UNIVERSITY OF CAMBRIDGE

Cambridge University History of Mathematics Society

presents an illegal, immoral, *and* fattening lecture series,
without the endorsement, approval, or approbation of University authorities on:

HISTORY OF SCIENCE IN ANTIQUITY

To be held on

***Thursdays,* Michaelmas & Lent Terms 2024-25**

These lectures were first given in response to some Cambridge maths undergraduates being curious about history of science beyond the history of mathematics lectures I have given for many years, and who asked to have some lectures giving more of the scientific context in which the mathematics of the past was done. Things went from bad to worse: they wanted more, and a proper course. And so evolved my three-year cycle of lectures (see below) on those parts of the history of science I know about. These lectures are no longer welcomed in the Faculty of Mathematics, so some undergraduates banded together to form the CU History of Maths Society to organise the continuing lectures on history of mathematics and history of science. This year these lectures are going to be on-line, at least to start; if suitable lecture rooms can be found at zero cost, then we will go hybrid and I will do face-to-face lectures and live-stream the lectures. But for the first few weeks of this term, at least, they will be on-line only. I am aware that there are people from outside the university, or former Cambridge students, who have attended my video lectures, and people from outside the University are most welcome to join the Zoom lectures. However, the lectures are generally aimed at a Cambridge undergraduate audience.

Lectures will be recorded and put up in a private site, so those in the know can find videos of past lectures. Location of recorded lectures, and the Zoom links to each weekly lecture Thursday at 4 pm, and other news items of greater or lesser importance will be given on the emails I will send out to those that sign up. These emails are famed for their eccentricity, so please beware that they sometimes lack a certain decorum. Like the lectures. The email list is an essential part of the lectures, so to get the links, you need to sign up. There is a QR code at the end of this introduction, or you can find the email list on the university email list server. Lectures will begin on Thursday 10 October, 4 pm.

Lecture topics this year

I give lectures in *history of science for mathmos* in a three year cycle: (*i*) history of science in antiquity, (*ii*) history of renaissance science and the scientific revolution, and (*iii*) history of science in early Islam. This year it is the turn of ancient science.

These lectures are independent of my history of mathematics lectures, although obviously you will benefit infinitely more if you attend both, and will benefit at least uncountably infinitely more if you attend both and laugh at my lame jokes. They are, of course, non-examinable and are just supposed to be fun (for an appropriately Cambridge definition of fun), and follow my own entirely eccentric story of ancient science.

No scientific, classical, linguistic, or mathematical background is assumed, although a sense of humour is required and a certain amount of mathmo-speak and mathmo jokes is inevitable, if regrettable. You will not be expected to do any extra work for these lectures, they are just for the general broadening of your scientific and intellectual culture and background so that you don't appear to be the cultural ignoramus that mathematicians from elsewhere tend to be; it is also a chance for you to gain polemical and authoritative opinions for pub discussions based on little evidence except for a dim recollection of my (polemical and authoritative) lectures. When delivered with appropriate (polemical and authoritative) confidence this will annoy everyone else in the pub discussion, but they will just think you are an arrogant Cambridge mathmo. This is not, of course, a news item.

Lectures this year will cover the following topics. I shall probably follow this order, but this is not the list of topics of individual lectures, just the syllabus that – possibly – I will follow. To some greater or lesser extent. Maybe.

(1) ***Overview***

Inevitably, I will begin with an introduction and overview of the course, and an overview of the time-line of ancient Greek science. And why you should care about it, even though it is 2000 years in the past and from the point of view of modern science, pretty much entirely wrong.

(2) ***Ancient Egypt and Mesopotamia***

Then I will talk a little about the extent to which we can find anything like science (technically: natural philosophy, or more generically 'the use of natural causes to explain natural phenomena' … for appropriate local definitions of natural, cause, and whatever they admitted as phenomena or real) in the civilisations of ancient Egypt and Mesopotamia. Of course there was interesting stuff going on in other societies elsewhere in the world, but I know a tiny bit about these societies and not others, so you'll get these guys. Ooops, did I say that out loud? The astronomy, medicine, and technology of these two early civilisations are good examples of often extremely impressive technical achievements, but without what I will want to call scientific (natural philosophical) thinking. They also illustrate the problem of sources in understanding ancient thinking.

(3) ***Early 'Homeric' Greeks***

Homeric Greeks (around 1000BC, maybe a little after, and a little before) were not particularly impressive compared to Mesopotamian or Egyptian civilisations as far

as their technology or understanding of nature; there is little to say about very early Greek 'science' for the simple reason that there wasn't any. The understanding and interest in causes of natural phenomena that we find in Homer, for example, are completely primitive, and show no signs of the kinds of thinking that were to emerge early in the 5th century BC. Something must have happened …

(4) *Philosophy and knowing nature*

Everything changed around the turn of the 5th century BC: the ancient Greeks developed the idea of what they called philosophy (gaining sure and true knowledge, or wisdom); I will discuss one argument about how this came about (weird politics, debates in the *agora*, and the Sophists), and how a group of learned men came to use rational scepticism ("arguments about arguments" as we say in the trade, or – even more obscurely - second order epistemology) and then quite soon after some of them started to use these tools to distinguish explanations of natural phenomena based on natural causes from explanations that invoke supernatural causes. The ambition emerged that reasoned arguments could be used to find explanations of everything (a *new* sense of 'explanation'), or at least natural phenomena.

(5) *And … it doesn't work*

The ambitions of the nascent natural philosophers (the earliest pre-Socratics) were dealt a near fatal blow by Parmenides (maybe -480?) and his devastating, radical, rational scepticism (using reason to criticise reasoning, in a nutshell). At this point the early natural philosophers either had to find an answer to Parmenidean scepticism or give up the pretentions of natural philosophy as offering sure and certain and timeless explanations of the world and go off and do sociology or underwater basket-weaving. Parmenides' critique of the pretentions of natural philosophy is maybe the defining moment of the birth of western civilisation. What follows is a couple of thousand years seeking answers to Parmenidean scepticism, and no, String Theory is not the answer.

(6) *Answers to Parmenides I*

Possibly the earliest answer to Parmenides was the theory of atomism of Leucippus (ca. -450) and Democritus (and Epicurus, a century later); it is a "yes, but" sort of answer, and never really took off (I mean, who would believe such a ridiculous idea as the world being made of invisibly small atoms?) … but the arguments around this ontological conjecture proved extremely fruitful, even if the idea of unchanging ultimate units of matter turned out not to work as a way of explaining the material world. Try very hard not to confuse ancient atomism with 19th century and subsequent doctrines of atoms: only the word 'atom' is the same.

(7) *Answers to Parmenides II*

It is possible that one of the reasons the Pythagoreans gained any traction whatsoever in the 5th century BC – and I don't think they gained much – was that they attempted to give an answer to Parmenides. Maybe. Or maybe not. Whatever,

the Pythagoreans were at best late arrivals to the fashion of rationalism, whatever it might have been; they are a waste of time, mostly scientific dullards, did pretty much no mathematics of any even miniscule significance and generally are of exceedingly limited importance. And no, Pythagoras probably never existed, didn't discover, and didn't prove the Theorem. I will not bother to be polite in my excoriation of the historical profile of early Pythagoreanism and my denigration of those who think the 'school' is of any significance. It is all mostly an invention of Hellenistic hagiographers.

However, I think other things were going on in mathematics in the last decades of the first half of the 5th century BC … and mathematics might just have provided at least some sort of answer to Parmenides. Well, some people who were playing with geometry found ways of using it as a counter example to the Parmenidean claim that true and certain timeless knowledge was not available to humans, only the gods. This isn't the Pythagoreans, but someone else.

(8) *Answers to Parmenides III: Socrates*

Entire lecture courses can be given trying to piece together the teachings and context of Socrates – who is at least as important as Parmenides in the development of scientific thinking; I will talk briefly about how with Socrates it looks like epistemology finally got serious, and the conditions for obtaining sure and certain knowledge (philosophy) of the world were finally examined with considerable care and depth. With Socratic teaching, Greek rationalism finally can take off as a project to gain sure, certain, timeless knowledge of the world (i.e. natural philosophy).

(9) *Rational medicine (otherwise, Hippocrates of Cos)*

It was around now – the last half of the 5th century – that we also find the strange, interesting case of the Asclepion, the plague in Athens, the crisis for non-Ascelepaic medics, and the emergence of one of the first 'successful' consequences of the fashion for rationalism. This is what we call Hippocratic medicine (although Hippocrates of Cos was not involved) as evidenced by the *Hippocratic Corpus* (not written by Hippocrates of Cos, of course).

Another successful consequence of this fashion is the raised status of geometry as a potentially true and certain form of knowledge (as evidenced in the work of Hippocrates of *Chios*, who is not Hippocrates of *Cos*) apparently immune to Parmenidean scepticism; I discuss this in my history of maths lectures.

(10) *'A more* philosophical *people'? Really?*

Somewhere here it would be good to take a vacation from all of this speculative natural philosophy with a quick tour of a little ancient technology; traditionally the Ancient Greeks have been seen as a "more philosophical people" … and a quick look at their technological abilities shows this to be utter nonsense. Maybe I should talk about the Trireme, for example …

(11) *Answers to Parmenides IV: the Stoics*

Late in the 5th century BC another school of thought emerged that may also be an answer to Parmenides, although we know little of its early natural philosophical doctrines … but they had a few core ideas (particularly the life-giving, space filling, self-conscious *pneuma*) that were extremely influential in the long term.

(12) *Answers to Parmenides V: Plato*

Several long courses would be needed to do the thinking of Plato justice; a pupil of Socrates and possibly one of the three or four most influential human beings ever and certainly one of the cleverest things ever to walk on two legs. Developed his so-called Theory of Forms which offers the first even reasonably successful answer to Parmenides, and it is easy to argue is the beginning of western science. Amongst other things. Plato founded the Academy (which was to survive for a thousand years), articulated a clear programme for why we should do natural philosophy, and thought deeply about the nature of mathematics and its relationship with the physical world. If you are a mathmo, you are very likely a Platonist (even if you don't know it); Bertrand Russel wrote that all philosophy (and therefore science) is a footnote to Plato, and that's not wrong. I will talk about Plato and knowing about the world (and astronomy, maths), the *Republic* and the *Timeaus* in a little detail.

(13) *Eudoxus*

Eudoxus was at the Academy with Plato, and he is probably is the origin of the western tradition of (mathematical) astronomy, and he seems to have started the mathematical programme that dominated the next two thousand years (the study of curves). Eudoxus seems to have solved the major mathematical problems of his day: a new theory of proportion, the problem of the nature of curvilinear area, answered Plato's problem of a mathematical account of the movement of the heavens, and probably changed geometry from a visibly demonstrable science to a science of pure logic. The word awesome doesn't even begin to describe the significance of Eudoxus. You don't get Euclid without first Eudoxus. You don't get the western mathematical tradition down to the 19th century without Eudoxus.

(14) *Answers to Parmenides VI: Aristotle*

The next candidate for most important human being ever, cleverest thing on two legs ever, brain the size of Jupiter, founder of western science, and a further long list of superlatives, is Plato's pupil Aristotle. Aristotle rejected Plato's Theory of Forms and came up with a different way of understanding what is unchanging in the world, and with it a fairly explicit explanation of what we would call scientific laws; he was an empiricist but – for good reasons – eschewed experiment, and unlike Plato had a limited role for mathematics in our understanding of the world … but a much more important role for observation and interaction with the material world. Above all Aristotle considered deeply a theory of matter, and the notion of causality; his thinking about biological causation and physiology give rise, a couple of generations later, to the start of sensible and useful rational medicine. His theory of the large

scale structure of the heavens was to remain accepted until the early 17th century, and generally Aristotle's thinking was to dominate Christian and Muslim thinking and western science into the 17th century.

(15) *Answers to Parmenides VII: Epicurus*

Epicurus (who was not *all that* concerned about eating well, *pace* modern cliches), at the end of the 4th century BC, developed a singularly sensible Atomistic natural philosophy and epistemology that gave rise to a new way of thinking about the natural world; this does not seem to have held enormous sway and did not give rise to a great deal of new scientific thinking. His attitude seems to have generally been that if you had a controversy between philosophical doctrines A and B, and it makes no difference to your life whichever you choose, then you shouldn't worry overly about A or B, and worry more about things that matter. If you have a phenomenon that you can't explain because you cannot know something about the phenomenon (like something is too small to see), then you know you can't know the answer … and stop worrying. Relax. Have some chocolate and think about something that does make a difference. A doctrine that String Theorists should perhaps be taught.

(16) *Alexandrian medicine 3rd century BC*

The happy coincidence of a fairly relaxed atmosphere in the new, hyper-wealthy Greek colony in Alexandria in Egypt, a bunch of rationalist medics who had been taught Aristotelian causal physiology, and the freedom to do human dissections (which only lasted perhaps a generation, sometime in the first half of the century) gave rise, at last, to rationalist medicine that actually was different in more than rhetoric from other medical traditions. Herophilus and Erasistratus are the two towering theoreticians and practical medics who seem to have actually started rationalist medicine as a systematic and empirical science … the Hippocratics of the later 5th century were a bunch of wind-bags, whereas the Aristotelian medics doing human dissections actually started to try to think about a materially causal medicine, understandable through reason and observation.

(17) *Astronomy changes*

In the late 4th and the earlier 3rd centuries BC it would seem that considerably more astronomical data were amassed (although by whom, where, and why are not known), and the inadequacies of the Eudoxean-Aristotelian model became evident; some anomalies appear to be completely unsolvable within Eudoxus' mathematical and Aristotle's physical models. Alternatives seem to have been discussed, although whether as physical or just calculational models is unclear; epicycle-deferent and deferent-epicycle models were discussed, and the mathematicians Apollonius and Archimedes seem to have entered into these discussions. Apollonius' model seems to have gained some traction – perhaps because it was linked to a Stoic physical model (but that is speculative). On the subject of mathematical games about the heavens, Aristarchus may have proposed a model with the Sun at the centre, although for what reason (a physical hypothesis? a mathematical game of showing off, or

criticising other mathematical games? a deliberate religious heresy?) we don't know.

(18) ***Anti-Kythera mechanism***

This is a bronze astronomical computer dating from around 100 BC that was first discovered and not understood very early in the 20th century. The story of its discovery and then how it has come to be understood (in phases since the 1970s) and our current understanding of the model is reasonably dramatic, and if our current understanding of this machine doesn't blow your socks off, you must have already been barefoot. We had absolutely NO idea, even remotely, that the ancient Greeks had this level of technological sophistication, and the currently developing understanding of this device is a total game-changer.

(19) ***Medical schools, Greek medicine in Rome, Galen***

After the 3rd Century BC Alexandrians rationalist medicine continued to develop, although not as dramatically, often deteriorating into rather dull debates between medical schools. Greek rationalist medicine found it difficult to make headway amongst the wealthy and learned elite of Rome until the 1st century AD, and then in the 2nd Century AD everything changed with the Greek doctor who really broke through to the Roman elite: Galen. Galen's medicine was the most significant in breadth, depth, and influence of antiquity, and Galenic medicine influenced all western (Christian and Islamic) medicine up into the 17th century – or even later. Ancient science produced few things more important than Galenic medicine.

(20) ***Astronomy – instrumental vs physical astrology***

In the 2nd century AD the Greek astronomer and astrologer Ptolemy (who I think was a Stoic) wrote a series of treatises on mathematical and physical astronomy, and astrology that were to hold sway over the rest of antiquity (and indeed, up into the 17th century). His *Almajest* was the most technically challenging and comprehensive treatise in astronomy of the ancient world, and an astonishingly deep and accurate mathematical model of the heavens. To what extent it was intended only as a calculational model or was also based on physical hypotheses is controversial, so I have some strong and dogmatic opinions about it. I might possibly take the opportunity to tell you about said opinions, although that is uncharacteristic of me.

(21) ***Chimea and later Hellenistic matter theory***

Later Hellenistic theory of matter became imbued with all sorts of interesting more-or-less mystical ideas (giving rise, eventually, to what you call alchemy – from the Arabic *al-Chimea*), may have become quite experimental (although the sources are not as many as we might like) and a complex web of pagan, Cabbalistic, mystical, and Christian ideas … that were to produce, amongst other things, the (mystical, barking mad) Hermetic texts – which were to be briefly but crucially important in the western renaissance.

(22) ***Galenic medicine and Christians***

About a century after his death, Galenic medicine had become the dominant rationalist medical tradition and most medicine was reduced to a repetition or detailing of Galenic doctrines. The famous medical schools of antiquity (such as Cos, Pergamum, and Alexandria) vied with each other to teach a more complete Galenic corpus. As later antiquity went on, Greek rationalist ideas about disease (it has a natural, material cause) began to conflict with the growing body of Christian beliefs (that disease and pain were God's punishment for sins), and medicine became a conflict zone between a rationalist view of the world and a mystical supernaturally-caused view of the world. This proved to be an interesting conflict; this is also where something not far off hospitals began to evolve.

(23) ***Divergence of pagan and Christian natural philosophy***

Particularly in the Greek world, those who followed the new miracle religion of the Christians soon had to learn rational argument so as to meet pagan (Greek rationalist) arguments, and Christian theologians were soon playing around with Platonic, rationalist Aristotelian and other rational ideas. This meant that as Christian theology and philosophy developed (250-550 AD), the theological disputes became ever more sophisticated and Greek, and vicious; one result of this (apart from early or Patristic Christian theology) was a diaspora of Christian refugees fleeing east into Syria, Arabia, and Persia, carrying with them an assortment of books and an assortment of rich, heretical, Greco-Christian ideas.

(24) ***The east: collapse; the west: total collapse***

We can end the story of ancient science conveniently early in the 6th century AD; in 529 AD the eastern emperor Justinian (may he rot in hell) closed the pagan schools in the eastern empire, thus ending the last vestiges of the public teaching and dissemination of classical Greek pagan thinking. Of course it also survived the closing of the schools, but in the face of both Christian hostility and an institutional vacuum, and then a couple of centuries of Byzantine anti-Hellenism, Byzantine economic decline, and the pandemic plague ('the plague of Justinian'), it soon really did vanish. In the Latin west the last vestiges of the western (Latin) Roman Empire also disappeared around the start of the 6th century, leaving only the western Church to maintain a tiny, tiny thread of learning and a faint, distant recollection of the glories of ancient Greece and Rome, and the faintest memory of ancient science. As far as natural philosophy goes, the Latin west became pretty much a desert, and the Greek east, Byzantium, was only marginally better. Probably.

(25) ***7th Century: and then came Islam***

If there is time (which is unlikely unless the audience listens very quickly) I will talk about what happened when the cool new religion of the Arabs – very quickly a cool new international Middle-Eastern religion – became interested in ancient Greek science. In my ***Early Islam*** course I talk in more detail about the conditions that lead the Abbasid court in Baghdad to get so interested (750-950 AD) in the Greek

philosophy and natural philosophy of the Christian diaspora that had fled from Byzantium to Persia, but I might try to outline this adoption of classical Greek science and rationalism by some Muslim intellectuals.

(26) ***8th Century: Al-Andalus***

And again, if there is time I will talk about the most remarkable flourishing of this Muslim interest in classical Greek science in al-Andalus (the Iberian peninsula ca. 750-1000), and how from the middle of the 11th century this Greco-Islamic natural philosophy came to be transmitted from al-Andalus into the rest of the Latin west, giving rise to both the western, Latin Middle Ages and the foundations of modern, western scientific thinking.