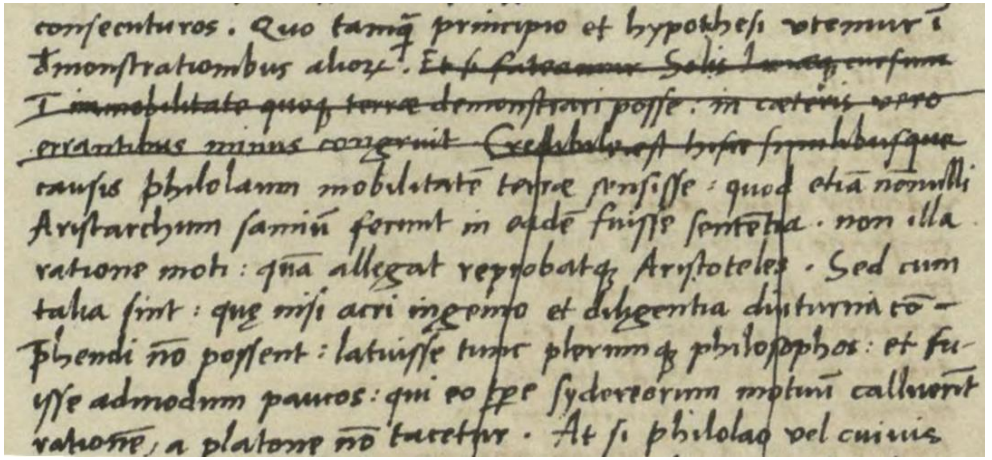
Aristarchus of Samos (310 – 230 BC; mathematician and astronomer), introduced the heliocentric model for the solar system 1800 years before Copernicus. He also said that the stars were distant suns and made calculations on the relative sizes of the Sun, Earth and Moon. Notably, before him also the Pythagorean philosopher Philolaus (470 – 385 BC) had moved the Earth from the center of the cosmos and made it a planet, but in Philolaus's system Earth does not orbit the Sun but rather a central fire.

Interestingly, Copernicus in the manuscript of his book De revolutionibus included a citation to Philolaus and Aristarchus but he crossed it out before publication. The point that was crossed out, translated in English (Gingerich, 1973, 1985), reads:

> […] *It is credible that for these and similar causes (and not because of the reasons that Aristotle mentions and rejects), Philolaus believed in the mobility of the Earth and some even say that Aristarchus of Samos was of that opinion. But since such things could not be comprehended except by a keen intellect and continuing diligence, Plato does not conceal the fact that there were very few philosophers in that time who mastered the study of celestial motions.*

Part of page 22 of Book 1 of Copernicus's manuscript showing the references to Philolaus, Aristarchus and the Greek cosmology, which he crossed out before publication of his book De revolutionibus

Source: http://copernicus.torun.pl/en/archives/De_revolutionibus/1/?view=gallery&file=1&page=22



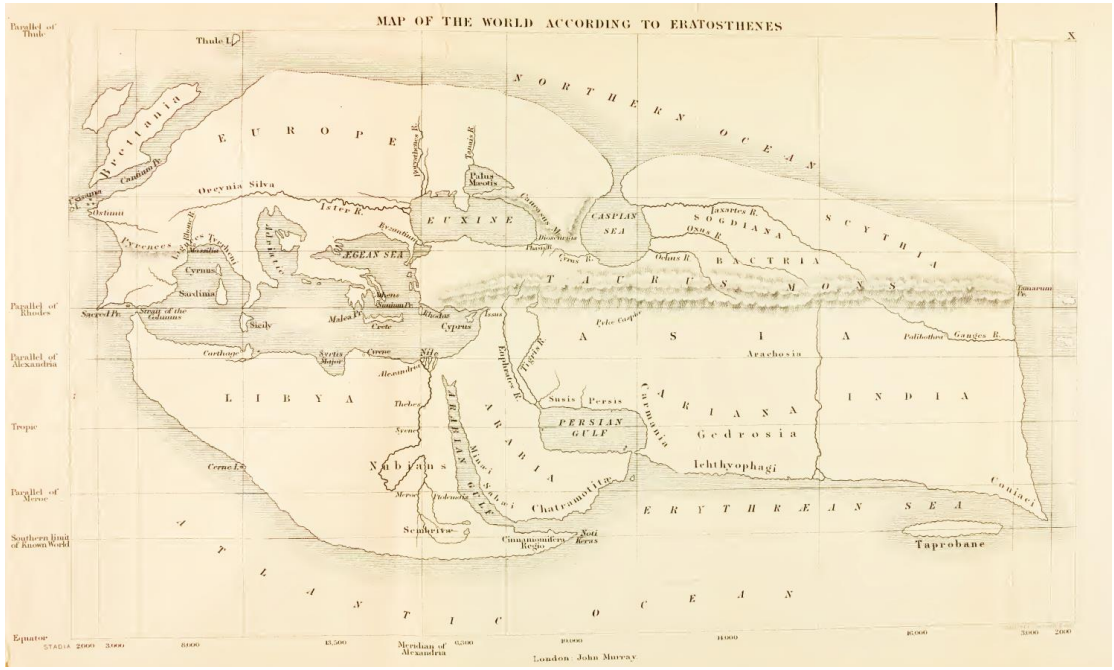
Prominent scientists of the Hellenistic period: Eratosthenes

Eratosthenes (276 – 195 BC; head of the Library at Alexandria, following the windings of the Nile, calculated the distances between several points on the Nile up to Meroe (Strabo, Geography, 17.1.2; Rawlins, 1982). Perhaps because of this, he is often credited by several authors for solving the paradox of the Nile.

However, in view of the information provided here (in particular by Proclus), his achievement seems to be no more than a further verification of Aristotle's theory. He also seems to have been aware of the earlier expedition to the Nile sources for the purpose of proving Aristotle's theory (Burstein, 1976).

One of his biggest achievements was to calculate, with remarkable accuracy (<2.5%) the Earth's circumference by measuring, at the noon of the day of summer solstice, the shadow cast by a gnomon at Alexandria and the distance between and Alexandria and Syene, where the latter is situated close to the Tropic of Cancer.

Despite the advancements in geography during the Hellenistic period, the achieved geographical representation of the Earth was rather poor.



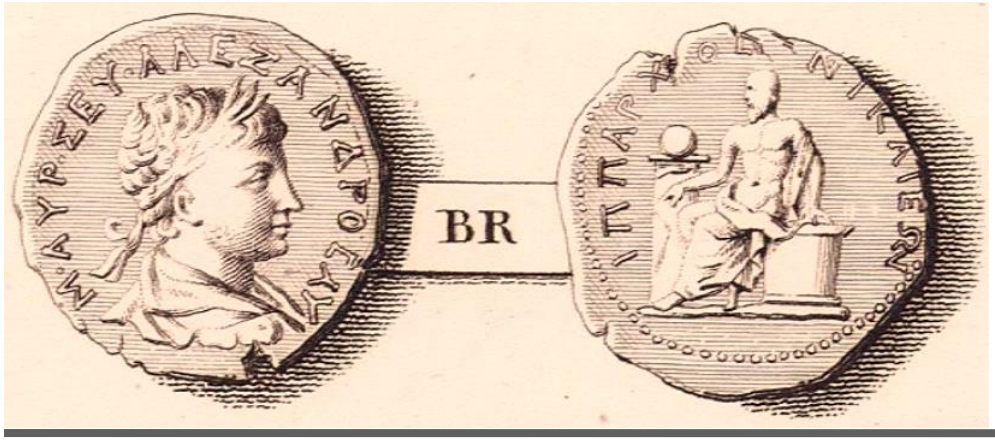
Map of the World according to Eratosthenes
Reproduced by Rhys (1912)

Prominent scientists of the Hellenistic period: Hipparchus

Hipparchus, the Greek astronomer, geographer and mathematician, and founder of trigonometry introduced the term climate (κλίμα, pl. κλίματα). Its etymology from the verb κλίνειν (= to incline) expresses the dependence of climate on the seasonal pattern of inclination angles of the incoming sunbeams.

Note that the notion of climate had been studied earlier by Aristotle, who used another term, crasis (κρᾶσις = mixture, blend) (see also Koutsoyiannis, 2021a,b).

Perhaps Hipparchus's most remarkable achievement is the discovery of the precession of the equinoxes, one of the cycles in Earth's motion, with period of about 21 000 years, that determine the long-term changes of the climate. This constitutes one of the several now called Milankovitch cycles.



Hipparchus of Nicaea (190 – 120 BC), depicted in the back facet of a coin whose front facet shows the Roman emperor Severus Alexander (M. AYP. ΣEY. ΑΛΕΞΑΝΔΡΟΣ AY = Marcus Aurelius Alexandros Augustus)
Image source: 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 perhaps the greatest mathematician of all time. While Aristarchus's heliocentric system was contrary to "consensus theory" for 1800 years, it is important to notice that it was adopted by Archimedes. In fact, he 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 (Πνευματικά; Schmidt, 1899, p. 192, "Ὑδραυλικοῦ ὀργάνου κατασκευή"; 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' ἐνὸς 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)

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 low 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 arca 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)

Modern scientific terminology related to *hydrology*

Several terms related to hydrology appear in the ancient Greek literature. Specifically:

- The modern term *ὑδραυλική* (*hydraulics*) stems from *ὑδραυλικὸν* (*hydraulic*) *ὄργανον*, a musical instrument operated by hydraulics and invented by Ctesibius*; it is also known as *ὕδραυλις* (ἡ), which is played by a musician called ὑδραύλης.
- The term *meteorology* stems from *μετεωρολογία*, which in turn stems from *μετέωρα* (meteors; note, in the ancient literature, in addition to hydrometeors, meteors include the heavenly bodies); a person who studies *μετεωρολογία* is *μετεωρολόγος* or *μετεωρολογικός* (cf. Plato's Phaedro 270a and Aristotle's Meteorologica).
- The term *climate* stems from *κλίμα* (meaning the inclination angle of the incoming sunbeams; pl. *κλίματα*); a property pertaining to *κλίμα* is *κλιματικός*.

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*Related ancient Greek terms, not in international use today, include:

- The conveyance of water or liquids is termed *ὑδραγωγία* (ἡ), and a person (or device) related to it *ὑδραγωγός*.
- The actions of drawing, fetching or distributing water are termed *ὑδρεία*, *ὕδρευσις* and *ὑδροπαροχία*; a person related to them is termed *ὑδροπάροχος* and a guard or inspector of aqueducts or irrigation works *ὑδροφύλαξ*.
- The action or art of seeking or discovering water is termed *ὑδροσκοπία*, *ὑδροσκοπική* or *ὑδροφαντική* (verb: *ὑδροσκοπέω*); a person related to it is *ὑδρόσκοπος*, *ὑδρογνώμων* or *ὑδροφάντης* and a related instrument is *ὑδροσκόπιον*.

The term *hydrology* in modern times

Hydrology is a Greek word (i.e., ὑδρολογία; feminine noun transliterated in Latin as hydrologia), but it does not appear in the ancient Greek literature. The closest match it contains is ὑδρολόγιον (hydrologion, a noun in neuter gender), which however is a water-clock. Its plural, ὑδρολόγια, is transliterated in Latin as hydrologia, precisely the same as the transliteration of ὑδρολογία (notice that in Greek there is a difference in the location of the accent).

According to our search in digital archives of old books, the first containing the term hydrology in its French version, hydrologie, is the book by Landrey (1614). It appears that the main orientation of those books was medical.

At the end of the 18th century and during the 19th century, the domain covered by the term hydrology is expanded to include natural sciences (physics, meteorology, climatology), geography and hydraulics.

At the end of the 19th century an international congress of hydrology and climatology was held at Biarritz, France (in Bay of Biscay close to the Spanish borders) as reported by Symons (1887). In this, hydrology was divided in two branches, medical hydrology and scientific hydrology; key persons of that congress were medical doctors but there was also one explorer and geographer, and one meteorologist.

Books published in the 17th through 19th century whose title/subtitle contains the term hydrology

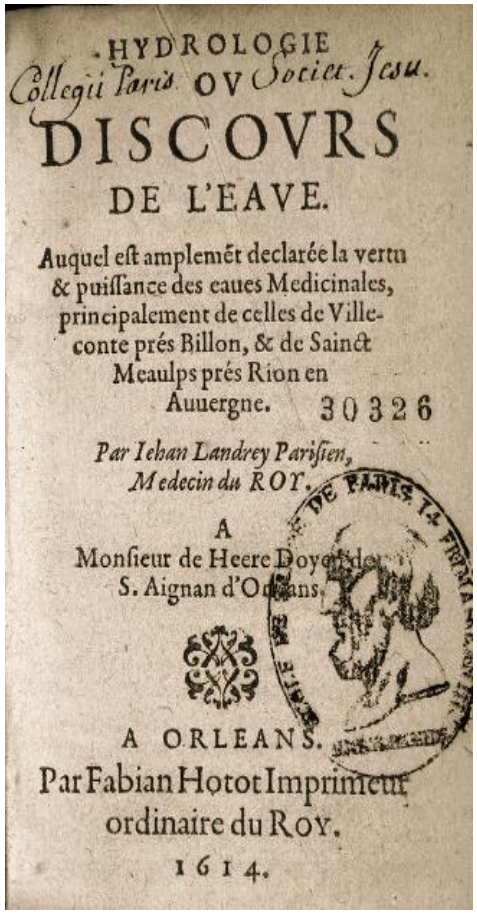
No.	Author (year)	Title	Language	Scope*
1	Landrey (1614)	Hydrologie ou Discours de l'Eaue	French	M,P
2	Licetus (1655)	Hydrologiae Peripateticae Disputationes de Maris Tranquillitate	Latin	P
3	Derham (1685)	Hydrologia Philosophica	English	M,P
4	Melchiore (1694)	Hydrologia Brevis Quidem	German	M
5	Vinayma (1738)	Hydrologia, o Tratado de las Aguas Ferrugíneas …	Spanish	M
6	Wallerius (1751)	Hydrologie	German†	C
7	Cartheseur (1758)	Rudimenta hydrologiae systematicae	Latin	M
8	Hanovius (1765)	Philosophiae Naturalis sive Physicae Dogmatica … Continens Aërologiam et Hydrologiam	Latin	P
9	Monnet (1772)	Nouvelle Hydrologie	French	C
10	Eliseo (1790)	Physicae Experimentalis Elementa … Hydrostatica, Hydrodinamica, Hydraulica, Hydrologia	Latin	H,N
11	Barrington (1850)	A Treatise on Physical Geography Comprising Hydrology, Geognosy, Geology, Meteorology…	English	G
12	Beardmore (1862)	Manual of Hydrology	English	H

* Main scope classified as follows: C- Chemistry, mineralogy, G: Geography; H: Hydraulics; M: Medicine; N: Natural sciences (physics, meteorology, climatology); P: Philosophy.

† Translation from the original edition in Swedish (1748)

See also Koutsoyiannis (2012).

Hydrologie ou Discours de l'Eaue



HYDROLOGIE
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DISCOVRS
DE L'EAVE.

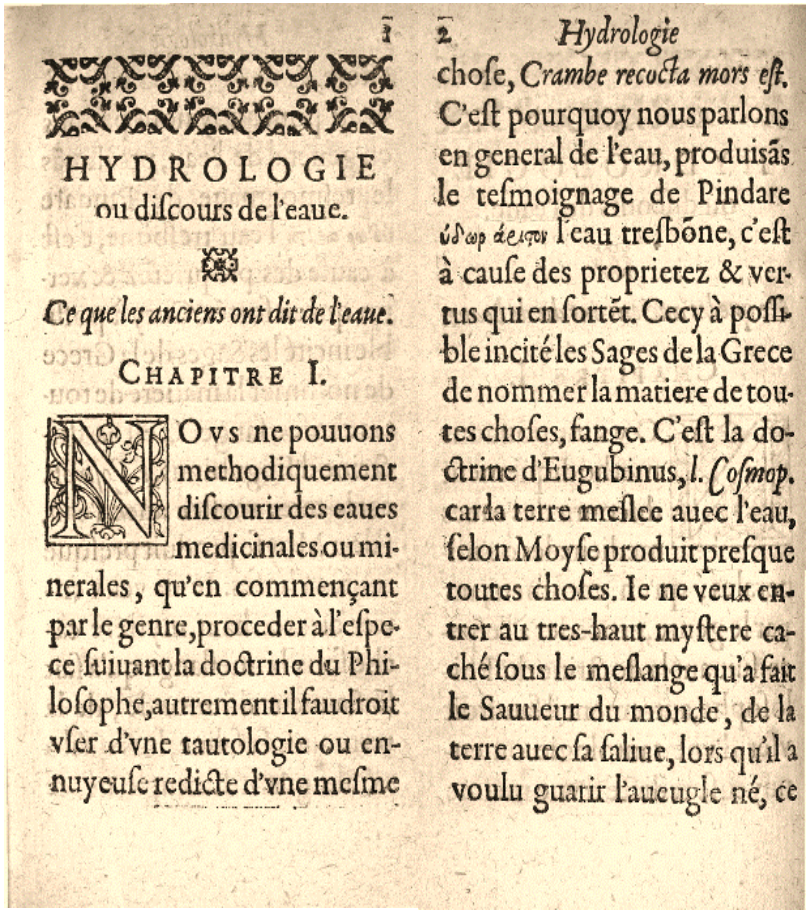
Auquel eſt amplemẽt declarée la vertu & puiſſance des eaues Medicinales, principalement de celles de Ville-conte prés Billon, & de Sainct Meaulps prés Rion en Auuergne.

30326

Par Iehan Landrey Pariſien, Medecin du ROY.

A Monſieur de Heere Doyen de S. Aignan d'Orleans.

A ORLEANS.
Par Fabian Hotot Imprimeur ordinaire du Roy.
1614.



1

HYDROLOGIE
ou diſcours de l'eaue.

Ce que les anciens ont dit de l'eaue.

CHAPITRE I.

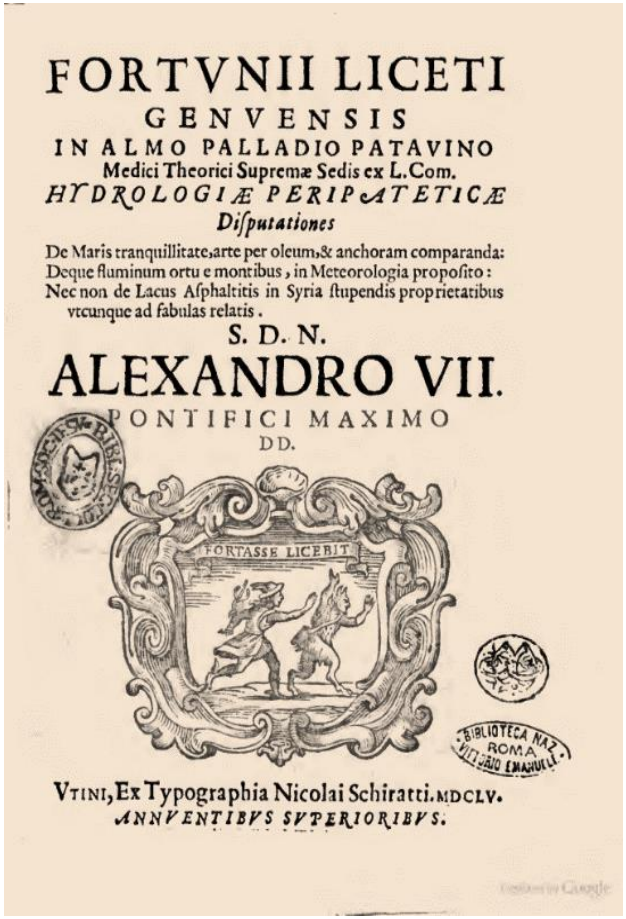
NOvs ne pouuons methodiquement diſcourir des eaues medicinales ou minerales, qu'en commençant par le genre, proceder à l'eſpece ſuiuant la doctrine du Philoſophe, autrement il faudroit vſer d'vne tautologie ou ennuyeuſe redicte d'vne meſme

2 Hydrologie

choſe, *Crambe recocta mors eſt.* C'eſt pourquoy nous parlons en general de l'eau, produisãs le teſmoignage de Pindare ὕδωρ ἄριστον l'eau treſbõne, c'eſt à cauſe des proprietez & vertus qui en ſortẽt. Cecy à poſſible incité les Sages de la Grece de nommer la matiere de toutes choſes, fange. C'eſt la doctrine d'Eugubinus, *l. Coſmop.* car la terre meſlee auec l'eau, ſelon Moyſe produit preſque toutes choſes. Ie ne veux entrer au tres-haut myſtere caché ſous le meſlange qu'a fait le Sauueur du monde, de la terre auec ſa ſaliue, lors qu'il a voulu guarir l'aueugle né, ce

Title page and first two pages of the book Hydrologie ou Discours de l'Eaue by Jehan (Jean) Landrey (a French King's doctor) (Landrey, 1614). From the title page it becomes clear that the book is about the virtue and power of medicinal waters (la vertu & puissance des eaues médicinales). In the first pages the author declares that he follows the doctrine of the philosopher to begin with the genus and proceed to the species, while he quotes Pindar's verse ὕδωρ ἄριστον (l'eau tres bone; water is best; the exact quotation is ἄριστον μὲν ὕδωρ, Pindar, Olympian Odes, 1).

Hydrologia Peripatetica



FORTVNII LICETI
GENVENSIS
IN ALMO PALLADIO PATAVINO
Medici Theorici Supremæ Sedis ex L.Com.
HYDROLOGIÆ PERIPATETICÆ
Disputationes

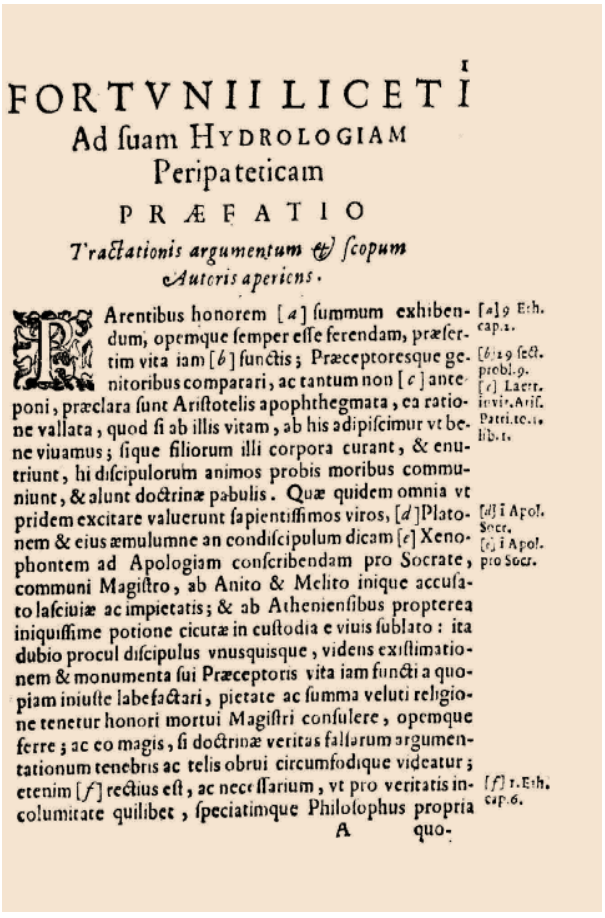
De Maris tranquillitate,arte per oleum,& anchoram comparanda: Deque fluminum ortu e montibus, in Meteorologia proposito: Nec non de Lacus Asphaltitis in Syria stupendis proprietatibus vtcunque ad fabulas relatis.

S. D. N.
ALEXANDRO VII.
PONTIFICI MAXIMO
DD.

FORTASSE LICEBIT

BIBLIOTECA NAZ. ROMA VITTORIO EMANUELE

VTINI, Ex Typographia Nicolai Schiratti. MDCLV.
ANNVENTIBVS SVPERIORIBVS.



FORTVNII LICETI
Ad suam HYDROLOGIAM
Peripateticam
PRÆFATIO
Tractationis argumentum & scopum Autoris aperiens.

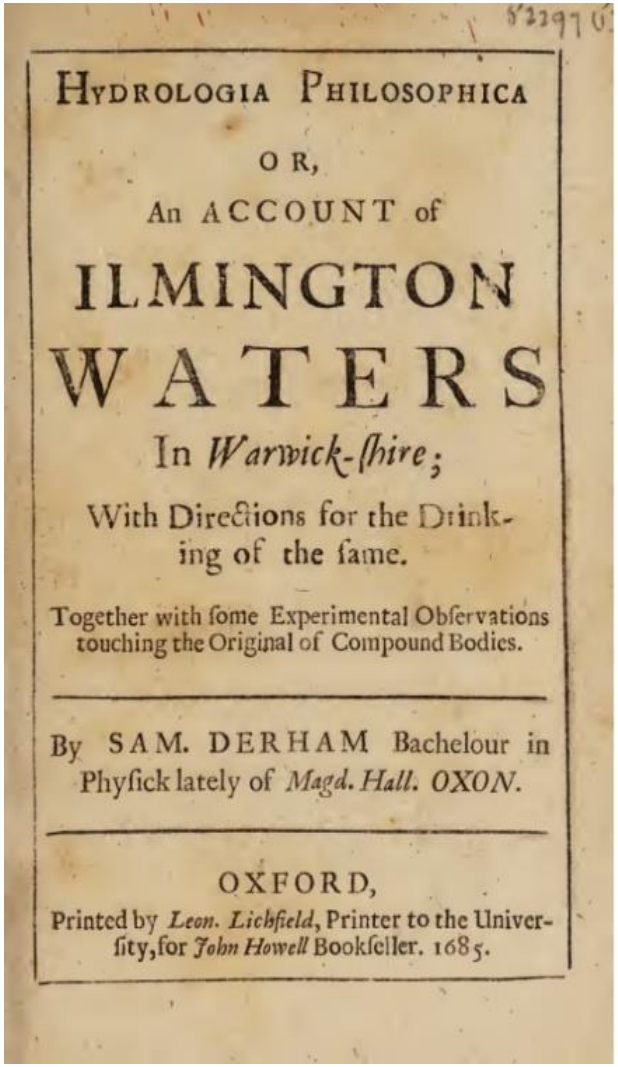
PArentibus honorem [a] summum exhibendum, opemque semper esse ferendam, præsertim vita iam [b] functis; Præceptoresque genitoribus comparari, ac tantum non [c] anteponi, præclara sunt Aristotelis apophthegmata, ea ratione vallata, quod si ab illis vitam, ab his adipiscimur vt bene viuamus; sique filiorum illi corpora curant, & enutriunt, hi discipulorum animos probis moribus communiunt, & alunt doctrinæ pabulis. Quæ quidem omnia vt pridem excitare valuerunt sapientissimos viros, [d] Platonem & eius æmulumne an condiscipulum dicam [e] Xenophontem ad Apologiam conscribendam pro Socrate, communi Magistro, ab Anito & Melito inique accusato lasciuiæ ac impietatis; & ab Athenienfibus propterea iniquissime potione cicutæ in custodia e viuis sublato: ita dubio procul discipulus vnusquisque, videns existimationem & monumenta sui Præceptoris vita iam functi a quopiam iniuste labefactari, pietate ac summa veluti religione tenetur honori mortui Magistri consulere, opemque ferre; ac eo magis, si doctrinæ veritas fallarum argumentationum tenebris ac telis obrui circumfodique videatur; etenim [f] rectius est, ac necessarium, vt pro veritatis incolumitate quilibet, speciatimque Philosophus propria

A quo-

[a] 9 Eth. cap. 2.
[b] 29 sect. probl. 9.
[c] Laert. in vit. Arist. Patri. tes. lib. 1.
[d] in Apol. Socr.
[e] in Apol. pro Socr.
[f] 1. Eth. cap. 6.

Title page and first page of the book Hydrologiae Peripateticae Disputationes de Maris Tranquillitate by Fortunio Liceti (1577–1657, an Italian physician and philosopher) (Licetus, 1655). The adjective Peripatetica in the book title shows the influence of Aristotle (whose School was named Περιπατητική Σχολή) on Liceti. The title page summarizes the content of the book (origin of the rivers from the mountains, meteorology, Dead Sea/Lacus Asphaltitis etc.). The names of Aristotle, Plato, Xenophon and Socrates appear already in the first page. The content of the book includes descriptions of various rivers in Asia, Africa (including the Nile) and Europe (mostly Greece).

Hydrologia Philosophica



HYDROLOGIA PHILOSOPHICA

OR,

An ACCOUNT of

ILMINGTON

WATERS

In *Warwick-ſhire;*

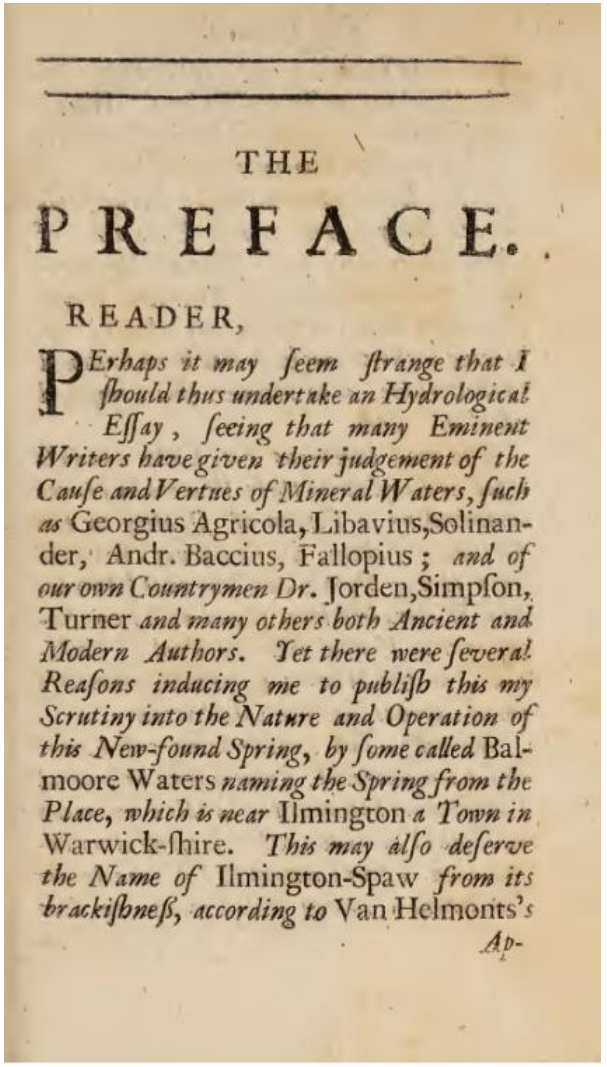
With Directions for the Drinking of the ſame.

Together with ſome Experimental Obſervations touching the Original of Compound Bodies.

By SAM. DERHAM Bachelour in Phyſick lately of *Magd. Hall. OXON.*

OXFORD,

Printed by *Leon. Lichfield*, Printer to the Univerſity, for *John Howell* Bookſeller. 1685.



THE

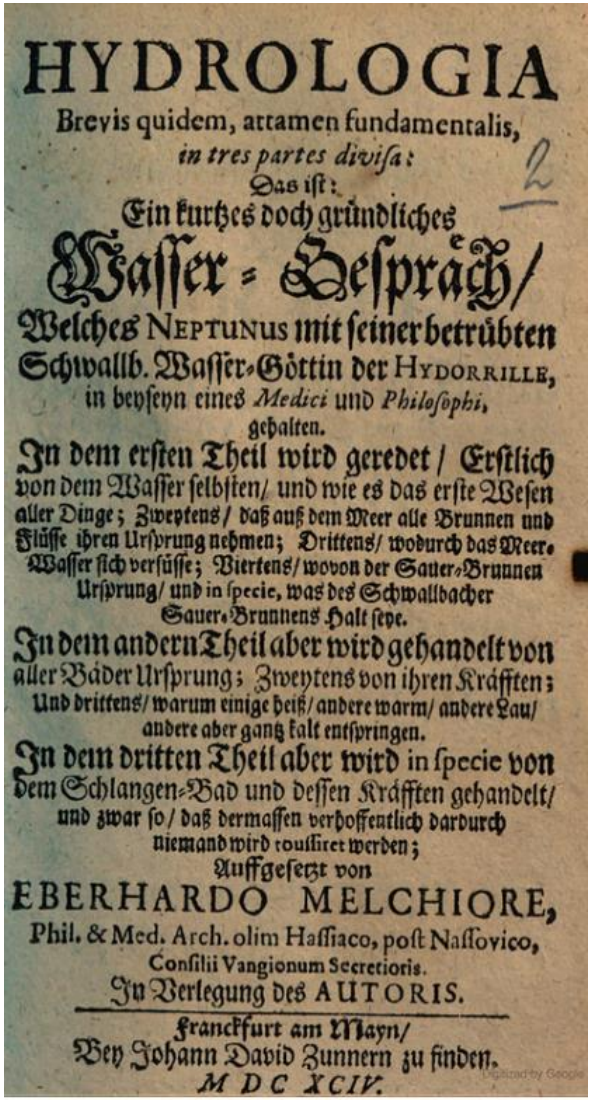
PREFACE.

READER,

PErhaps it may ſeem ſtrange that I ſhould thus undertake an Hydrological Eſſay, ſeeing that many Eminent Writers have given their judgement of the Cauſe and Vertues of Mineral Waters, ſuch as Georgius Agricola, Libavius, Solinander, Andr. Baccius, Fallopius; *and of our own Countrymen Dr.* Jorden, Simpſon, Turner *and many others both Ancient and Modern Authors. Yet there were ſeveral Reaſons inducing me to publiſh this my Scrutiny into the Nature and Operation of this New-found Spring, by ſome called* Balmoore Waters *naming the Spring from the Place, which is near* Ilmington *a Town in* Warwick-ſhire. *This may alſo deſerve the Name of* Ilmington-Spaw *from its brackiſhneſs, according to* Van Helmonts's *Ap-*

Title page and first page of the book Hydrologia Philosophica by Samuel Derham (1577–1657, a British physician) (Derham, 1685). As clarified in its subtitle, the book is not quite philosophical but refers to properties of the water of a particular spring.

Hydrologia Brevis Quidem



HYDROLOGIA

Brevis quidem, attamen fundamentalis,
in tres partes divisa:
Das ist:
Ein kurtzes doch gründliches

Wasser-Gespräch/

Welches NEPTUNUS mit seiner betrübten Schwallb. Wasser-Göttin der HYDORRILLE, in beyseyn eines *Medici* und *Philosophi*, gehalten.

In dem ersten Theil wird geredet / Erstlich von dem Wasser selbsten/ und wie es das erste Wesen aller Dinge; Zweytens/ daß auß dem Meer alle Brunnen und Flüsse ihren Ursprung nehmen; Drittens/ wodurch das Meer-Wasser sich versüsse; Viertens/ wovon der Sauer-Brunnen Ursprung/ und in specie, was des Schwallbacher Sauer-Brunnens Halt seye.

In dem andern Theil aber wird gehandelt von aller Bäder Ursprung; Zweytens von ihren Kräfften; Und drittens/ warum einige heiß/ andere warm/ andere Lau/ andere aber gantz kalt entspringen.

In dem dritten Theil aber wird in specie von dem Schlangen-Bad und dessen Kräfften gehandelt/ und zwar so/ daß dermassen verhoffentlich dardurch niemand wird tousliret werden;

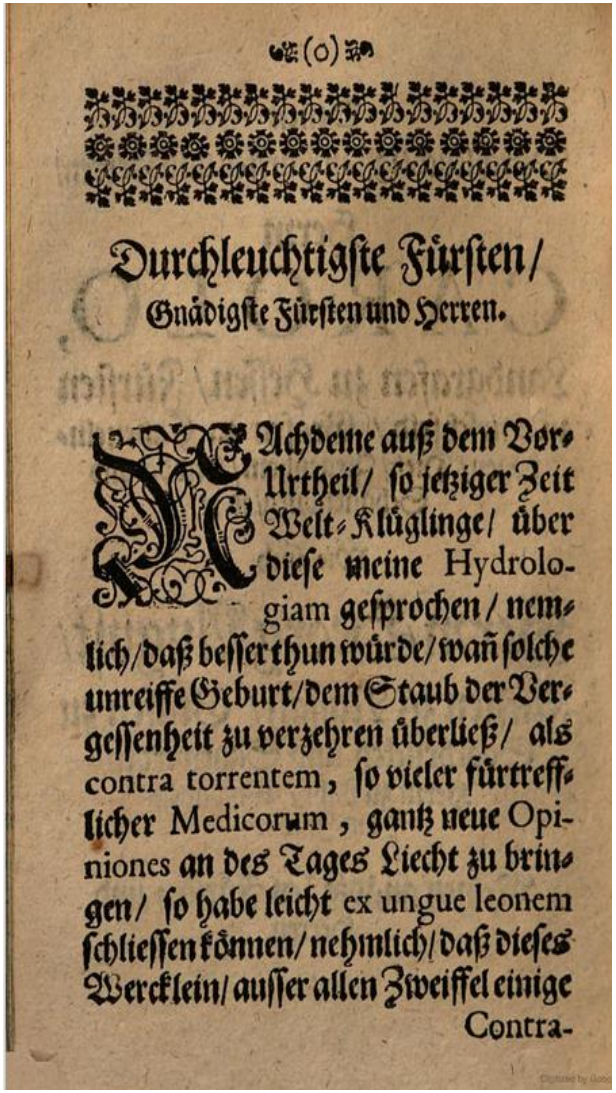
Auffgesetzt von

EBERHARDO MELCHIORE,

Phil. & Med. Arch. olim Hassiaco, post Nassovico, Consilii Vangionum Secretioris.

In Verlegung des AUTORIS.

Franckfurt am Mayn/
Bey Johann David Zunnern zu finden.
M D C XCIV.



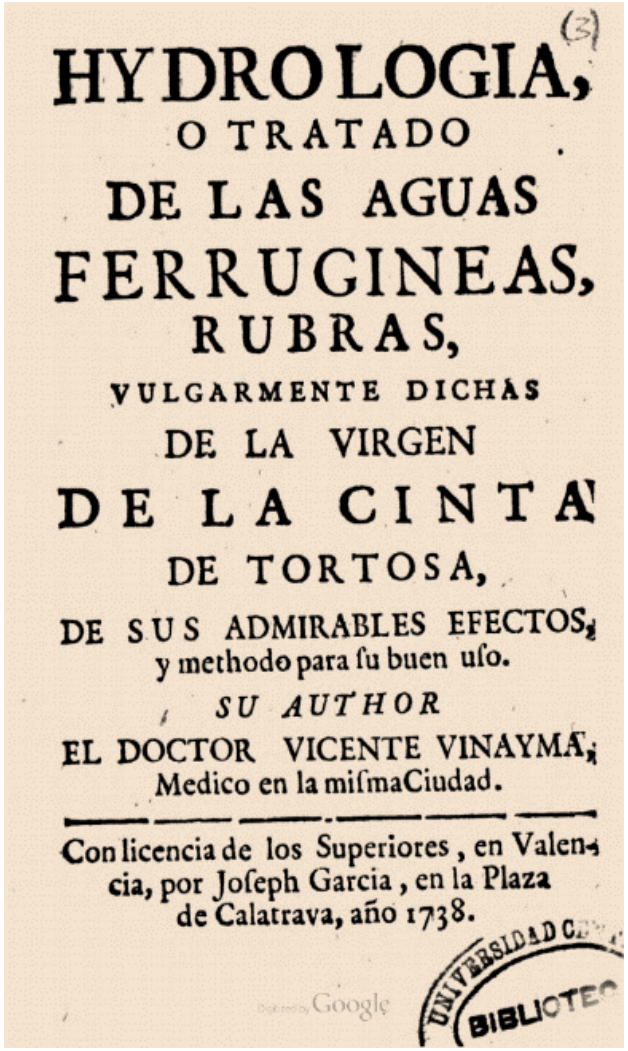
(o)

Durchleuchtigste Fürsten/
Gnädigste Fürsten und Herren.

Nachdeme auß dem Vor-Urtheil/ so jetziger Zeit Welt-Klüglinge/ über diese meine Hydrologiam gesprochen / nemlich/ daß besser thun würde/ wañ solche unreiffe Geburt/ dem Staub der Vergessenheit zu verzehren überließ/ als contra torrentem, so vieler fürtrefflicher Medicorum, gantz neue Opiniones an des Tages Liecht zu bringen/ so habe leicht ex ungue leonem schliessen können/ nehmlich/ daß dieses Werckleín/ ausser allen Zweiffel einige Contra-

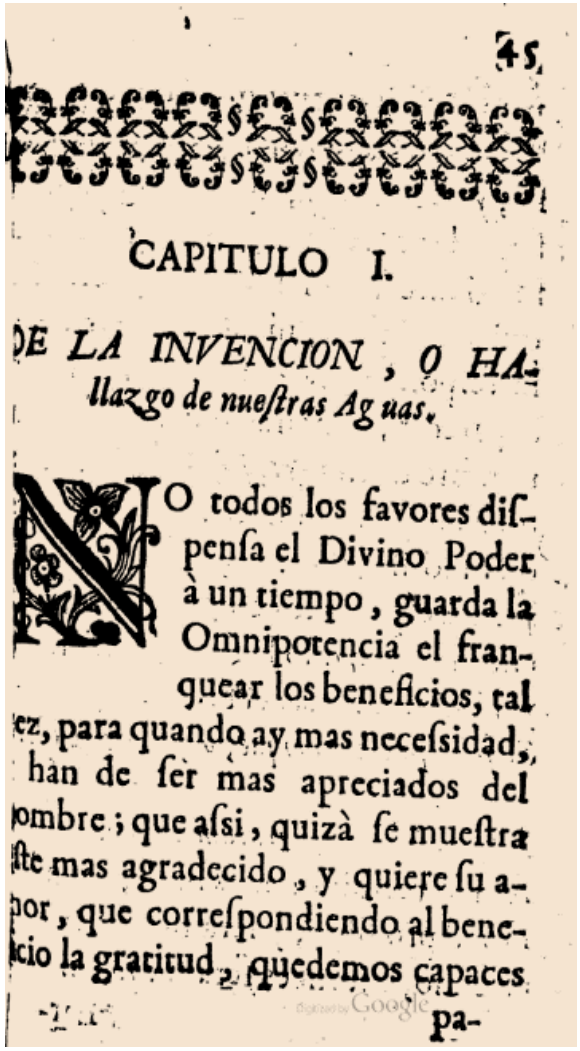
Title page and first page of the book Hydrologia Brevis Quidem by Eberhard Melchior (unknown details) (Melchiore, 1694)

Hydrologia, o Tratado de las Aguas Ferrugíneas



HYDROLOGIA,
O TRATADO
DE LAS AGUAS
FERRUGINEAS,
RUBRAS,
VULGARMENTE DICHAS
DE LA VIRGEN
DE LA CINTA
DE TORTOSA,
DE SUS ADMIRABLES EFECTOS,
y methodo para su buen uso.
SU AUTHOR
EL DOCTOR VICENTE VINAYMA,
Medico en la misma Ciudad.

Con licencia de los Superiores, en Valencia, por Joseph Garcia, en la Plaza de Calatrava, año 1738.



45

CAPITULO I.

DE LA INVENCION, O HALLAZGO de nuestras Aguas.

NO todos los favores dispensa el Divino Poder à un tiempo, guarda la Omnipotencia el franquear los beneficios, tal ez, para quando ay mas necesidad, han de ser mas apreciados del ombre; que assi, quizà se muestra ste mas agradecido, y quiere su amor, que correspondiendo al beneficio la gratitud, quedemos capaces pa-

Title page and first page of chapter 1 of the book Hydrologia, o Tratado de las Aguas Ferrugíneas … by Vicente Vinayma (a Spanish medical doctor; unknown details) (Vinayma, 1738). The book features a divine link of water.

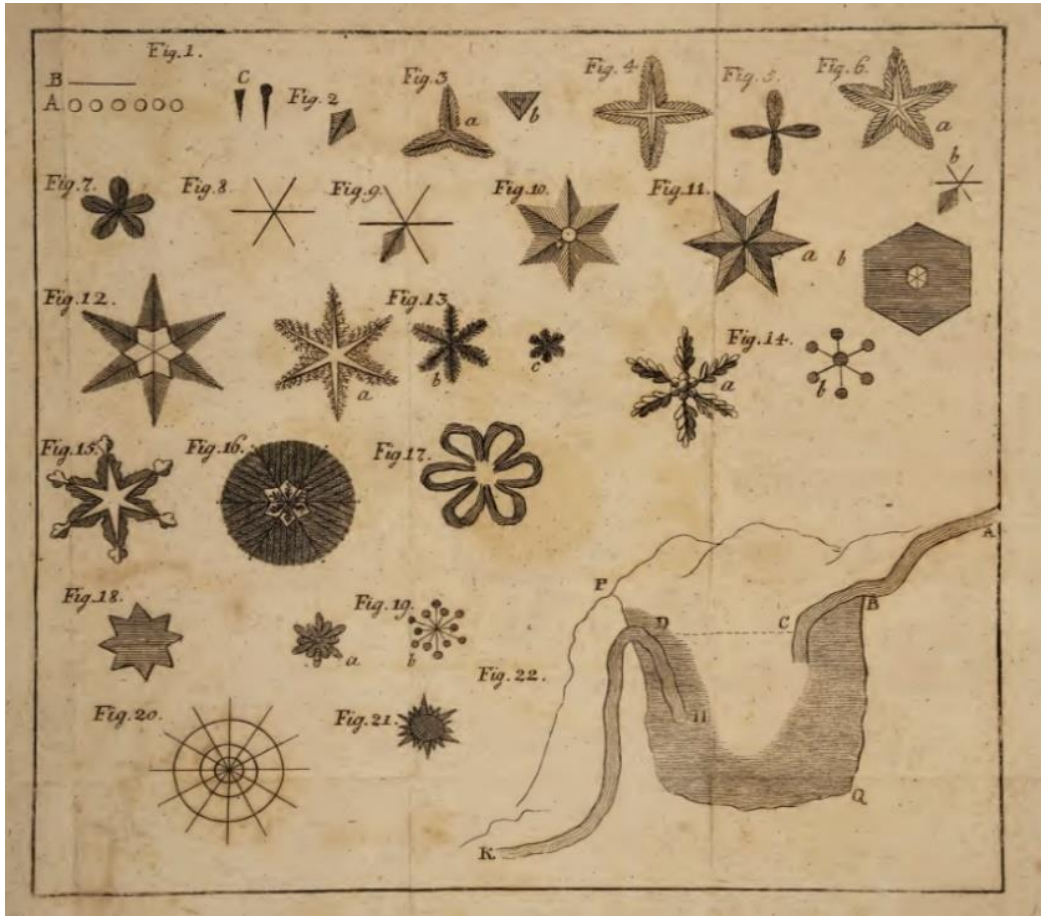
Hydrologie

Joh. Gottschalk Wallerius,
der Weltweisheit und Arzneykunst Doctors auf der königl. schwedischen Akademie zu Upsala, der medicinischen Facultät Adjuncti, der römisch kayserlichen Akademie der Naturforscher, auch des königl. medicin. Collegii zu Stockholm Mitgliedes.

Hydrologie,
oder
Wasserreich,
von ihm eingetheilet und beschrieben:
nebst einer Anleitung
zur Anstellung der Wasserproben:
wie auch
dessen Gedanken
vom
Dannemarks-Gesundbrunnen.
Ins Deutsche übersetzt
von
Johann Daniel Denso,
Königl. Professore am Collegio Gröningiano zu Stargard in Pommern, Conrectore an der Stadtschule, der königl. deutschen Gesellsch. zu Königsb. auch der zu Leipzig Mitgliede.

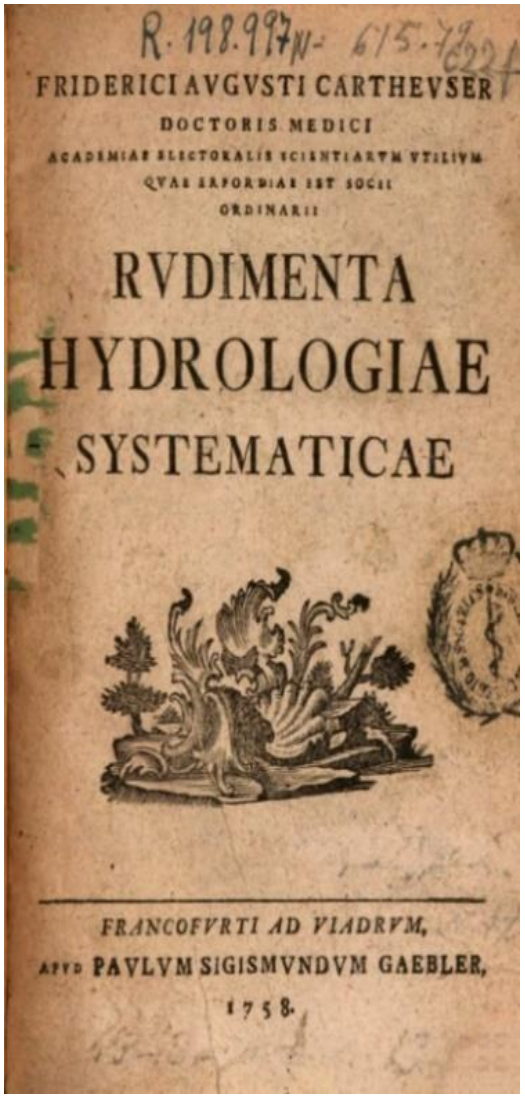
Mit Königl. Pohlnis. und Preußis. auch Churfürstl. Sächsischen und Brandenburgischen PRIVILEGIO.

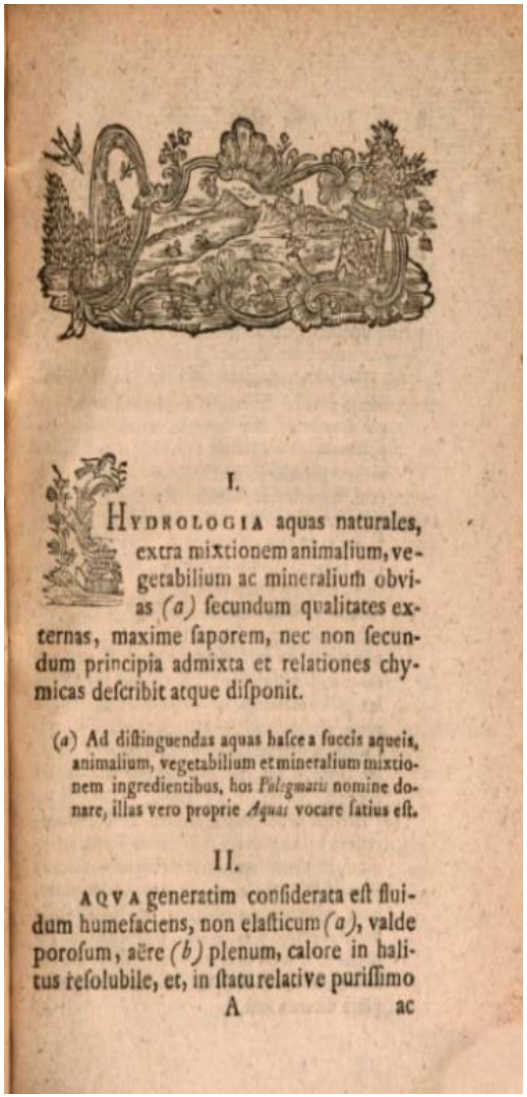
Berlin,
Verlegts Christoph Gottlieb NICOLAI,
1751.



Title page and last page with figures of the book Hydrologie by Johan Gottschalk Wallerius (1709-1785; a Swedish chemist and mineralogist), translated to German by Johann Daniel Denso (Wallerius, 1751) from the original edition in Swedish (Hydrologia; Wallerius, 1748)

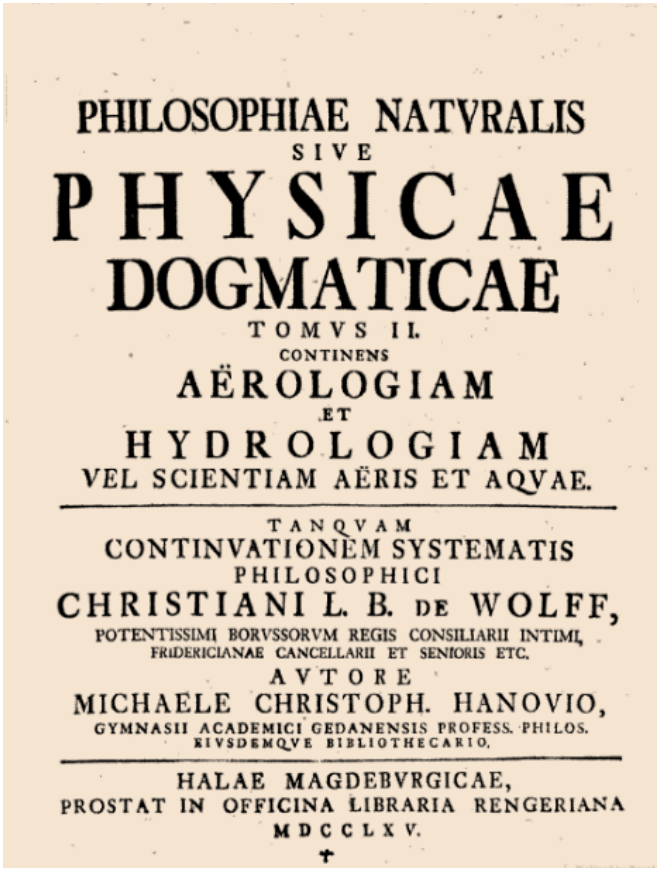
Rudimenta hydrologiae systematicae





Title page and first page of the book Rudimenta hydrologiae systematicae by Friedrich August Charteuser (medical doctor; unknown further details) (Cartheseur, 1758).

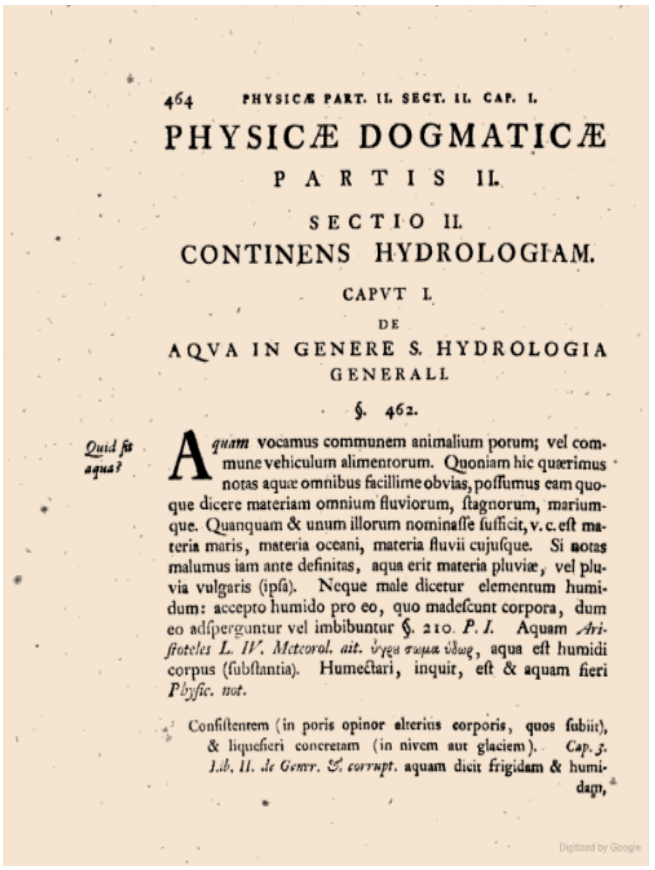
Philosophiae Naturalis sive Physicae Dogmaticae



PHILOSOPHIAE NATVRALIS
SIVE
PHYSICAE
DOGMATICAE
TOMVS II.
CONTINENS
AËROLOGIAM
ET
HYDROLOGIAM
VEL SCIENTIAM AËRIS ET AQVAE.

TANQVAM
CONTINVATIONEM SYSTEMATIS
PHILOSOPHICI
CHRISTIANI L. B. DE WOLFF,
POTENTISSIMI BORVSSORVM REGIS CONSILIARII INTIMI,
FRIDERICIANAE CANCELLARII ET SENIORIS ETC.
AVTORE
MICHAELE CHRISTOPH. HANOVIO,
GYMNASII ACADEMICI GEDANENSIS PROFESS. PHILOS.
EIVSDEMQVE BIBLIOTHECARIO.

HALAE MAGDEBVRGICAE,
PROSTAT IN OFFICINA LIBRARIA RENGERIANA
MDCCLXV.



464 PHYSICÆ PART. II. SECT. II. CAP. I.

PHYSICÆ DOGMATICÆ
PARTIS II.
SECTIO II.
CONTINENS HYDROLOGIAM.
CAPVT I.
DE
AQVA IN GENERE S. HYDROLOGIA GENERALI.

§. 462.

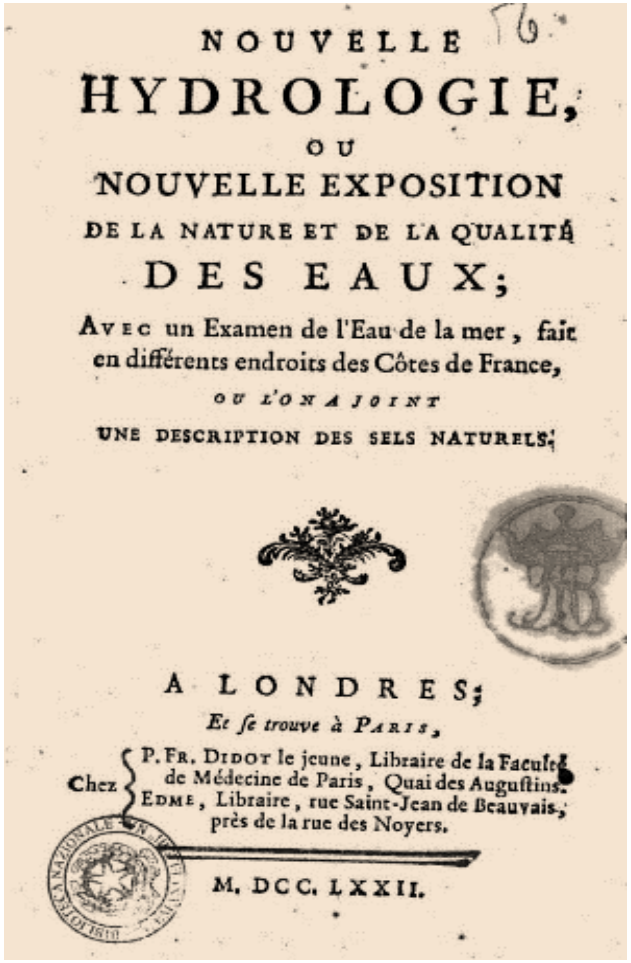
Quid ſit aqua?

Aquam vocamus communem animalium potum; vel commune vehiculum alimentorum. Quoniam hic quærimus notas aquæ omnibus facillime obvias, poſſumus eam quoque dicere materiam omnium fluviorum, ſtagnorum, mariumque. Quanquam & unum illorum nominaſſe ſufficit, v. c. eſt materia maris, materia oceani, materia fluvii cujuſque. Si notas malumus iam ante definitas, aqua erit materia pluviæ, vel pluvia vulgaris (ipſa). Neque male dicetur elementum humidum: accepto humido pro eo, quo madeſcunt corpora, dum eo adſperguntur vel imbibuntur §. 210. *P. I.* Aquam *Ariſtoteles L. IV. Meteorol. ait. ὑγρὸν σωμα ὑδατος*, aqua eſt humidi corpus (ſubſtantia). Humectari, inquit, eſt & aquam fieri *Phyſic. not.*

Conſiſtentem (in poris opinor alterius corporis, quos ſubiit), & liquefieri concretam (in nivem aut glaciem). *Cap. 3. Lib. II. de Genr. & corrupt.* aquam dicit frigidam & humidam,

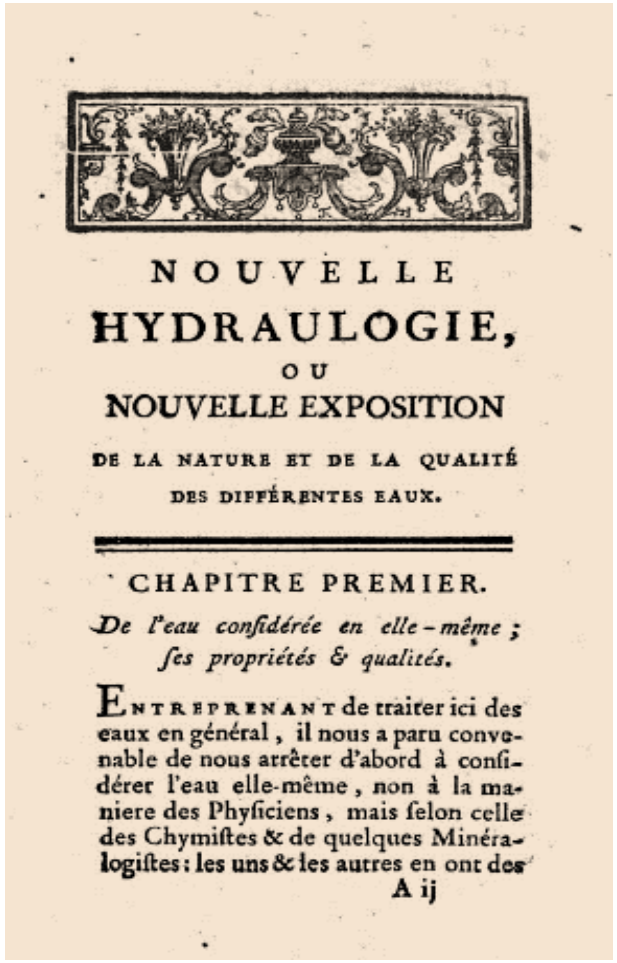
Title page and first page of the book Philosophiae Naturalis sive Physicae Dogmaticae (vol. 2 of 4) by Michaele Christoph Hanovius (Michael Christoph Hanov, 1695-1773; a German meteorologist, historian and mathematician) (Hanovius, 1765). The book cover states that it is a continuation of the philosophical system of the German philosopher Christianus de Wolff . An impressive element in the title is the “dogmatic” character, which today would be regarded inconsistent with physics. In addition to hydrologia, the book contains aerologia, perhaps influenced by the Hippocratic discourse “Περί αέρων, υδάτων, τόπων”.

Nouvelle Hydrologie



NOUVELLE
HYDROLOGIE,
OU
NOUVELLE EXPOSITION
DE LA NATURE ET DE LA QUALITÉ
DES EAUX;
AVEC un Examen de l'Eau de la mer, fait en différents endroits des Côtes de France,
OU L'ON A JOINT
UNE DESCRIPTION DES SELS NATURELS;

A LONDRES;
Et se trouve à PARIS,
Chez P. FR. DIDOT le jeune, Libraire de la Faculté de Médecine de Paris, Quai des Augustins.
EDME, Libraire, rue Saint-Jean de Beauvais, près de la rue des Noyers.
M. DCC. LXXII.



NOUVELLE
HYDRAULOGIE,
OU
NOUVELLE EXPOSITION
DE LA NATURE ET DE LA QUALITÉ
DES DIFFÉRENTES EAUX.

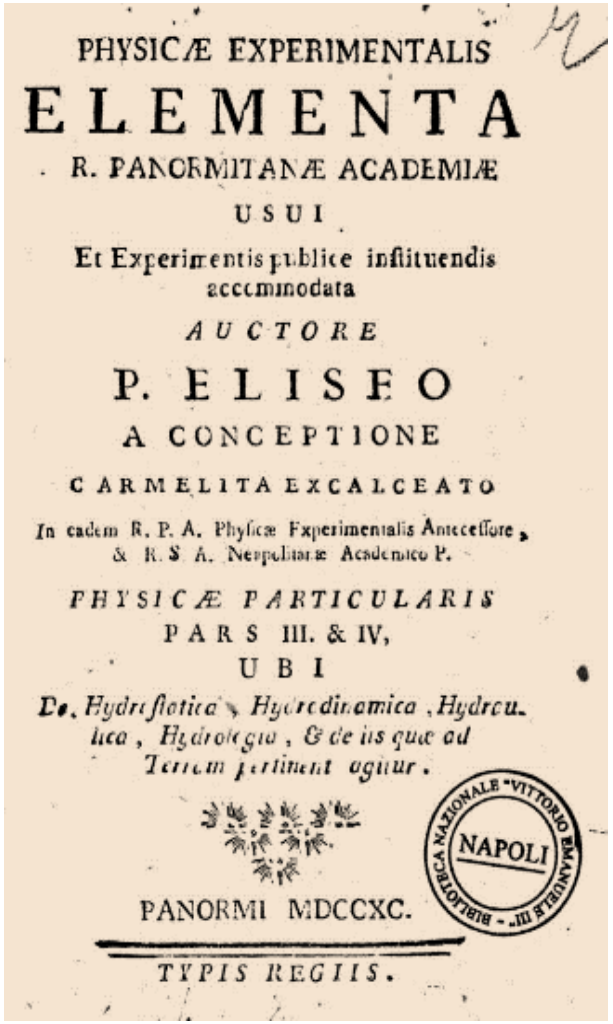
CHAPITRE PREMIER.
De l'eau considérée en elle-même; ses propriétés & qualités.

ENTREPRENANT de traiter ici des eaux en général, il nous a paru convenable de nous arrêter d'abord à considérer l'eau elle-même, non à la maniere des Phyſiciens, mais ſelon celle des Chymiſtes & de quelques Minéralogiſtes: les uns & les autres en ont des

A ij

Title page and first page of the book Nouvelle Hydrologie by Antoine Grimoald Monnet (1734-1817; a French mineralogist) (Monnet, 1772). In addition to the quality of potable water, it examines the sea water and the natural salts (sels naturels). Notable is the spelling hydraulogie (likely influenced by hydraulics) in the first page, also used throughout the entire book, which is different from that in the book cover, hydrologie.

Physicae Experimentalis Elementa



PHYSICÆ EXPERIMENTALIS

ELEMENTA

R. PANORMITANÆ ACADEMIÆ

USUI

Et Experimentis publice instituendis accommodata

AUCTORE

P. ELISEO

A CONCEPTIONE

CARMELITA EXCALCEATO

In eadem R. P. A. Physicæ Experimentalis Antecessore, & R. S. A. Neapolitanæ Academico P.

PHYSICÆ PARTICULARIS

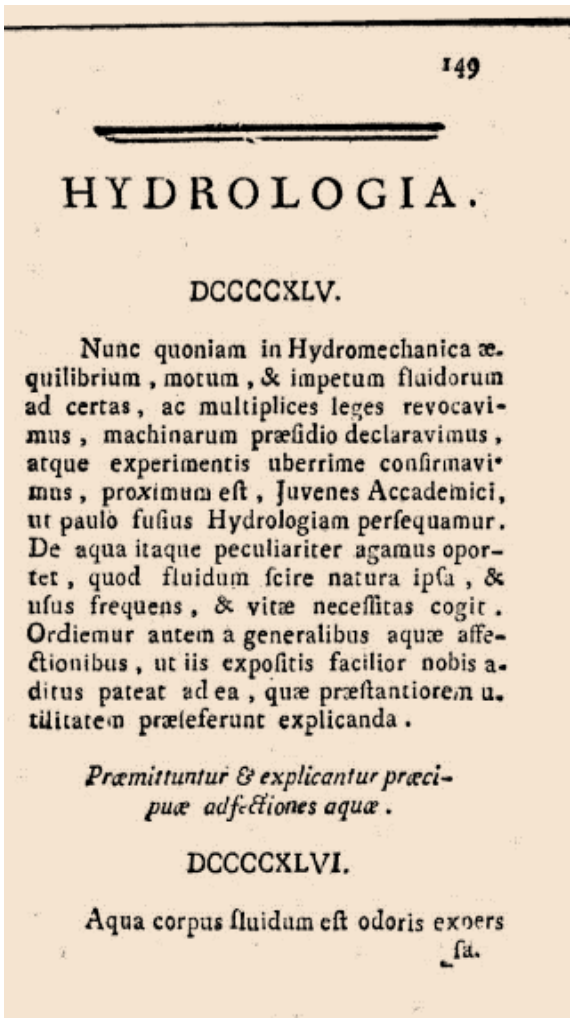
PARS III. & IV,

UBI

De Hydrostatica, Hydrodinamica, Hydraulica, Hydrologia, & de iis quæ ad Terram pertinent agitur.

PANORMI MDCCXC.

TYPIS REGIIS.



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HYDROLOGIA.

DCCCCXLV.

Nunc quoniam in Hydromechanica æquilibrium, motum, & impetum fluidorum ad certas, ac multiplices leges revocavimus, machinarum præsidio declaravimus, atque experimentis uberrime confirmavimus, proximum est, Juvenes Academici, ut paulo fusius Hydrologiam persequamur. De aqua itaque peculiariter agamus oportet, quod fluidum scire natura ipsa, & usus frequens, & vitæ necessitas cogit. Ordiemur autem a generalibus aquæ affectionibus, ut iis expositis facilior nobis aditus pateat ad ea, quæ præstantiorem utilitatem præferunt explicanda.

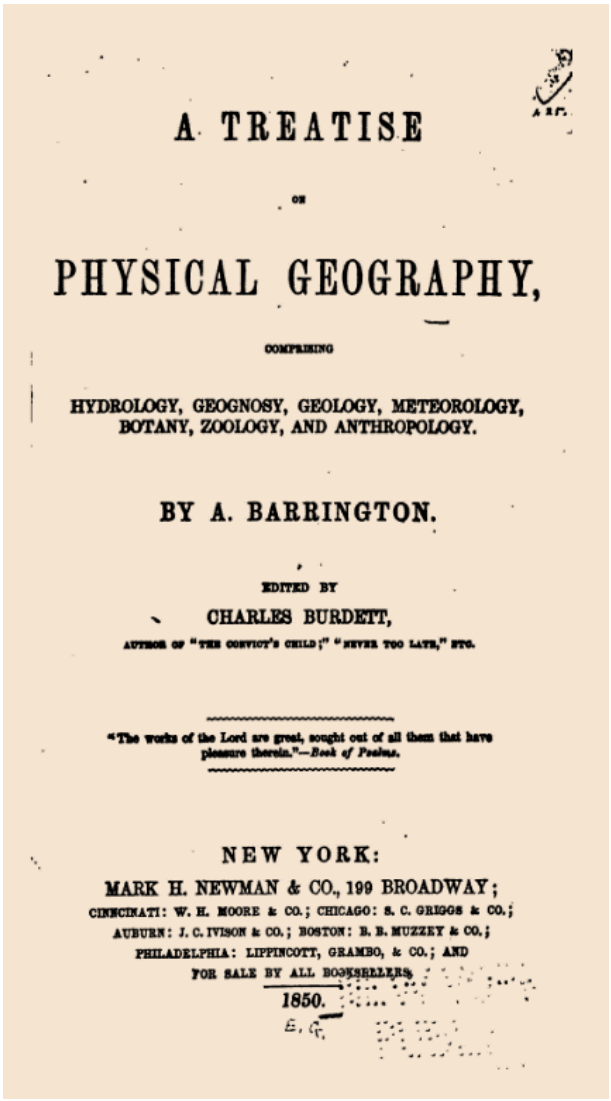
Præmittuntur & explicantur præcipuæ adfectiones aquæ.

DCCCCXLVI.

Aqua corpus fluidum est odoris exors sa.

Title page and first page of the book Physicae Experimentalis Elementa by p. Eliseo a Conceptione (Eliseo della Concezione, 1725-1809, an Italian scholar) (Eliseo a Conceptione, 1790). The book contains hydrostatics, hydrodynamics, hydraulics and hydrology.

A Treatise on Physical Geography



A TREATISE

ON

PHYSICAL GEOGRAPHY,

COMPRISING

HYDROLOGY, GEOGNOSY, GEOLOGY, METEOROLOGY, BOTANY, ZOOLOGY, AND ANTHROPOLOGY.

BY A. BARRINGTON.

EDITED BY

CHARLES BURDETT,

AUTHOR OF "THE CONVICT'S CHILD;" "NEVER TOO LATE," ETC.

"The works of the Lord are great, sought out of all them that have pleasure therein."—*Book of Psalms.*

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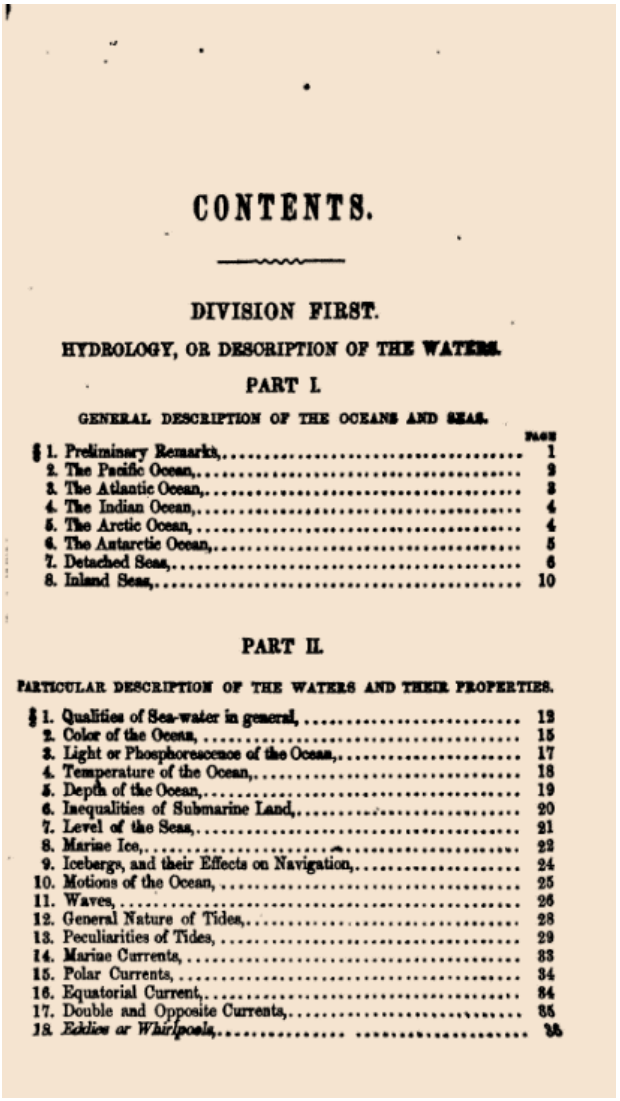
1850.



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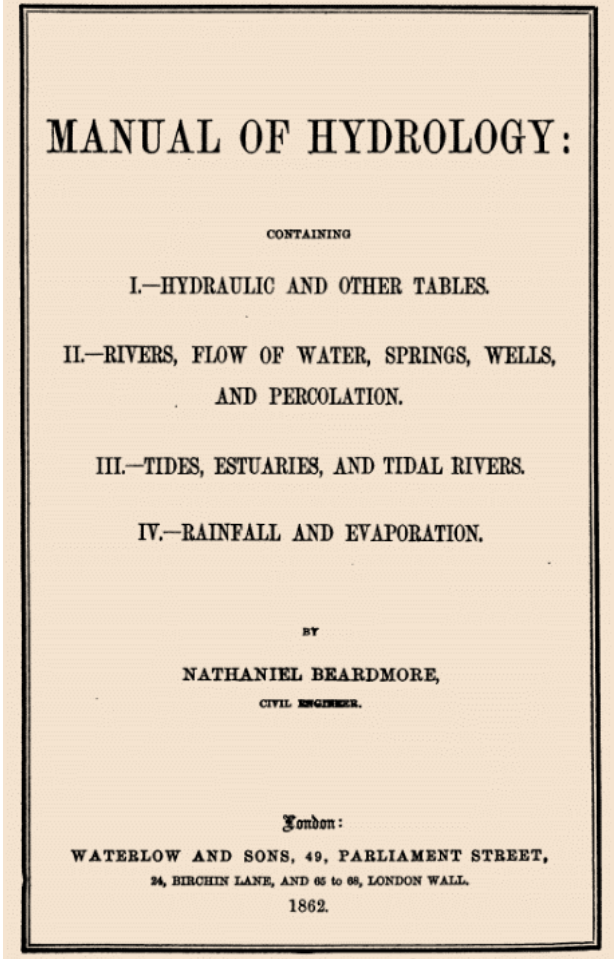
Title page and first page of the Contents of the book A Treatise on Physical Geography by A. Barrington (1850), whose first chapter is devoted to hydrology, beginning with a geographic description of the oceans.

Manual of Hydrology



MANUAL OF HYDROLOGY:

CONTAINING

I.—HYDRAULIC AND OTHER TABLES.

II.—RIVERS, FLOW OF WATER, SPRINGS, WELLS, AND PERCOLATION.

III.—TIDES, ESTUARIES, AND TIDAL RIVERS.

IV.—RAINFALL AND EVAPORATION.

BY

NATHANIEL BEARDMORE,

CIVIL ENGINEER.

London:

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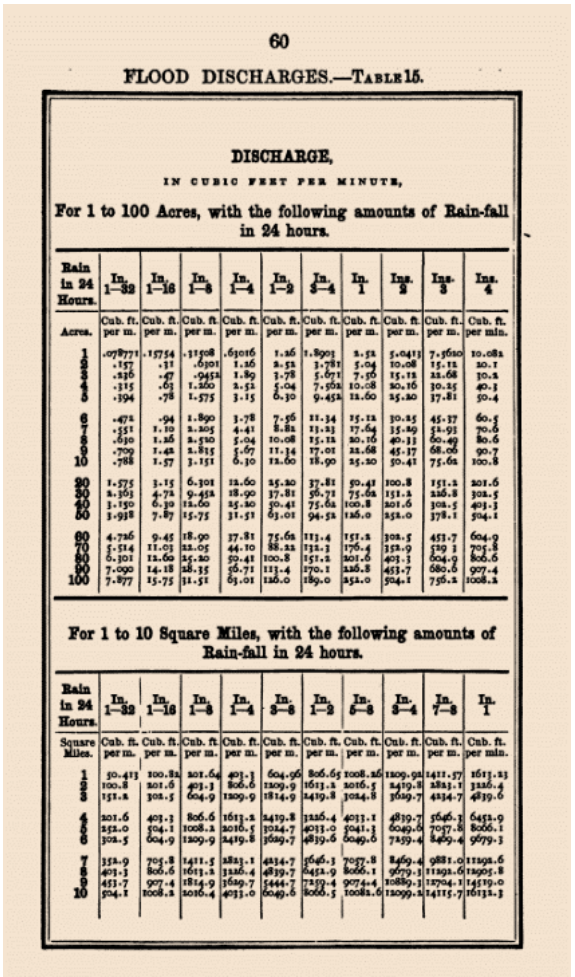
1862.



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FLOOD DISCHARGES.—TABLE 15.

DISCHARGE,

IN CUBIC FEET PER MINUTE,

For 1 to 100 Acres, with the following amounts of Rain-fall in 24 hours.

Rain in 24 Hours.	In. 1—32	In. 1—16	In. 1—8	In. 1—4	In. 1—2	In. 3—4	In. 1	Ins. 2	Ins. 3	Ins. 4
Acres.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per min.
1	.078771	.15754	.31508	.63016	1.26	1.8903	2.52	5.0413	7.5620	10.082
2	.157	.31	.6301	1.26	2.52	3.781	5.04	10.08	15.12	20.1
3	.236	.47	.9452	1.89	3.78	5.671	7.56	15.12	22.68	30.2
4	.315	.63	1.260	2.52	5.04	7.562	10.08	20.16	30.25	40.3
5	.394	.78	1.575	3.15	6.30	9.452	12.60	25.20	37.81	50.4
6	.472	.94	1.890	3.78	7.56	11.34	15.12	30.25	45.37	60.5
7	.551	1.10	2.205	4.41	8.82	13.23	17.64	35.29	52.93	70.6
8	.630	1.26	2.520	5.04	10.08	15.12	20.16	40.33	60.49	80.6
9	.709	1.42	2.835	5.67	11.34	17.01	22.68	45.37	68.06	90.7
10	.788	1.57	3.151	6.30	12.60	18.90	25.20	50.41	75.62	100.8
20	1.575	3.15	6.301	12.60	25.20	37.81	50.41	100.8	151.2	201.6
30	2.363	4.72	9.452	18.90	37.81	56.71	75.62	151.2	226.8	302.5
40	3.150	6.30	12.60	25.20	50.41	75.62	100.8	201.6	302.5	403.3
50	3.938	7.87	15.75	31.51	63.01	94.52	126.0	252.0	378.1	504.1
60	4.726	9.45	18.90	37.81	75.62	113.4	151.2	302.5	453.7	604.9
70	5.514	11.03	22.05	44.10	88.22	132.3	176.4	352.9	529 1	705.8
80	6.301	12.60	25.20	50.41	100.8	151.2	201.6	403.3	604.9	806.6
90	7.090	14.18	28.35	56.71	113.4	170.1	226.8	453.7	680.6	907.4
100	7.877	15.75	31.51	63.01	126.0	189.0	252.0	504.1	756.2	1008.2

For 1 to 10 Square Miles, with the following amounts of Rain-fall in 24 hours.

Rain in 24 Hours.	In. 1—32	In. 1—16	In. 1—8	In. 1—4	In. 3—8	In. 1—2	In. 5—8	In. 3—4	In. 7—8	In. 1
Square Miles.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per min.
1	50.413	100.82	201.64	403.3	604.96	806.65	1008.26	1209.92	1411.57	1613.23
2	100.8	201.6	403.3	806.6	1209.9	1613.2	2016.5	2419.8	2823.1	3226.4
3	151.2	302.5	604.9	1209.9	1814.9	2419.8	3024.8	3629.7	4234.7	4839.6
4	201.6	403.3	806.6	1613.2	2419.8	3226.4	4033.1	4839.7	5646.3	6451.9
5	252.0	504.1	1008.2	2016.5	3024.7	4033.0	5041.3	6049.5	7057.8	8066.1
6	302.5	604.9	1209.9	2419.8	3629.7	4839.6	6049.6	7259.4	8469.4	9679.3
7	352.9	705.8	1411.5	2823.1	4234.7	5646.3	7057.8	8469.4	9881.0	11292.6
8	403.3	806.6	1613.2	3226.4	4839.7	6451.9	8066.1	9679.3	11292.6	12905.2
9	453.7	907.4	1814.9	3629.7	5444.7	7259.4	9074.4	10889.1	12704.1	14519.0
10	504.1	1008.2	2016.4	4033.0	6049.6	8066.5	10082.6	12099.2	14115.7	16132.3

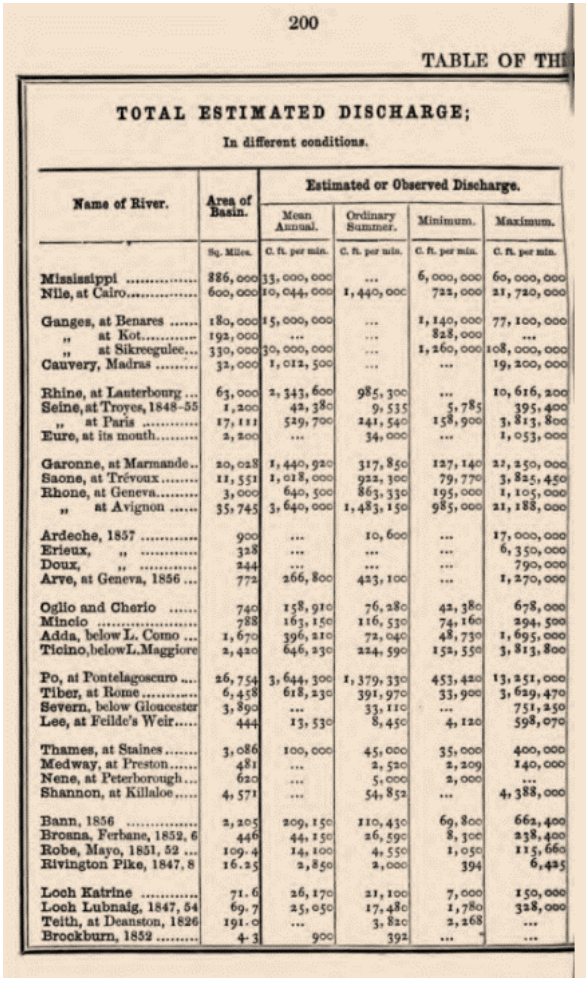

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TABLE OF THE

TOTAL ESTIMATED DISCHARGE;

In different conditions.

Name of River.	Area of Basin.	Estimated or Observed Discharge. Mean Annual.	Ordinary Summer.	Minimum.	Maximum.
	Sq. Miles.	C. ft. per min.	C. ft. per min.	C. ft. per min.	C. ft. per min.
Mississippi	886,000	33,000,000	...	6,000,000	60,000,000
Nile, at Cairo	600,000	10,044,000	1,440,000	722,000	21,720,000
Ganges, at Benares	180,000	15,000,000	...	1,140,000	77,100,000
,, at Kot	192,000	...	...	828,000	...
,, at Sikreegulee	330,000	30,000,000	...	1,260,000	108,000,000
Cauvery, Madras	32,000	1,012,500	...	...	19,200,000
Rhine, at Lauterbourg	63,000	2,343,600	985,300	...	10,616,200
Seine, at Troyes, 1848–55	1,200	42,380	9,535	5,785	395,400
,, at Paris	17,111	529,700	241,540	158,900	3,813,800
Eure, at its mouth	2,200	...	34,000	...	1,053,000
Garonne, at Marmande	20,028	1,440,920	317,850	127,140	22,250,000
Saone, at Trévoux	11,551	1,018,000	922,300	79,770	3,825,450
Rhone, at Geneva	3,000	640,500	863,330	195,000	1,105,000
,, at Avignon	35,745	3,640,000	1,483,150	985,000	21,188,000
Ardeche, 1857	900	...	10,600	...	17,000,000
Erieux, ,,	328	...	...	...	6,350,000
Doux, ,,	244	...	...	...	790,000
Arve, at Geneva, 1856	772	266,800	423,100	...	1,270,000
Oglio and Cherio	740	158,910	76,280	42,380	678,000
Mincio	788	163,150	116,530	74,160	294,500
Adda, below L. Como	1,670	396,210	72,040	48,730	1,695,000
Ticino, below L. Maggiore	2,420	646,230	224,590	152,550	3,813,800
Po, at Pontelagoscuro	26,754	3,644,300	1,379,330	453,420	13,251,000
Tiber, at Rome	6,458	618,230	391,970	53,900	3,629,470
Severn, below Gloucester	3,890	...	53,110	...	751,250
Lee, at Feilde's Weir	444	13,530	8,450	4,120	598,070
Thames, at Staines	3,086	100,000	45,000	35,000	400,000
Medway, at Preston	481	...	2,520	2,209	140,000
Nene, at Peterborough	620	...	5,000	2,000	...
Shannon, at Killaloe	4,571	...	54,852	...	4,388,000
Bann, 1856	2,205	209,150	110,430	69,800	662,400
Brosna, Ferbane, 1852, 6	446	44,150	26,590	8,300	238,400
Robe, Mayo, 1851, 52	109.4	14,100	4,550	1,050	115,660
Rivington Pike, 1847, 8	16.25	2,850	2,000	394	6,425
Loch Katrine	71.6	26,170	21,100	7,000	150,000
Loch Lubnaig, 1847, 54	69.7	25,050	17,480	1,780	328,000
Teith, at Deanston, 1826	191.0	...	3,820	2,268	...
Brockburn, 1852	4.3	900	392	...	...

Title page and two pages from the book Manual of Hydrology by Nathaniel Beardmore, (1816-1872, a British civil engineer) (Beardmore, 1862). Page 60 provides a generic transformation of rainfall to river discharge and p. 200 gives discharge observations or estimates of big rivers.

The first congress on hydrology

ON THE PROCEEDINGS OF THE

INTERNATIONAL CONGRESS OF HYDROLOGY AND CLIMATOLOGY AT BIARRITZ,

OCTOBER 1886.

BY G. J. SYMONS, F.R.S., F.R.MET.SOC., SECRETARY.

[Read December 15th, 1886.]

After several addresses had been delivered the Bureau was constituted as follows, and the meeting closed :—

President.	Dr. Durand-Fardel.
Secretary.	Dr. Garrigou.
Vice-Presidents.	M. Antoine d'Abbadie. Dr. Martineau. M. O'Shea.
Vice-Presidents (Foreign).	M. Chiminelli, of Florence. M. Kisch, of Prague. M. Soutschinsky, of St. Petersburg. M. Symons, of London. M. Taboada, of Madrid.

At 8 p.m. there was a reception at the Palais-Biarritz (formerly the Villa Eugénie), in order to facilitate personal intercourse between the members.

On October 2nd the sectional work began, three sections sitting at once. The sittings began at 8.30 a.m. and lasted till about noon ; resuming at 2 p.m. and closing about 4 p.m. The list of papers as printed did not by any means include all that were read ; but even as it stood the programme was sufficiently formidable, the number of memoirs for each section being respectively—

I. *Scientific Hydrology.*—Water analysis, micro-organisms, collection of mineral waters, geological influences, bathing apparatus, 34.

II. *Medical Hydrology.*—Physiological and medical questions, 40.

III. *Climatology, scientific and medical*, 35.

Part of the paper On the proceedings of the international congress of hydrology and climatology at Biarritz (Symons, 1887)

Quantification of the concept of hydrological cycle

Several scientists of the 16th century and later, whose lives and works are extensively reviewed by Biswas (1970), have contributed in shedding light on the hydrological cycle, even though they did not use that term—not even the term hydrology. Among these, most prominent are:

- Bernard Palissy (c. 1510 – c. 1589; French Huguenot potter, hydraulics engineer and craftsman),
- Pierre Perrault (1611-1680; Receiver General of Finances for Paris),
- Edme Mariotte (c. 1620 –1684; French physicist and priest),
- Edmond Halley (1656 – 1742; English physicist, mathematician, astronomer, geophysicist and meteorologist),
- John Dalton (1766 –1844; English chemist, physicist, and meteorologist)/

The last four have been the pioneers of the quantification through measurement, of hydrological cycle—not of the concept per se, which in fact is by centuries older.

Perrault's book is instructive in this respect, as the author puts his own work in the perspective of the old literature. Interestingly, he published his book anonymously in 1674 in French, as well as an extended abstract in English (Anonymous, 1675), but a few years later the book was republished with his name (Perrault, 1678), while more recently a full translation in English appeared (Perrault, 1967).

Summary of Perrault's book

In the first part of his book, Perrault critically reviews other philosophers, Ancient Greek (Plato, Aristotle, Epicurus), Roman (Vitruvius, Seneca, Pliny), medieval (Thomas Aquinas) and early modern (including Gassendi, François the Jesuit, and Palissy). In particular he disagrees with Vitruvius, Gassendi, François and Palissy, whose ideas he refers to as the Common Opinion (l'Opinion Commune). In the second part he presents measurements, calculations and theories. Referring to the River of Seine, his final result is this:

> *So that there needs but the sixth part of the Rain and Snow-water that falls in a year, to run continually through the whole year.* (Anonymous, 1675).

Interestingly, Perrault also refers to the Nile as follows:

> *But when there would be countries where it never rains, that would not prevent rivers from flowing which would have their sources in other countries where it rains, as does the Nile which flows in Egypt where it does not rain. […]*
>
> *Continuation of the Author's opinion.*
>
> *After having* ***rejected the Common Opinion****, after having shown that the water which flows in the Rivers for a year is not so considerable* ***as Aristotle and those who followed him imagined****, and that the rains can provide sufficient water to maintain their course for a year, it only remains for me to show how the waters of the rain and the snow that have fallen in the Rivers, can come out through the top of the mountains to make springs.* (Perrault, 1678, p. 207)

This is puzzling as in fact Aristotle's theory on the Nile was exactly this, i.e., that rainfall in another area (Ethiopia) was providing the water to sustain the flow (actually flood) of the Nile.

Recapitulation and relevance to modern science

1. *Posing scientific questions* (e.g., the Nile paradox) and seeking scientific explanations was a crucial historical development, which did not prevail in earlier civilizations, as exemplified by Herodotus's contrast between Greek philosophers and Ancient Egyptian intellectuals (and priests).
2. Science and philosophy were not only invented but also defined, with their meaning clarified to be the *genuine pursuit of truth*, independently of other (e.g. economic) interests.
3. Science, then called *natural philosophy*, was developed as part of philosophy, with other parts thereof, i.e., metaphysics, epistemology, logic and axiology (ethics, aesthetics), being equally developed.
4. The development of (Aristotelian) *logic* offered a powerful instrument for science to distinguish sense from nonsense as well as deduction from induction, and the relative validity of the inference based on each of these two methods.
5. The gradual development of the *scientific method*, which constitutes part of philosophy, by incorporation of observation, experience and, at a later stage, experiment, provided a solid foundation of science.
6. Central in Ancient Greek thought was *reasoning* as the main tool for the search for truth. By no means does this imply that the philosophers of Ancient Greece tended to distrust observations, as incorrectly asserted by some modern scholars (where samples are given in the Introduction). Obviously, if this happened, it would contradict reasoning per se (it is totally unreasonable to dismiss observations).

Recapitulation and relevance to modern science (2)

7. *Clarity* (*σαφήνεια*) was also a desideratum so strong that Aristotle identified it with truth. This is also related to the accurate accounting of the phenomena and the attainment of accurate scientific knowledge (Lesher, 2010). The introduction of terminology, i.e., of sophisticated terms whose meaning may not be identical to the colloquial one, and their definitions, is another reflection of the clarity desideratum.
8. Formulation of a *plurality of ideas* by different scholars, as well as their debate, were vital for the development of science. It is clear from the quotations given above that Ancient Greek scholars cite and discuss each other's ideas and theories, mostly with proper respect and sometimes with moderate irony. Thanks to these discussions, today we are aware of opinions of philosophers whose original works are totally lost.
9. The plurality of ideas and diversity of opinions, some of which necessarily were better than other, resulted in an evolutionary process which in turn enabled *scientific progress*. It appears that such recently promoted ideas as that of a "settled science" did not have a place in the ancient environment of scientific inquiry.
10. An important development that expedited scientific progress was the *creation of Philosophical Schools*, functioning as centres of higher-level education and research, similar to modern universities. Plato's Academy, Aristotle's Lyceum (or Peripatetic School), Epicurus's Kepos (meaning garden), Zeno's Stoa (meaning arcade) were some of the most famous. After nine centuries of continuous operation, they were massively closed in 529 AD by an infamous emperor Justinian's edict, which marked a societal paradigm shift and a millennium-long regression in scientific inquiry.

Recapitulation and relevance to modern science (3)

11. The communication of ideas among philosophers and to the public was organized in the form of books. Within this practice, a writing style or code was developed, characterized by critical literature review and expression of own thoughts, using a sophisticated language. This writing style is more or less followed even in present day, as can be inferred by inspecting several extracts from Ancient Greek texts given above.
12. According to Plato and Aristotle the motivation of philosophers is their curiosity to explain Nature, but according to Herodotus, it is their ambition to achieve reputation for wisdom. Noting that even this latter does not look an unethical incentive, we may assert that the development of science complies with the development of axiology and of ethical values, including the promotion of the *truth* as an ethical value and the *modesty* of those seeking it. Even the term *philosophy* (*φιλοσοφία*) reflects this modesty. Notably, the term *philosopher* (*φιλόσοφος*) replaced the earlier term *sophos* (*σοφός*, translated in English as *sage* or *wise*, as in the expression "Seven Sages"). According to an Heraclitian aphorism, *wise is only one* (*ἕν τὸ σοφὸν*, meaning something supernatural, i.e. God) and henceforth Pythagoras introduced the term *philosopher*, meaning *lover* (or *friend*) of *wisdom* (*φίλος σοφίας*). This is clarified in the following quotation:

    Φιλοσοφίαν δὲ πρῶτος ὠνόμασε Πυθαγόρας καὶ ἑαυτὸν φιλόσοφον […]*· μηδένα γὰρ εἶναι σοφὸν [ἄνθρωπον] ἀλλ' ἢ θεόν* (Διογένης Λαέρτιος, *Βίοι καὶ γνῶμαι τῶν ἐν φιλοσοφίᾳ εὐδοκιμησάντων*, A.12).

    Pythagoras was the first to name it philosophy and himself a philosopher […] *for no man is wise, but God alone.* (Diogenes Laertius, Lives of the Philosophers, 1.12)

Back to Aristotle: importance of seeking the truth

«*φίλος μέν Σωκράτης, ἀλλά φιλτάτη ἡ ἀλήθεια*»
(Latin version: "*Amicus Socrates, sed magis amica veritas*")

"*Socrates is dear* (friend)*, but truth is dearest*"
(Ammonius, Life of Aristotle)

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

«*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).

It takes courage to formulate scientific theories — now as well as then

«*ὁ γὰρ πρῶτος σαφέστατόν τε πάντων καὶ θαρραλεώτατον περὶ σελήνης καταυγασμῶν καὶ σκιᾶς λόγον εἰς γραφὴν καταθέμενος Ἀναξαγόρας* οὔτ᾽ αὐτὸς ἦν παλαιὸς οὔτε ὁ λόγος ἔνδοξος, ἀλλ᾽ ἀπόρρητος ἔτι καὶ δι᾽ ὀλίγων καὶ μετ᾽ εὐλαβείας τινὸς ἢ πίστεως βαδίζων. *οὐ γὰρ ἠνείχοντο τοὺς φυσικοὺς καὶ μετεωρολέσχας τότε καλουμένους, ὡς εἰς αἰτίας ἀλόγους καὶ δυνάμεις ἀπρονοήτους καὶ κατηναγκασμένα πάθη διατρίβοντας τὸ θεῖον, ἀλλὰ καὶ* ***Πρωταγόρας ἔφυγε, καὶ Ἀναξαγόραν εἱρχθέντα μόλις περιεποιήσατο Περικλῆς****, καὶ* ***Σωκράτης****, οὐδὲν αὐτῷ τῶν γε τοιούτων προσῆκον, ὅμως* ***ἀπώλετο διὰ φιλοσοφίαν***» (Πλουτάρχου Βίοι Παράλληλοι, Νικίας, 23).

"*The first man to put in writing, most clearly and most courageously of all, the explanation of the moon's illumination and darkness, was Anaxagoras. But he was no ancient authority, nor was his account in high repute. It was still under seal of secrecy, and made its way slowly among a few only, who received it with a certain caution rather than with confidence. For people did not tolerate the natural philosophers and stargazers, as they were then called, because they reduced the divine agency down to unreasoning causes, blind forces, and necessary incidents. Even* ***Protagoras was exiled, Anaxagoras was imprisoned and with difficulty rescued by Pericles****, and* ***Socrates****, though he had nothing whatever to do with such matters, nevertheless* ***lost his life because of philosophy***" (Plutarch, Nicias, 23; cf. I. Velikovsky, Anaxagoras, http://www.varchive.org/ce/orbit/anax.htm)

Note: Anaxagoras was charged of impiety, and he was sentenced to death by the Athenian court. He avoided this penalty by leaving Athens, and he spent his remaining years in exile.

Concluding remarks

- **Scientific theories are mostly wrong**. It is a matter of time for any theory to be replaced by a better one.
- Naturally, all theories developed in the dawn of science (2600 years ago) have been replaced. **This does not make them non-scientific.**
- It is a good practice to study the history of science, recognize the past contributions and give credit to those who made them. (Notifications: (a) consulting original texts is useful; (b) humour is different from arrogance).
- This study –of the history of hydrology in particular– is useful as it reveals the **effectiveness of thought and logic**, which were the basic tools of ancient philosophers, in compiling a sensible world vision with some admirable elements, even though other elements are inconsistent according to modern knowledge.
- As the information provided here shows, in addition to thought and logic, **experimentation, measurement, and observation** were all used by ancient philosophers, particularly by Aristotle.
- As evident from our terminology (*meteorology*, *climate*, *hydraulics*) and even the scientific writing style, **modern science is not independent from the ancient one**; advances of the Greek antiquity have been particularly seminal for the modern science after the Renaissance.

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