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The Hellenic Civilization

INTRODUCTION

The pre-Hellenic civilizations, as discussed in the previous chapter, grew up mainly on the banks of the three major river systems: the Nile, the Tigris-Euphrates, the Indus, and their tributaries. The Hellenic Civilization came into being in about 600 B.C. with the birth of the Ionian school in Asia Minor. Its science was certainly indebted to older civilizations, mostly perhaps to that of the Egyptians, but there, for the first time, people engaged in a pursuit of knowledge for its own sake. Reymond said of it: 'Compared with the empirical and fragmentary knowledge which the peoples of the East had laboriously gathered together during long centuries, Greek science constitutes a veritable miracle. Here the human mind for the first time conceived the possibility of establishing a limited number of principles, and of deducing from those a number of truths which are their rigorous consequence'[1].

The failure of the Greek philosophers to establish some of the basic principles of water science was not due to any neglect of facts, as they certainly had noted certain aspects of those principles, but the number thereof was too few. Moreover, they failed to undertake a consideration of all the facts in their possession simultaneously. Instead, they followed a procedure, as recommended by Aristotle, to consider only small portions of them at a time. It is not surprising therefore that many conflicting theories were advanced on almost every subject. This circumstance was summed up by Rapin as follows:

'All the power of ancient philosophy was not able to settle any one principle of nature. Thales maintain'd that the water was the great source of all things; Heraclitus declar'd for the fire; Anaximenes for the air; Pythagoras for numbers; Democritus for atoms; Museus for unity; Parmenides for infinity... Protagoras affirmed that every thing was really true which appear'd to be so. Aristippus allow'd nothing to be true but what men are thro'ly convinc'd of by inward perswasion of the mind. Chrysippus declares, that the senses are always in the wrong: Lucretius contends, that they are always in the right.'[2]

Rapin concluded charmingly that 'it must be confess'd that there's nothing so certain in nature, but what may be made the subject of dispute'.[2]

THALES, THE ANCIENT HYDROLOGIST

At the threshold of the Ionian philosophy, stood the semi-legendary yet very real and outstanding figure of Thales of Miletos (624?–548? B.C.). Very little is known about him (figure 1). Whatever we are able to credit him with comes mostly from Aristotle and Herodotus. Even during the fourth century B.C., the time of Aristotle, Thales was well on his way toward becoming a legendary figure. Sarton speaks of Thales as a sort of Benjamin Franklin. Both of those men had open minds, a curiosity to learn about new elements, and both applied their knowledge to the solution of practical problems.

Like Franklin's visit to England, Thales went to Egypt, and like Franklin, he was impressed with what he saw.

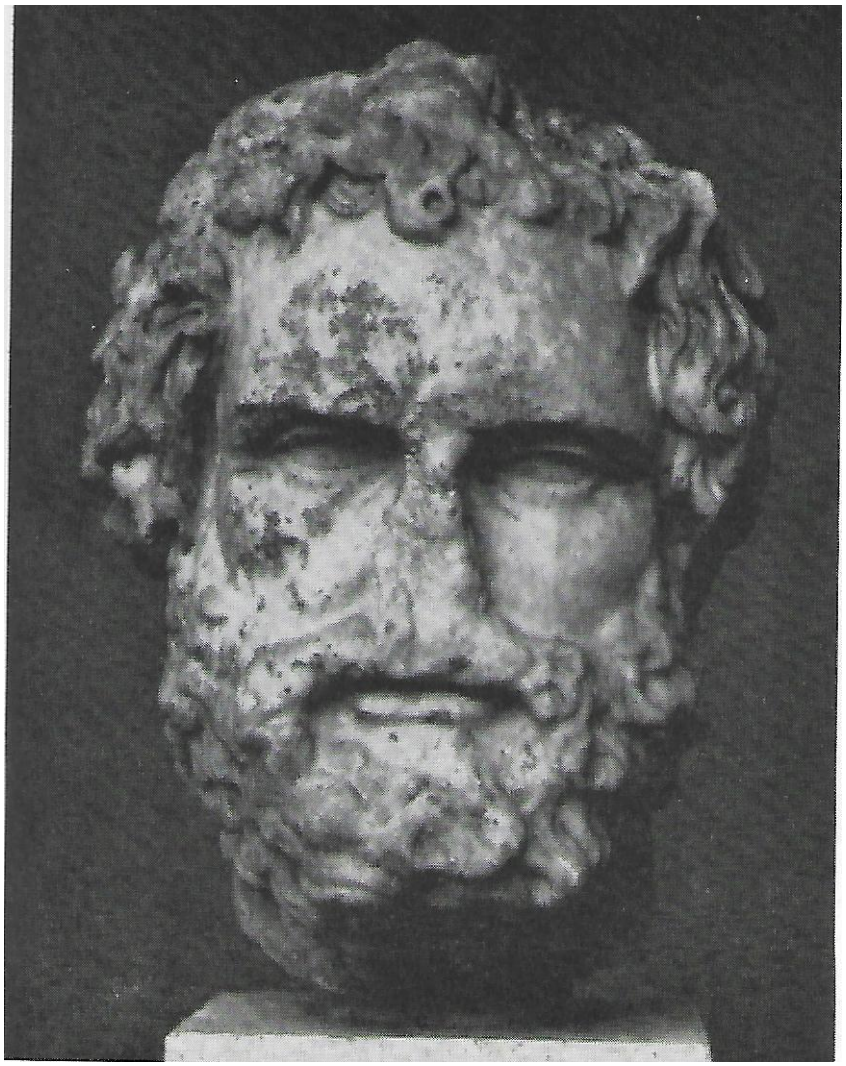

Figure 1. Thales, the founder-member of the Seven Wise Men (by courtesy of Ny Carlsberg Glyptotek, Copenhagen).

Thales was acknowledged universally as one of the Seven Wise Men of the ancient times (figure 2). It is amusing to note the statement by Demetrios Phalersus that Thales 'received the title of sage' – as if it were a sort of honorary doctorate! The unusual fame of Thales and the esteemed title of 'wise man' did not come to him from the fact that he was the first Greek astronomer nor because he was the first Greek mathematician, but rather because of the application of his knowledge to practical advantage.[3]

Figure 2. Mosaic of the Seven Sages from Torre Annunziata near Pompeii. Identification is rather difficult, but the third from the left is probably Thales (by courtesy of National Museum, Naples).

In a dissertation on the history of hydrology, we are interested in the following statements which can, according to Aristotle, be attributed to Thales:

(1) The earth floats on the water,[4] and
(2) Water is the original substance, and hence is the material cause of all things.[5]

The first of these two statements was quite common in the Egyptian and the Babylonian cosmogonies. The Egyptian priests believed that the earth was created out of the primordial waters of Nūn and that such waters were still everywhere below it.[6] According to a Babylonian legend prevailing at that time, 'All the lands were sea... Marduk bound a rush mat upon the face of the waters, he made dirt and piled it beside the rush mat'.[7] Marduk was the legendary Creator of the Babylonians, and since Thales travelled extensively, it is reasonable to assume that he knew of that legend, but when he expressed the above theory, Marduk was not mentioned. It also seems possible that Thales might have obtained his theory from Homer who thought that the earth was surrounded by a vast expanse of water beyond the sea – which has no source or origin. Or Thales possibly tried to rationalize the Egyptian and the Babylonian theories, and ended up with the concept that the earth floated on water like a fiat disc.

His second statement that water is the fundamental or primary matter might sound foolish at first reading but appears quite reasonable after closer scrutiny. It is far from being nonsense. When Thales visited Egypt, he must have observed the Nile – an almost legendary river. It was then a

common belief that Egypt had been created by the Nile. And, if he had noticed the process of delta building by the river, he might well have reasoned that the land was actually being produced by the water. The very lives of the Egyptians depended entirely on the regular inundations of the Nile, yet they never seem to have presented a rational reason or explanation for them. Eventually, the Ionian offered an explanation for the phenomenon, but to the Egyptians this was just another of their numerous mysteries.

Water is the only liquid that was well known in its three physical states liquid, vapour and solid. Its transformation from one state to another takes place quite easily, and it is commonly found in nature in all three states. Because it comes down from above as rain, hail or dew, some early philosophers erroneously believed by that became changed into earth by some mysterious process. The thought of associating the origin of streams and rivers with precipitation was at first an extremely remote possibility – a concept at will be discussed in later chapters. Another erroneous belief was that the fires of heavenly bodies were fed by the moisture drawn from rivers and seas through the process of evaporation.[8] Probably a major factor which caused Thales to assume that water was the primary element, was that life cannot exist without it. That fact must have been driven home rather forcefully when he visited the arid country of Egypt.

Some authorities like Oswiecimski have tried to justify Thales' concept on somewhat different grounds. He contended that:

'essence of water is, of course, what is most obvious in water, i.e., humidity or fluidity which can be easily identified with humidity. It was easy for Thales to observe that such a solid and 'dry' body in its normal state as iron even in its liquid condition (e.g. when melting ore) is not only water, but even, under the influence of heat, cannot contain any water in the usual sense of the word. Yet it is a liquid, and liquid in general is easy to be identified with humidity. So if iron is really, according to Thales' theory, one of the forms of water or – what is the same – arose from primitive water, it is not the form of water itself but of its essential part, of its essence: humidity-fluidity which he understood in a material sense, not as a quality but rather as a concrete matter.'[9]

Situated at the dispassionate distance of some 2500 years, it is futile to argue against the actual contention of the founder of the Milesian school. A woman wearing her grandmother's dress may look like her grandmother but her thoughts, no doubt, would be different. Hence we refer to Aristotle to obtain an insight into Thales' reasons for describing water as the primary substance. Aristotle suggested three reasons for Thales' philosophy: (a) nutriment of all things is moist, (b) heat is generated from moisture and also kept alive by it, and (c) seeds of all things have a moist constituency.

Like all ancient philosophers Thales was fascinated by the River Nile. His attempts to explain the cause[10-14] of its regular inundations will be discussed in chapter 6.

The search for the primary substance or *archē*- continued long after Thales' time. Heraclitus thought it was fire, and the priests of magic broadened the concept to include both fire and water. Euripides considered the primary substances to be air and earth, and believed that the generation of mankind and the animals was due to the fact that the earth was impregnated by the seeds contained in the precipitation[l5] from the heaven. When all the living things were destroyed by time, they returned again to their point of origin – the heaven. Empedocles of Agrigentum (490–430 B.C.) postulated that there were four primary elements or roots (rhizōmata) – fire, air, water, and earth, from which all the materials of the world were constituted by their combination in different proportions.[16] Bones, for example, were made of two parts of earth, two of water, and four of fire.

This concept of the constitution of materials by different ratios of the four 'elements' probably came about through the mathematical influence of Pythagoras.

ANAXIMANDER TO XENOPHANES

Anaximander of Miletos (610–545 B.C.) was a contemporary of Thales, and hence it is not surprising to find that Thales influenced him to a certain extent. He considered the Thalesian concept of water as the primary substance to be too tangible, and hence he selected something more intangible which he called *apeiron*. That word meant something infinite, indefinite, undetermined or even inexperienced. Since only fragments of Anaximander's works are available to the present historians of science, there is considerable controversy over the true meaning of the word *apeiron*.[17] Like Thales, Anaximander believed that in the beginning, human, as well as animal life, originated in water. With gradual but continuous evaporation, land emerged where once was an all-engulfing sea.[18]

Aristotle later discussed that view as follows: 'But those who are wiser in the wisdom of men give an [explanation of the] origin of the sea. At first, they say, all the terrestrial region was moist; and, as it became dried up by the sun, the portion of it that evaporated produced the winds and the turnings of the sun and the moon, while the portion left behind was the sea. So they think the sea is becoming smallest by being dried up, and that finally it will all become dry.'[19]

According to Hippolytos, Anaximander believed that precipitation was due to the moisture being drawn up from the earth by the sun.[20] Anaximenes (d. 528–525 B.C.) believed that when rain is frozen while falling it resulted in hail, whereas snow was produced when air was imprisoned within the water.[21] Xenophanes of Colophon lived somewhere within the period 570 to 470 B.C. He believed that the 'sea is the source of water, and the source of wind. For neither could (the force of the wind blowing outwards from within) come into being without the great main (sea), nor the stream of rivers, nor the showery water of the sky; but the mighty main is the begetter of clouds and winds and rivers'.[22] Thus Xenophanes presented an argument of purely tautological character to prove his point. Clouds, rains, springs, and streams, he claimed, all originate from the sea;[23] if there was no sea, none of these would have existed but since there is sea they do exist! From his observation of the presence of shells on high mountains and fossils of marine animals at various land areas of the earth, he reasoned that the land must have been under the sea at one time. For those observations, he could be considered the earliest geologist as well as the earliest palacontologist.[24]

ANAXAGORAS AND HIPPON

Anaxagoras of Clazomenae (500–428 B.C.) was endowed with spirit of inquiry, and was the last of the renowned Ionian philosophers. His explanation for the regular rise of the river Nile was almost the correct one, and it will be discussed in chapter 6. His main thoughts concerning hydrology were the following:

'Of the moisture on the surface of the earth, the sea was produced from the waters of the earth, ... and from the rivers which flow into it.'
'Rivers depend for their existence on the rains and on the waters within the earth, as the earth is hollow, and has water in its cavities. And the Nile rises in summer owing to the water that comes down from snows in Ethiopia.'[25]

Hippon of Samos flourished around the middle of the fifth century B.C. According to him: 'All water that is drunk comes from the sea; for of course the wells from which we drink are not deeper than the sea, for in that case the water would not be from the sea but from elsewhere. But in fact the sea is deeper than the water. It follows therefore that all water that is above the sea comes from the sea'.[26]

CONTRIBUTIONS OF HERODOTUS

Herodotus of Halicarnassus (484–495 B.C.) considered all knowledge to be his particular prerogative, and pursued that subject with great enthusiasm. Hydrologic phenomena were included among the many things he was particularly curious about and so he searched diligently for their explanations. Any reasons he could find, rational or irrational, were carefully entered in his notebook. As an example, he describes the three prevailing theories as to why the River Nile's inundation began at the commencement of the summer solstice. Those three theories had all been expressed by the Greeks, and that fact caused him to note that the Egyptians did not have any theories thereon. Regardless of their source, however, he dismissed them all disdainfully, and submitted a fantastic theory thereon of his own accord. More information about it will appear in chapter 6.

Herodotus studied the Nile with particular interest. He said that any one with only ordinary powers of observation could see that Egypt was an acquired country, a gift of the river. Its alluvial land had been gradually built up by the deposition of silt brought there by the river.[27] If one dropped a sounding line a day's sailing time away from the coast, he would find mud there at a depth of eleven fathoms.[28] That indicated that soil eroded by the river had been carried for that distance. With brilliant geological reasoning almost unparalleled in ancient history, Herodotus opined that all of Lower Egypt had once been under the sea. Like the Red Sea, the Nile valley was once an arm of the sea but silt carried by the river gradually filled in the basin between Thebes and Memphis.[29] The delta formed while the area was gradually being filled. That filling had taken place during the 'ages that passed before I was born by the great River Nile which works great changes'.[30] The presence of sea shells on the hills and the high salinity of the land, helped to confirm his conclusions.[31]

The Egyptians became amused as well as horrified when they learned that Greece did not have a river such as the Nile for producing an annual inundation, and that rainfall was the only source of fresh water in Greece. They believed that if the Gods decided not to send rain to Greece, the poor Greeks would become wretchedly hungry – a belief which must have caused the father of history to chuckle to himself. According to 'strong evidence' provided by the priests at Heliopolis, the Nile, during the reign of King Moeris, overflowed all Egypt below Memphis as soon as the river stage rose to only eight cubits (12 ft). When Herodotus visited Egypt some 900 years later, however, the river had to rise to sixteen cubits (24 ft) to produce the same effect.[32] If the land kept on increasing in height at the same rate, it was obvious that a time would come when the Nile would no longer be capable of flooding its banks. Without an annual inundation in an almost rainless country, this astute historian reasoned, the chances were that it would be the Egyptians who would then go hungry, rather than the Greeks.

Herodotus was fascinated by the Ister River (Danube), almost as much as he was by the Nile. In contrast to the Nile, which overflowed its banks with almost unbelievable regularity, the Ister maintained practically the same level during the summer as it did during the winter.[33] This was true despite the fact that it snowed during the winter and there was scarcely any rain, whereas during the summer extra water was brought to the river by both melting snow and rainfall. The sun's power of attraction was greater during the summer, however, and because the two effects tended to counterbalance each other, the flow in the Ister remained at essentially the same level throughout the

entire year.[34] Where did the Ister get its supply of water during the winter to maintain that flow? The historian has not told us, and it is futile to speculate as to what reason or reasons he could have given if he were to explain that circumstance. Whewell believed that Herodotus' statement that 'the sun *draws*, or attracts, the water' was a metaphorical term, 'obviously intended to denote some more general and abstract conception than that of the visible operation which the word primarily signifies. This abstract notion of 'drawing' is, in the historian, as we see, very vague and loose; it might, with equal propriety, be explained to mean what we now understand by mechanical or chemical attraction, or pressure, or evaporation'.[35] Was Whewell correct? We can only conjecture, but who really knows the truth?

Herodotus also had an interest in various other river characteristics. He describes in great detail[36] the river systems of Scythia (figure 3). He also noted that when the Nile was about to rise, the hollows and marshy spots near the river became flooded because of the water percolating through the riverbanks.[37] Possibly the historian's worst errors were in the descriptions he gave of the general courses of the Danube and the Nile. He believed that like the Danube, which flows across Europe from the west toward the cast, the upper Nile flowed in that direction also.[38] He confused the great river 'containing crocodiles' with the Niger. Later both juba II, the King of Mauretania, and Pliny made similar mistakes.[39] Considering that these erroneous ideas continued in one form or another for nearly the next 2200 years, this early historian deserves to be excused.[10]

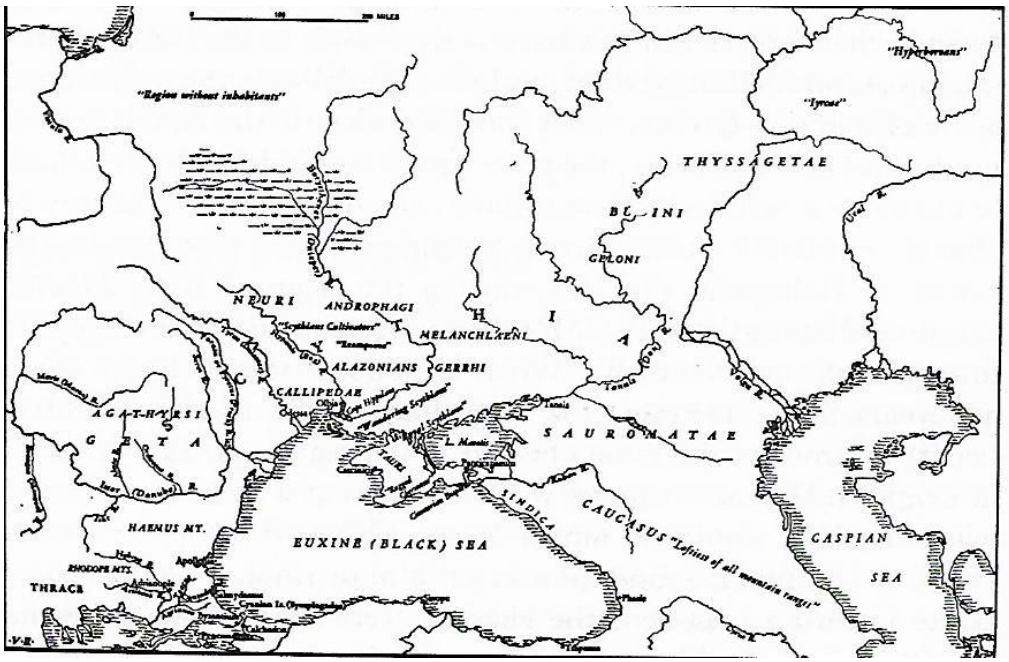

Figure 3. River systems of Scythia according to Herodotus.

HIPPOCRATES CONCEPT OF WATER

It is difficult to believe that the concepts of the Ionian philosophers had for their bases any observed facts or even a limited amount of experimentation. With characteristic aplomb they proclaimed that the ultimate ingredients of all material things in the universe consisted of water, or air, or atoms, or

the four elements – as if the whole process of evolution* had taken place before their very eyes. Plato later describes those concepts as being no more than a 'plausible tale'. However, things were different with respect to medical science. Hippocrates (460–400? B.C.), the father of medicine, had some definite ideas about the constitution of water.[40] He thought water was comprised of two parts: one part was thin, light, and clear – the other was thick, turbid, and dark coloured. The sun attracted and raised only the lightest and the thinnest part of water – as should be obvious from the salty part which was always left behind. Water could be withdrawn from all things which contained humidity – and there was humidity in everything. Of all waters, he declared rain water was the lightest, sweetest, thinnest, and clearest.

'When attracted and raised up, being carried out and mixed with the air, whatever part of it is turbid and darkish is separated and removed from the other and becomes cloud and mist, but the most attenuated and lightest part is left, and becomes sweet, being heated and concocted by the sun, for all other things when concocted become sweet. While dissipated then and not in a state of consistence it is carried aloft. But when collected and condensed by contrary winds, it falls down wherever it happens to be most condensed. For this is likely to happen when the clouds being carried along and moving with a wind which does not allow them to rest, suddenly encounters another wind and other clouds from the opposite direction: there it is first condensed, and what is behind is carried up to the spot, and thus it thickens, blackens, and is conglomerated, and by its weight it falls down and becomes rain.'[10]

Hippocrates conducted an experiment to show that some portions of water (the thinnest and lightest portions) could be eliminated by evaporation. A measured quantity of water was poured into a vessel and was then exposed to the open air in winter till it became frozen. The next day it was brought into a 'warm situation' until the ice melted, whereupon it was weighed and found to be much less than the original quantity. From this he concluded that he had 'a proof that the lightest and thinnest part became dissipated and dried up by the congelation, but not the heaviest and thickest, for that would be impossible'.[40] A few hundred years ago, Anaximenes had declared his concept on the effect of reduction of temperature on the density, i.e., the hotter, the thinner; the colder, the denser.[41] Had he tried a simple experiment like Hippocrates, he probably would have thought twice before propounding such a general and universal concept. Water when heated becomes vapour and expands; but what happens when it is frozen? Does it contract into a smaller volume as anticipated by this theory? Had he kept a jar of water outside on a wintry night, he would have noticed that instead of contracting it expanded, and possibly would have even split the container. In comparison, the simple experiment conducted by Hippocrates was a major development. It undoubtedly was a step forward in the right direction – that of conceiving of methods for conducting scientific investigations.

ARISTOPHANES

The Athenian playright Aristophanes (445?–385? B.C.) ridiculed the then prevailing concept that rain was sent by the almighty god Zeus. The dialogue between Strepsiades and Socrates, as contained in his play *The clouds*, is worth quoting:

'Strepsiades: No Zeus up aloft in the sky!
Then, you first must explain, who it is sends the rain;

* The evolution process, of course, was not known at that time.

Or I really must think you are wrong,
Socrates: Well then, be it known, these send it alone:
I can prove it by arguments strong.
Was there ever a shower seen to fall in an hour
when the sky was all condes and blue?
Yet on a fine day, when the clouds are away,
he might send one according to you.
Strepsiades: Well, it must be confessed, that chimes in with the rest:
your words I am forced to believe.
Yet before, I had dreamed that the rain-water streamed
from Zeus and his chamber-pot sieve.'[42]

CONCLUSION

The tradition of free inquiry started with the Milesian school, notably from the time of the 'first philosopher' Thales, and every physical phenomenon was made the subject of discussion and criticism. It was during this time of the Hellenic Civilization that man first seriously attempted to understand nature, and began giving thought to natural causes rather than divine ones. Thales was the first man to assign much importance to water. His thoughts were echoed later by Pinder, who in the fifth century B.C., flatly stated that the best of all things is water. Here, for the first time in history, man pursued knowledge for its own sake. During this period also, the seeds of hydrology as a science were being sown. They finally blossomed some 2200 years later with the seventeenth century experimental works of Pierre Perrault, Edmé, Mariotte and Edmond Halley.

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