

# Chapter 1

## The Evolution of Science

*And which of the gods was it that set them on to quarrel? It was the son of Jove and Leto; for he was angry with the king and sent a pestilence upon the host to plague the people, because the son of Atreus had dishonoured Chryses, his priest. Now Chryses had come to the ships of the Achaeans to free his daughter, and had brought with him a great ransom: moreover he bore in his hand the sceptre of Apollo wreathed with a suppliant's wreath and he besought the Achaeans, but most of all the two sons of Atreus, who were their chiefs.  
Homer: Iliad*

### 1.1 Greece: The Dawn of Science

Only a short moment's contemplation shows us that science plays an enormous role in modern western societies. Scientific achievements have improved quality of life for billions of people in many ways. On the other hand, in certain respects, scientific advancements have worsened our quality of life. In addition, scientific advancement has often come at the expense of the rest of nature. In fact, some would even argue that science causes more harm than good, an opinion which I deem absurd. In any case, everyone can agree that science has greatly influenced the course of life all over the world.

From a global perspective, the evolution of science, and the consequent transformation of society, is a unique process. Throughout the ages, many societies have attained high levels of cultural development and organization (streets and roads, irrigation, educational institutions, organized postal service, formal justice systems, etc.). Yet, for the most part, modern western societies were the first to develop systems that saved large portions of its population from starvation and lengthened the average lifespan. Natural questions one might wish to ask in the light of these phenomena are how this societal change began, why it began in Western Europe, and why it began when it did?

Most would agree that these questions regard a profound change—a true revolution—that is considered the most significant historical development since the invention of agriculture. One can distinguish two somewhat distinct processes in this revolution: (i) the scientific revolution, which is usually placed in the period 1550–1650 A.D. and (ii) the industrial revolution, which began in England in the

1700s. The connection between these two revolutions is a controversial issue: some think that the industrial revolution was, for the most part, independent of the science of the day, while others think that a pertinent precondition for this process is the evolution of science and the so-called *scientific perspective*.

That the industrial transformation of western societies in the last hundred years is largely a result of scientific developments is undisputed. However, there is a question as to the role played by scientific insights in the beginning of the industrial transformation. In other words, we may ask, when did science begin to gain industrial and economic importance? Without taking a definite stance to this question, one can point at Sadi Carnot's (1796–1832) studies concerning the effectiveness of steam engines as a clear example of a scientific study, which was not founded on pragmatic demands, and yet had direct technical relevance. In his famous book 'Reflections on the Motive Power of Fire' (1824) Carnot discusses the effectiveness of the steam engine, starting from purely theoretical principles. Guided by his insights, one could immediately introduce substantial improvements in the efficiency of steam engines. A crucial step was Carnot's introduction of the concept of a quantitative measure of heat, *Calorie*. The previous long-lived idea that heat was a substance was replaced by the conception of heat as a quantitative property and the successful use of Carnot's theory convinced people that this new conception was correct.

However, the scientific revolution started much earlier at around the middle of the 1500s in northern Italy, England, and Holland, the commercial centres of the time. Why then and in those areas? What are the causes of the scientific revolution? These questions are not only of historical interest! Many developing countries are now quickly attempting to embrace scientific and technological achievements with the kind assistance of humanitarian and U.N. organizations. However, the results of these endeavours are varied and sometimes discouraging. Thus there is anecdotal evidence that we lack sufficient understanding of the essential aspects of this process of transition.

In all likelihood, a wide range of circumstances is required for scientific thinking to emerge in a society and be applied in economic and industrial contexts. Among these circumstances one may distinguish between *external* and *internal* factors. External factors include, but are not limited to, religious, economical and political factors, and they act in fairly obvious ways as external constraints on our society's intellectual development. Internal factors include theories of knowledge, world-views, and norms of argumentation, which are, by and large, inherited. The ideas and concepts inherited from ancient thinkers is a factor that I shall argue actively contributed to the scientific revolution gaining momentum during the renaissance in Western Europe. We must keep in mind that many cultures have preceded ours in history; and yet, none of them achieved a similar breakthrough in scientific thinking. Which components of this ancient heritage were significant, and what was lacking from those earlier cultures whose absence prevented them from developing an active science?

As every history must begin somewhere, and as the germ of science is clearly gleaned in ancient Greece, let us begin this brief study of the historical preconditions of science there. To fully appreciate ancient Greek efforts towards scientific thinking, one would have to consider and discuss a great many things, but I shall here limit myself to four ideas that have proven particularly significant. I do not dare argue that these four ideas are the *most* significant as regards the evolution of scientific thinking, only that they are important. The four ideas are (1) the Ionian natural philosopher's way of explaining nature, (2) the emphasis on rational argumentation, (3) Aristotle's introduction of the concept of logical validity, and (4) Euclid's axiomatic mathematics.

*1. Ionian Natural Philosophy* We usually consider the dawn of philosophy and science to have occurred around 600 B.C. in the Greek cities along the coast of Asia Minor, particularly Miletus. The first of the famous philosophers of this period are *Thales* (approx. 600 B.C.), *Anaximander*, Anaximander (610–546 B.C.), and *Anaximenes* (?–525 B.C.). Based on the fragments left behind, and the comments of their successors, we can conclude that these three philosophers asked the question: What is it that comprises all things? What is the underlying substrate? They thought that there must be something constant lying behind all of nature's transformations: plants and animals grow, thrive, produce offspring and die, weather varies and everything in nature changes. But changes presuppose something that does not change.

Thales thought that the underlying substrate, or principle,<sup>1</sup> that which is responsible for the change in all things, is water. This is perhaps not so strange an idea, since all biological processes require water, and all living things contain large amounts of water. Thales perhaps reached this conclusion by noticing that a living organism requires a large amount of water for its survival, and similarly, when it dies it releases a great deal of water.

Anaximander argued that the underlying substance was not any of the then recognized elements, earth, water, air or fire, but a more primary substrate, *apeiron* ('the indefinite'), which was thought to be boundless, eternal and unchanging. His argument against Thales is quite interesting: If water was the underlying substance, then over time it would have won the cosmic battle against the other elements, and everything would have returned to water. However, this is not the case. Thus the underlying substrate must be neutral with respect to the four elements. Obviously, the tacit assumption is that changes are to be conceived as a kind of struggle between the elements.

Lastly, Anaximenes claimed that the underlying substrate or principle was air. His idea was that all the other elements were comprised of condensed or rarefied air. This theory, although false, is interesting as it is purely physical and explains the generation of the other elements.

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<sup>1</sup> The Greek word is 'aitia' which is translated as 'cause', 'reason', or 'responsibility'.

These primitive ideas do not strike us as particularly scientific, but we must not judge them based on what we now know. Rather, they should be judged with respect to the general presuppositions and ways of thinking that existed during that time period. In this context, it is apparent that the Ionian thinkers had taken a significant step toward developing a scientific mode of enquiry. For how did the Greeks and other peoples of the time think about natural phenomena? What did one see as the cause of nature's changes? One could summarize the typical answer in one word: myths. Natural phenomena – including personal destinies – were controlled by various gods, spirits, or demons, whose favour one was want to win. One can find examples of this thinking in Homer's *Iliad* and *Odyssey* (ca. 700 B.C.). Particularly illuminating is Homer's explanation (in the beginning of *Iliad*, see the quotation at the beginning of this chapter) of an outbreak of plague in the Greek army that was besieging Troy. The cause of this outbreak was said to be that the god Apollo was angry with Agamemnon, because he, the king and commander, had insulted Apollo's priest; and therefore Apollo sent the plague. In short, changes in nature were thought to depend upon the will of the gods. That is to say, one explained natural phenomena in the same terms as one would explain human actions. The Ionian philosopher's broke with this tradition of thought; and in so doing, took a step towards a scientific approach.

A clear example of the Ionian philosopher's influence on Greek culture is Hippocrates' (460–377 B.C.) view on the origins of disease. He writes the following regarding epilepsy, called 'the sacred disease' because it commonly was thought to have been sent by the gods:

It is thus with regard to the disease called Sacred: it appears to be nowise more divine nor more sacred than other diseases, but has a natural cause from the originates like other affections. Men regard its nature and cause as divine from ignorance and wonder, because it is not at all like other diseases. And this notion of its divinity is kept up by their inability to comprehend it, and the simplicity of the mode by which it is cured, for men are freed from it by purifications and incantations. . .

And the disease called the Sacred arises from causes as the others, namely, those things, which enter and quit the body, such as cold, the sun, and the winds, which are never changing and are never at rest. And theses things are divine, so that there is no necessity for making a distinction, and holding this disease to be more divine than the others, but all are divine, and all human.<sup>2</sup>

2. *Rational Argumentation* Ancient Athenians took a lively interest in argumentation. This may be connected to the fact that its democratic constitution. Athens was under the classical period (ca. 400 B.C.) a democracy, although one that excluded women and slaves. Political decisions were taken by the citizens assembled at the agora. In a democracy each person who wishes to implement his ideas must convince others by arguing for them. The natural question then is to which forms of argument are effective, and thus arose an interest in rhetoric and argumentation. Another effect of democracy is a change in attitude towards other people, since one

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<sup>2</sup> Hippocrates: *On the Sacred Disease*, <http://classics.mit.edu/Hippocrates/sacred.html>

cannot usually convince people by treating them as subordinates. This realization led free male adults in ancient Athens to treat each other as equals.

The difference between ancient Athens and other highly developed cultures of the same time period, e.g. China, is illuminating. During this period, China was split into many different states, all controlled by autocratic kings. Political influence was thus only possible for the advisors to these kings. This had the effect that more authoritarian attitudes were promoted. In order to illustrate the difference between Chinese and Greek societies during this period, we can compare two texts. The Chinese text is taken from ‘Analects’ by Confucius, or Kung Fu Tzu (551–479 B. C.), in which he (who made his living as an advisor to kings and rulers) is conversing with his students. The Greek text is Plato’s ‘Theaetetus’, in which Socrates is conversing with Theaetetus, a young man who is studying mathematics:

From ‘Analects’:

Tzu Kung (one of Confucius’ disciples) asked about the conditions for government.

The Master replied	‘The requisites for the exercise of power are enough food, enough weapons, and the confidence of the people.’
Tzu Kung said	‘Suppose you had to do without one of these; which would you give up first?’
The Master said	‘Weapons.’
Tzu Kung said	‘What if you had to give up one of the remaining two; which would it be?’
The Master said	‘Food. All men must die, but a state cannot survive without the confidence of its people.’ <sup>3</sup>

From ‘Theaetetus’

Theaetetus	Well, Socrates, after such encouragement from <i>you</i> , it would hardly be decent for anyone not to try his hardest to say what he has in him. Very well then. It seems to me that a man who knows something perceives what he knows, and the way it appears at present, at any rate, is that knowledge is simply perception.
Socrates	There’s a good frank answer, my son. That’s the way to speak one’s mind. But come now, let us look at this thing together, and see whether what we have here is really fertile or a mere wind-egg. You hold that knowledge is perception?
Theaetetus	Yes.

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<sup>3</sup> Different translations have divided Analects differently. At <http://classics.mit.edu/Confucius/analects.3.3.html> the quotation is in section 3, part 12, at [http://www.indiana.edu/%7Ep374/Analects\\_of\\_Confucius\\_\(Eno-2015\).pdf](http://www.indiana.edu/%7Ep374/Analects_of_Confucius_(Eno-2015).pdf) the passage is found in book 12.

- Socrates But look here, this is no ordinary account of knowledge you've come out with: it's what Protagoras used to maintain. He said the very same thing; only he put it rather a different way. For he says, you know, that 'Man is the measure of all things: of the things which are, that they are, and of things which are not, that they are not.' You have read this, of course?
- Theaetetus Yes, often.
- Socrates Then you know that he puts it something like this, that as each thing appears to me, so it is for me, and as it appears to you, so it is for you – you and I each being a man?
- Theaetetus Yes, that is what he says.' (Trans. M. J. Levett)

The exemplified difference in attitude between teacher and pupil is pretty clear, in my view.

*3. The Discovery of Logic* Aristotle (384–322 B.C.) made many important contributions to science and philosophy, but we shall here only discuss his introduction and analysis of *logical validity*. Whether an argument is valid has to do with its *form*, and not with the *meaning* of the words used—excepting the logical ones—used in the argument. Aristotle was the first to make this distinction, and the first to study the general rules for argumentation. Here I shall briefly discuss his theory of *sylogisms*. A syllogism is an argument that can be constructed using the following four sentence types:

- All A are B.
- Some A are B.
- Some A are not B.
- No A are B.

The symbols A and B stand for categories. If one takes three such sentences where each pair contains one common category term, one can produce 256 different combinations. A couple of examples are

- All A are B
- All B are C
- All A are C

and similarly

- All A are B
- No B are C
- No A are C

It is easy to convince oneself that in both these examples, *if* the first two sentences are true, *then* the third sentence *must* also be true. It makes no difference which categories one chooses the symbols A, B, and C to stand for. This is a definition of *logically valid inference*. Aristotle analysed all 256 of the possible

variations and showed that only 24 of them are such that, if the first two sentences were true, then the third must also be true.

Of course, syllogisms are only a small part of logic, but what is important here is that Aristotle realized that in analysing an argument one can pose two questions, namely (1) are the premises true, and (2) does the conclusion follow from the premises? In order for an argument to be deemed sound, both of these questions must be answered in the affirmative. Aristotle's priceless contribution is that he drew attention to the formal side of argumentation.

*4. The Axiomatic Ideal* The fourth important contribution to the development of the scientific approach is Euclid's axiomatization of mathematics. This was an enormous step forward from what had previously been known about mathematics. The students of the time before Euclid were taught a great deal about practical mathematics. That is to say, they were taught mathematical methods for solving practical problems associated with commerce, transportation, astronomy and measurement. In these situations, there can be raised two fundamental questions: (i) do these rules for calculation give accurate results, and (ii) in cases in which one is certain that the results are accurate, on what grounds do we base this mathematical certainty?

Euclid's contribution was to show that all the mathematics of the day (and a great deal more) could be logically deduced from a few axioms, i.e., sentences that were obviously true and did not require further justification. Mathematics became a *deductive* science: from secure premises (axioms), new knowledge was inferred using strict logical rules. That is to say, a mathematical proof gives certainty. Euclid was so successful with his axiomatic-deductive method that for a long time it was considered the archetype of how science should operate. A good example of Euclid's influence is Baruch Spinoza's magnum opus *Ethica Ordine Geometrico Demonstrata* (1675). As the title ('Ethics proven by Geometric Methods') suggests, Spinoza presents ethics as an axiomatic system, precisely as Euclid did with geometry.

Euclid's axiomatic mathematics led to a scientific ideal, *the axiomatic science ideal*, which can be characterized in the following way:

- Science aims to attain certain knowledge, not mere beliefs or opinions.
- Begin by setting up axioms, i.e. truths so obvious that they require no further justification.
- Next, deduce new truths from these axioms using strict logical methods.

In geometry and elementary arithmetic it seems possible to find axioms just by reflecting upon geometrical figures and numbers, but how is it done in e.g. mechanics or biology? In other words, how do we recognize true general propositions from which one could deduce empirical facts in e.g., physics or biology? Aristotle discussed this (*Posterior Analytics* 2.19.100a6-8); he argued that repeated perceptions of things and events resulted in true general propositions, such as 'man is an animal', or 'the natural state of a body is rest'. The process of generalising from repeated experience to such general propositions he called

*epagoge*, usually translated as ‘induction’. However, one should keep in mind that he did not view this activity as a kind of scientific inference or be represented as an inductive argument. (So the translation ‘induction’, given the usual meaning of this word, is somewhat misleading.) Rather he describes the process more like an automatic working of the mind in forming concepts and general propositions. Such general propositions could then be used as premises in scientific demonstrations. So all sciences have, in Aristotle’s view, the same axiomatic-deductive structure, but the way we recognize axioms is different in different sciences.<sup>4</sup>

These four elements of our ancient Greek heritage – to seek explanations of natural phenomena in nature’s internal properties, to argue on an even plane, to investigate the rules of argumentation and logical validity, and to build them into a logically consistent system—are all essential to the development of a scientific approach.

One may wonder why science did not flourish and develop in the days of the Roman Empire, or those of the Caliphate, since both of these cultures further developed the Greek culture. That this was not the case shows that the inheritance of these ideas, in and of itself, is not sufficient for a scientific revolution. However, Greek views were probably a necessary factor for the emergence of the scientific revolution almost 2000 years later. In order to understand just how monumental a change would ensue, it is perhaps prudent to look at how people thought during the middle ages.

## 1.2 The Medieval Worldview

The Roman Empire gradually declined and fell apart during the fifth century and the last emperor of Western Roman Empire, Romulus Augustus, lost power A.D. 476. The decline of the Western Empire was followed by a rapid decline of organised civilisation in Western Europe, and, astonishingly also a fast decline in population. (According to a quite modern hypothesis this decline in population was caused by a climate catastrophe, no summers for three consecutive years 536–538, which in turn might have been caused by volcanic activity from the Ilopango Caldera in central El Salvador, pouring out clouds of dust and hiding sunshine for several years.) The Eastern Roman Empire continued until A.D. 1453, and Plato’s Academy in Athens still existed for some time, but the Emperor Justinian closed it A.D. 529. Thus, organised study of philosophical and scientific texts from antiquity almost disappeared both in western and eastern Europe. One may say that in Europe

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<sup>4</sup> From a modern view-point, Aristotle’s account needs two modifications; (i) From a series of observations one can generalise in many ways and the most natural one might be the wrong one, as is illustrated by his own mistaken theory of motion and (ii) mathematical axioms are nowadays not viewed as self-evident, but chosen by mathematicians for certain purposes.

the philosophical and scientific heritage from Greece was lost for several hundred years.

Population and culture slowly improved during the early Middle Ages and around 1100 A.D. higher education started to reappear in the Western world. The first institutions of higher education—the precursors of the eventual Medieval Universities – were medical and legal colleges in Italy. A century later, these colleges had expanded into universities with various faculties: theological, medical, juridical and *artium liberalium*, i.e., the liberal arts. Education in these universities consisted in studying canonical works from ancient times, like Euclid's *Elements* or Galen's works on anatomy. The view regarding knowledge at the time was that knowledge was obtained through the study of classical texts. That one could discover new information, or that the ancient thinkers could have made mistakes, were not viable options (Fig. 1.1). When Aristotle became known in Christendom around 1200 A.D. as a result translations from Arabic to Latin of Aristotle's works (the Greek heritage had been tended by Arabic scholars throughout the Dark Ages in western Europe), Thomas Aquinas (1225–1274) began what he saw as the important task of interpreting Aristotle in a way that would not conflict with Christianity. The result of Aquinas' toils was what we now call scholasticism.

A good, though quite late, example of the medieval view of how one accrued knowledge is given by Olaus Magnus' *Historia de Gentibus Septentrionalibus* ('History of the Nordic Peoples') (1555). Each and every chapter gives a fully detailed description of what past authors have to say on the matter and how they approached the subject. For example, Olaus Magnus often refers uncritically to what Tacitus and Jordanes wrote about Ultima Thule. One would think that Olaus Magnus, who was born and raised in Sweden, ought to have seen himself as a superior authority on Nordic history, geography and habits and manner of living than an author from antiquity who relied merely on hearsay. This lack of a critical stance illuminates the scholarly attitude of the time. Certainly one does find some passages where Magnus is describing his own observations, but nowhere does one find a passage of the form 'the famous author X's view on the subject is incorrect because I have investigated the matter and found it *not* to be the case'. Olaus Magnus is essentially a Medieval scholar who was unaffected by the new currents, which had at that time clearly begun to flow.

But one could find tendencies of experimental science already during the Middle Ages, especially in England, though these tendencies did not lead directly to any breakthroughs. This was perhaps because of a general distrust in the ability of a sinful mankind to obtain true knowledge of God's inscrutable creation. Or perhaps it was due to the general opinion that this sort of knowledge was relatively unimportant. One did not live long, hence that which was essential was the soul's salvation and whether one was destined for hell or heaven.

In studying the history of art, it is not difficult to see a gradual shift in attitude and the way of thinking throughout this period. Early in the Middle Ages, art is for the most part symbolic and often intended to elicit religious emotions. Yet there arises a tendency towards more naturalistic and representational art. A major step in this process was the discovery of the central perspective that allowed artists to

**Fig. 1.1** An anatomy lecture given by the medical faculty at the University of Venice in 1493. The professor lectures from his desk, while two assistants dissect a body and point out the various organs. Neither the students nor the professor take part in the dissection, as the source of knowledge is the book from which the professor lectures



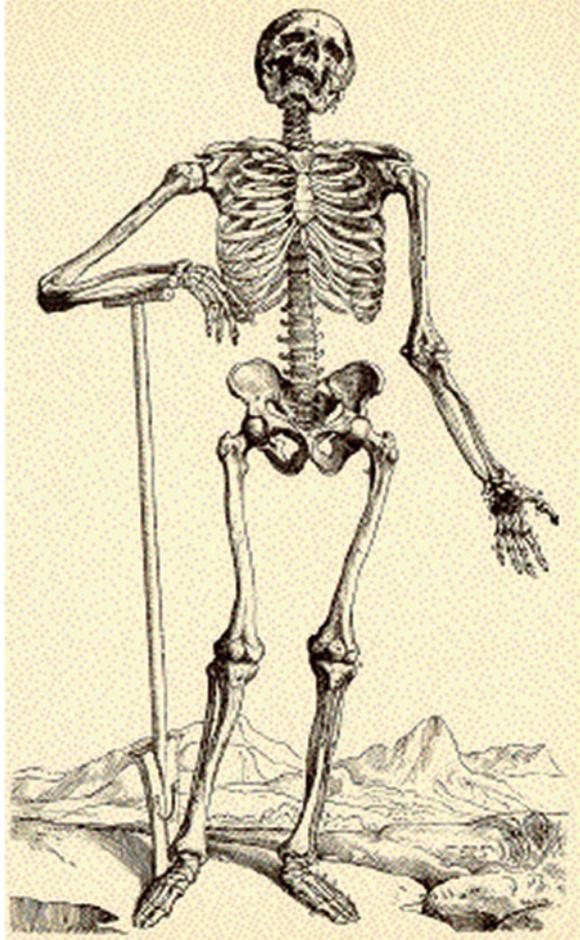
depict people and scenery more accurately. It gradually becomes clear that interest is shifting from art's religious function to the possibility of producing more accurate portrayals of the visible world. In due course, this shift leads eventually to the Renaissance. This major change in Western culture, which includes—among other things—a newfound interest in people and living conditions, helped lay the foundations of the scientific revolution.

### 1.3 The Scientific Revolution

An important element of the scientific revolution was a new approach to nature and the new form of knowledge thereof. People began to think that understanding natural phenomena was important and interesting, a view which few people, at least few among those who were literate and wrote, shared during the Middle Ages.

By the mid-1500s the belief that knowledge was to be found only in classical texts began to be replaced by the belief that one's own observations of natural

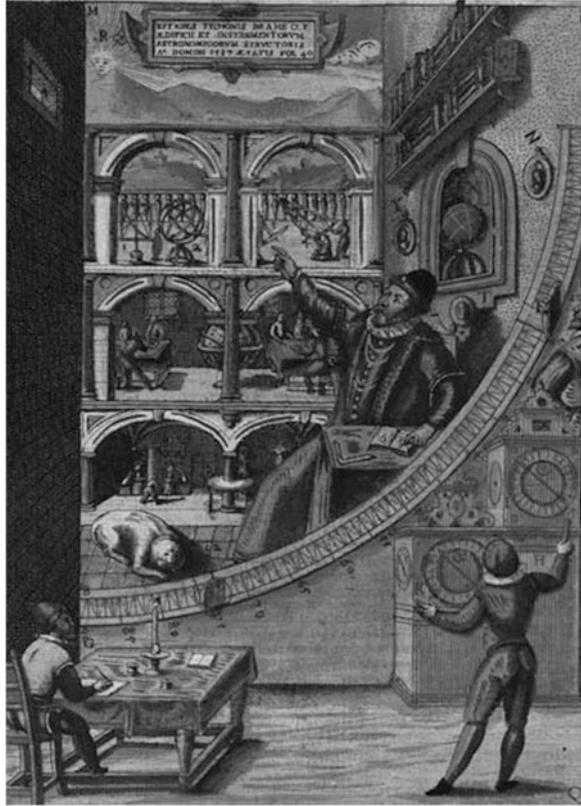
**Fig. 1.2** An illustration from Vesalius' 'On the workings of the human body'



phenomena were necessary for knowledge of those phenomena. Closely related to this belief was the idea that the authors of antiquity could be mistaken, and that it was possible for contemporaneous scholars to correct those mistakes. The leading reformer for this cause was Andreas Vesalius, (1514–1564) of the University of Padua. His magnum opus *On the Workings of the Human Body* (1543) is generally considered the first modern text on anatomy. Vesalius' book was built upon comprehensive dissections, and he was able to refute many of Galen's views, which had been hitherto accepted as the authority on such matters. It marked the first appearance of a well-researched and essentially accurate description of the human body (Fig. 1.2).

In the same year, 1543, Copernicus published his new theory regarding the solar system. He was the first in modern times (Aristarchus of Samos, circa 200 B.C., had made similar claims, which inspired Copernicus) to state that it is the sun, and not

**Fig. 1.3** Tycho Brahe observes the positions of the planets from his observatory, Uranienborg, on Ven. The image shows Brahe looking through a small hole in the wall, observing planetary positions via the large quadrant beside him, while his assistants record the time



the Earth, that is located at the centre of the universe, and that the Earth and the other planets revolve around it. One can argue quite confidently that these two events – the publications of Vesalius’ and Copernicus’ works – mark the starting point of the scientific revolution.

Another clear case of this new approach to obtaining knowledge is exemplified by Tycho Brahe (1546–1601). He devoted much effort to observing the positions and movements of celestial bodies from his observatory on the island of Ven in Denmark (now the island belongs to Sweden). Brahe’s meticulous observational data was later used by Kepler in the development of his famous three laws of planetary motion (Fig. 1.3).

It is quite apparent that Brahe realized that he could obtain *new* knowledge, knowledge that could not be found in the classical texts. Why else would he have spent so many years making original observations? We should also keep in mind that the telescope had not yet been invented, and yet Brahe was able to pinpoint the position of planets and stars with an accuracy of 1 arc-minute, i.e.  $1/60^\circ$ .

It is apparent that mere observation is not sufficient for doing science, in that one has to somehow ‘process’ the observations (e.g. make classifications). The following passage from Bacon<sup>5</sup> is an example of this new perception of knowledge:

Those who have treated of the sciences have been either empiricists or dogmatists. Empiricists, like ants, simply accumulate and use; Rationalists, like spiders, spin webs from themselves; the way of the bee is in between: it takes material from the flowers of the garden and the field; but it has the ability to convert and digest them. This is not unlike the true working of philosophy; which does not rely solely or mainly on mental power, and does not store the material provided by natural history and mechanical experiments in its memory untouched but altered and adapted in the intellect. Therefore much is to be hoped from a closer and more binding alliance (which has never yet been made) between these faculties (i.e. the experimental and the rational). (*The New Organon*, book 1, sec XCV)

Why did the scientific revolution begin in Western Europe at the end of the 1500s? Why did it not begin in China under the Tang dynasty, which was a cultural high period in China, or at the height of Arabic culture around the ninth century A. D.? Indeed, why did it not begin in the Aztec and Inca civilizations? In order to give a satisfactory answer to these questions one must, I think, apply both an *external* and an *internal* perspective. One must take into account both religious, economic and political factors (the external ones), as well as the ways that one obtains knowledge and the nature of knowledge in general (the internal ones). To properly merge these various aspects into a plausible explanation of why the scientific revolution began in Europe is an enormous project, and one that lies far beyond the scope of this book. However, one important question that we shall here discuss is whether there is a generally valid scientific method, and whether it was this method that began to be applied during the scientific revolution. My answer to this question is, reservedly, *yes*. There is a generally valid scientific method, the *hypothetico-deductive method*, of which more in Chap. 3, and it was this method that began to be applied in the work of Vesalius, Galilei, Harvey, Brahe, Kepler, Newton, and many more. The application of this method was an important factor, perhaps the most important, in the creation of the modern sense of scientific enterprise.

From the above discussion one might get the impression that the ancient Greek heritage had nothing to do with the development of modern science. This is, however, an incorrect conclusion. The scientific revolution consisted in a dramatic change in the medieval perception of knowledge, which was in large part inherited from the ancient Greeks. But, as we shall see in Chap. 3, there are ideas from antiquity actively operating at the emergence of the fully modern scientific method: the hypothetical-deductive method.

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<sup>5</sup> Francis Bacon, (1561–1626), English philosopher and Lord Chancellor. He argued for empirical and inductive methods in science.

## 1.4 Theory of Science and Philosophy of Science

Theory of Science is a discipline that consists in investigations into the operations of science from both external and internal perspectives. However, in the remainder of this book we shall concentrate only on the internal perspective, which is the ‘philosophical’ perspective. We shall discuss such questions as: What is science? How does one distinguish science from pseudo-science? What is knowledge? What is a scientific explanation? What is a cause? What is a scientific hypothesis? What is a scientific theory? What is a scientifically acceptable observation? Hence the aim of this book is to provide the reader with a basic understanding of these issues, and the key concepts and views that philosophers and scientists have developed to answer the questions above.

The internal questions of Theory of Science belong to a part of philosophy; namely, philosophy of science. Like all philosophy, philosophy of science begins with wonder and bringing into question ‘common knowledge’. One often speaks of science as something familiar, something that is easily identified. But, is this really the case? Does there exist a universally accepted definition of scientific practice? No, there does not; and even if it did, one could still ask how one might justify such a definition.

Theory of science, like the object of its study, also begins with questions regarding constitution and function. But Theory of Science differs from science proper in that there is no generally accepted school of thought from which to proceed. This fact can either be seen as a failure (Theory of Science has not been able to produce any lasting results) or as a distinctive character trait (Theory of Science *is* such that it does not produce solid foundations, rather it contributes to a critical review of science). In my opinion, the second alternative seems to be the most plausible.

Different questions within philosophy of science are relevant for different types of scientists. For example, the following questions are relevant for medical scientists: (1) What is a cause, in medical contexts? (2) What is the relation between the body and the mind? (3) What criteria should be used to distinguish between the practices of a charlatan and accepted scientific methods? The last question is a special case of the more general issue of distinguishing between science and pseudo-science. In discussing these three questions we are inevitably led to the questions regarding the nature of knowledge in general; what knowledge is, how it is that we obtain it, and how we can rely on this knowledge. Therefore, it is natural to proceed with a discussion of the nature of knowledge in general, and whether or not there is a common thread to be found in all activities we call science.

## 1.5 Summary

This chapter explains how our present conception of science is the result of a long evolution starting in ancient Greece. In particular four Greek ideas are pointed out as being crucial elements in scientific thinking: The first is the conviction that

properties and events in nature could be understood as the result of natural processes, not as the effect of actions of gods and other supernatural agents. The second is view that knowledge could be achieved by rational argumentation, not from holy authorities. The third is the idea that a science should be systematic body of knowledge and the fourth component is the discovery of logic as a basic ingredient in rational thinking.

There was a clear empiricist trend in pre-Socratic Greek thinking, and to some extent also later. This empiricist outlook regained importance in western thinking around 1500 and was the central aspect of the scientific revolution.

## Further Reading

- Goodman, D. C., & Russell, C. A. (1991). *The rise of scientific Europe 1500–1800*. London: Hodder & Stoughton.
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