基調講演2
The Transmission of Science in Greco-Roman Antiquity. Memory and Loss, Agency and Form

「古代ギリシア・ローマにおける科学の伝承。記憶と亡逸・担い手と形態」

Heinrich von STADEN
Institute for Advanced Study, Princeton

Introduction.

The renewed modern awareness that science, including scientific medicine, represents a significant component of Greco-Roman culture, and that a vast corpus of Greek and Latin scientific writing has survived, has prompted several excellent studies of the transmission of ancient science. I should perhaps clarify that by‘ transmission’ I simply mean, in the first instance, a transfer or conveyance from one person or place or time to another. And by‘ science’ I mean, in the first place, the intellectual and practical activities encompassing those branches of study that attempt to apply objective scientific methods to the phenomena of the physical, biological, and mathematical worlds, and, secondly, the ‘ knowledge’ which is claimed to have been gained by such methods. Many of the modern analyses of scientific transmission have concentrated on the centuries between late antiquity and the European Renaissance. At their centre have been, in particular, the study of Greek manuscripts of famous scientific texts, their translation into other pre-modern languages (for example, into Latin, Syriac, Arabic, Hebrew, and Armenian), early modern printed editions of Greek and Latin scientific texts, and the multiform appropriations of Greek science by pre-modern and early modern writers. While the focus on periods after Greco-Roman antiquity has generated invaluable contributions to our understanding of the remarkably rich history of the mediaeval and early modern reception and transmission of ancient Greek science, and while this focus has been essential to the production of modern critical editions of the ancient texts, it has been accompanied by the relative neglect of the nature and scope of the transmission of science within the ancient world itself. This brief lecture attempts to re-animate reflection on the nature of scientific transmission in ancient Greece and Rome.

In the context of this symposium it might be more useful to offer some brief preliminary reflections on five larger questions than to present one or two detailed case studies that would have illustrated more limited features of scientific transmission in antiquity: 1. What were the principal literary forms of scientific transmission in Greece and Rome? 2. What were the social and cultural contexts of transmission? 3. Who were the main agents of scientific transmission? In particular, did only individuals or also collectivities play a significant role? 4. What were the salient features of scientific transmission across linguistic and cultural boundaries? 5. What does scientific transmission in antiquity tell us about the nature and self-understanding of Greco-Roman science?

1. Literary forms of scientific transmission

Essential to an understanding of scientific transmission in antiquity is the question of the literary forms in which science circulated. Reflecting on the divergent forms in which scientific writers chose to present their science helps the modern reader to broach issues that are central to the history of transmission, such as the nature of the ancient audience(s) of science, the purposes of scientific writing in antiquity, and the relation between scientific investigation and its textual versions.

Paradoxical though it might seem at first glance, certain analogies between the transmission of science and the transmission of myth can illuminate important features of the relation between science, text, and literary form. Just as no Greek myth is co-extensive with any given Greek text, so too in the case of many extant Greek scientific theories, a given theory is not necessarily co-extensive with any Greek scientific text. Almost every Greek myth appears in a variety of ancient texts belonging to many different genres. The constraints imposed by the formal conventions and expectations of different literary genres, not to mention the divergent motives, interests, and strategies of different authors, led to well attested formal and thematic differences between different versions of the same myth. These competing textual versions of the same traditional tale sometimes disagree even in central respects. Yet we tend to speak, for example, of 'the myth of Pelops', as though we all know and can retell the same myth, although radically divergent versions of this myth are extant. Pindar's version of the myth, to mention only one, overtly departs from some of his predecessors' versions, of which he is sharply critical (*Olympian* 1.37-53).

Many an ancient scientific theory likewise appears in different texts using different literary forms. As in the case of the different retellings of a single myth, so different textual acts of transmitting the same scientific theory can display divergent emphases and far-reaching differences in detail. This is not a trivial point, because the non-identity of science and text—a point to which I shall return—represents a significant element of dynamic instability in the transmission of ancient science.

The ancient literary forms used to turn scientific investigations, theories, and practices into written, transmissible texts range from a rich variety of prose genres to epic, elegiac, and iambic poetry. In other words, to the extent that the scientific activities and achievements of the ancient Greeks and Romans were brought into written form, they did not lead to the establishment of one or two specific literary genres for scientific writing. I offer three brief examples of the transmission of the same scientific theories or data in several different literary forms.

(i) The atomistic physics of Epicurus was transmitted not only in a variety of ancient expository treatises written in Greek prose (by Epicurus, Philodemus, and others), but also in epistolary form (by Epicurus), in the dactylic hexameters of Latin epic poetry (Lucretius), in collections of aphoristic sayings, in doxographies, in commentaries, in inscriptions (Diogenes of Oenoanda), and so on.

(ii) Ancient Greek pharmacology, which has a remarkably rich and reasonably stable tradition from the Hellenistic period to late antiquity, is presented in comprehensive expository prose treatises (such as those of Dioscorides and Galen), in epistolary form (such as Scribonius Largus' *Compositiones*), and in a variety of verse forms, including iambic trimeter (Damocrates), elegiac couplets (Andromachus the Elder and Aglaias of Byzantium's poem on remedies for cataracts), and in epic hexameter (Nicander's *Theriaka* and *Alexipharmaka*, Marcellus of Side). Similar—and at times almost identical—compound drug prescriptions, usually including the precise quantities of each ingredient and of the dosages, thus appear not only in prose treatises that display divergent structures and different authorial strategies, but also in a variety of verse forms.

(iii) Astronomy and astrology likewise were transmitted in a variety of literary forms (astrology, of course, belongs to the history of ancient science: some of the more influential ancient astronomers, such as Ptolemy, presented their astrological works as the scientific application of astronomical data to the sublunary world). Among the forms are shorter prose introductions (e.g., Geminus' *Introduction* [*eisagoge*] *to Astronomy*), long systematic treatises written in expository prose (e.g., Ptolemy's *Mathematike Syntaxis*, better known as his *Almagest*), and numerous poems in Greek and Latin (e.g., Aratus' *Phainomena*, Manilius' *Astronomica*, Avienus' *Aratea phaenomena*, the *Apotelesmatika* attributed—probably erroneously—to the early Hellenistic Egyptian high priest Manetho, and the poem by Dorotheus of Sidon that later became so popular with Arabic astrologers).

The extant texts of some other branches of science also display a variety of literary forms, as do surviving papyrus fragments of scientific works. The papyri include not only school exercises in mathematics, astronomical data, and drug recipes, but also remnants of expository works and, strikingly, of poems on scientific subjects (for example, of poems on weights and measures, on fish, on Egyptian plants, and on medicinal plants).

Not only was a variety of metres used in didactic poetry devoted to scientific material, but in its formal development the 'genre'—which was not regarded as a distinct or separate genre by Greek and Roman literary theorists—also appears to have become more flexible and dynamic in certain respects at the time of the Roman empire. In particular, Greek didactic poets' uses of iambic trimeter display a new freedom and inventiveness, as in the pharmacological poetry of Damocrates. This flexibility rendered didactic poetry even more adaptable to the exigencies of highly technical scientific material than archaic verse had been.

Poetry thus played a significant role as a vehicle of scientific transmission. Each of the poems mentioned above attempts to convey and transfer to their audiences a body of highly specialized, carefully organized 'scientific' material or 'knowledge' that lays claim to the objective study of phenomena in the physical and/or biological universe. Many, though far from all, presented science produced by others, not by the poets themselves, and in that sense, too, they were transmitters. That these poets also wished to dazzle and please their audiences with their technical virtuosity, wit, and erudition goes without saying. And that some of these poets subordinated their renderings of science to a larger philosophical vision (for example, Aratus and Lucretius) or to a moral and political agenda (for example, Manilius) seems evident. But the attitude to such poems on the part of several of the more influential ancient 'working scientists'—i.e., scientists actively conducting and disseminating their own research—confirms that didactic poetry not only was a significant part of Greco-Roman literary culture, and did not just please and dazzle, but also was understood by some scientists themselves as a serious form of scientific transmission. I offer only two examples, one from astronomy, the other from medicine.

In the second century B.C. the astronomer Hipparchus transformed Greek astronomy from a theoretical science to a practical science, notably by applying to his predecessors' theoretical models numerical parameters derived from observational data. This made possible the accurate prediction of celestial positions for any given time. In recent years a persuasive case has been made that Hipparchus, in addition to being a mathematical genius, had access to the excellent, extensive observational records in Babylonian archives, and that his skill in combining the Greek and Babylonian traditions in astronomy was crucial to the propagation of European astronomy, in the form he gave it, for more than a thousand years. Yet the only surviving work of this brilliant astronomer is his commentary (in three books) on Aratus' didactic poem and on Aratus' fourth-century B.C. source, the mathematician and astronomer Eudoxus of Cnidus. Hipparchus offers updated observations, corrections, and criticisms, not only of Aratus' and Eudoxus' placings of the constellations and stars, but also of other ancient commentaries on Aratus' poem, notably of the commentary by the mathematician Attalus (apparently a contemporary of Hipparchus). In an epistolary preface to Aischrion, which serves as an introduction to the commentary, Hipparchus refers to several other commentaries that preceded his own (1.1.3: *alloi pleiones*) but were unsatisfactory, because they failed to recognize that some of Aratus' and Eudoxus' views were at odds with the *phainomena*.

Aratus' astronomical poem was a great success in antiquity and achieved a significant diffusion far beyond the relatively narrow circle of learned Hellenistic poets, as is also attested by its translations into Latin (see Part 4 below) and by the remarkably frequent quotations from it and allusions to it, both in literary and in scientific contexts. Aratus may not have been an original scientist, but his importance as an agent of scientific transmission (notably of Eudoxus' astronomy) is not in doubt. It is telling that a scientist as brilliant and influential as Hipparchus deemed Aratus' didactic poem worthy of a lengthy, if critical, commentary—and that Hipparchus was not the only Hellenistic scientist who wrote a commentary on the poem.

My second example is drawn from one of the most prolific and influential writers of the Greco-Roman world, Galen of Pergamum (ca. A.D. 129-216). In the more than 2,500 pages he devotes to his major pharmacological treatises, Galen repeatedly quotes—sometimes at length—not only from earlier treatises written in expository prose, but also from pharmacological poems, such as those by Damocrates and Andromachus the Elder. What does Galen, as a prose author who believes that medicine in all its parts is a completable, axiomatic science of the body and that scientists must continuously be attentive to the language they use, eschewing all figurative language and striving to use words only in their most common 'literal' sense, think of these poems? And, in particular, what does he think of the value of such poems as compared to the value of the wide variety of scientific prose treatises he quotes, excoriates, and praises?

Galen's criteria for evaluating earlier scientific works include not only their validity and their aptness for their intended audience (whether specialists or lay persons), but also their precision (*akríbeia*), clarity (*sapheneia*), and openness to memory (*mneme*). The latter constellation of concepts—precision, clarity, and memory—tend to dominate Galen's numerous comments on the literary genres most appropriate for scientific literature. In these contexts he remarks in Book V of his massive treatise *On the Composition of Drugs by Types*:

> "I have already often said that drug prescriptions *in verse form* are more useful than those written *in prose,* with a view not only to memory (*mneme*) but also to the accuracy (*akríbeia*) of the proportion in the mixture of the ingredients" (5.10; XIII. 820 K).

In Books I and VII of the same treatise Galen offers a similar justification for quoting extensively from Damocrates' pharmacological poem. And in his work *On Antidotes* he remarks:

> "The drug recipes written *in verse form* are the most useful with a view both to the accuracy (*akríbeia*) of the weights of the medicaments and to the memory (*mneme*) of them" (2.2. XIV. 115 K).

In these evaluative comments on poetry, a utilitarian, not an aesthetic, judgment prevails. This is also the case when Galen observes in *On Antidotes* that

> "Damocrates described the whole application [of his theriac antidote] with clarity (*sapheneia*). As is his custom, it has been *versified* and thus has the advantage not only that it is easy to retain in one's memory (*mneme*), but also that the proportions of the mixture cannot be falsified easily" (1. 15; XIV. 89 K).

The non-falsifiability of scientific data here is cited as a further advantage accruing from the rigid metrical demands of verse, which do not allow easy substitution of the specified quantities of drug ingredients. Like all ancient texts, a scientific text was susceptible to well-meaning, malicious or inadvertent intervention on the part of readers, copyists, commentators, and other transmitters, as Galen observes elsewhere. Neither literacy nor the seeming fixity entailed by the transformation of science into written texts can protect the integrity of a scientific theory or data. Not even when deposited in a library is a text transmitting science immune to tampering. Indeed, Galen reports cases of unscrupulous readers borrowing books from libraries and changing the quantities of the drug ingredients. To escape detection, he says, such forgers used the same kind of ink as in the original.

Poetic metres not only can shield a scientific text from deliberate falsification; at times, Galen suggests, verse also offers better protection against inadvertent errors in the process of transmission:

> "Since things transmitted in verse not only endure well in one's memory (*mneme*), but also have the advantage of being free of error (*anhamarteton*), it seemed better to me also to quote the verses of Damocrates at this point ..." [i. e., in addition to the prose account Galen himself has just offered] (*On Antidotes* 2.15; XIV. 191 K).

Once again, Galen has in mind not only the importance of precise quantification in science and the difficulty of remembering a sizable amount of quantitative data, but also the relative ease with which a wrong number can slip into a scientific text in the course of its transmission and dissemination. In the case of drug dosages, such a mistake could, of course, cost a patient his or her life.

Not all poems transmitting the same scientific content have equal value in Galen's view. The scientific validity of the transmitted material, the realization of the ideals of clarity and precision, and the ease with which such a poem can be memorized are among the criteria that led Galen to express a strong preference, for example, for Damocrates' poetry over Andromachus'. The latter's pharmacological poetry, he argues, fails the test of clarity (*sapheneia*).

At first glance Galen's explicit valorization of poetry as a superior vehicle of clarity, accuracy, and precision might be surprising, also in view of Galen's extensively developed theory of the language best suited to scientific communication—a 'literal' language which avoids the figurative strategies of poetic language, as he argues with misguided optimism in several works. But, like some of the Hellenistic commentaries on Aratus' astronomical poem, Galen's extensive quotations from, and comments on, pharmacological poems confirm that the literary forms which we nowadays lump together under the rubric 'didactic poetry' were not only highly esteemed in literary circles but also taken seriously by some members of the scientific community. Indeed, as we have seen, in certain cases scientists even held poetry to be superior to prose as a mode of scientific transmission. And when, like Hipparchus, they were critical of a‘ scientific’ poem on grounds of errors in its scientific contents, they still deemed it worthy of elaborate explication and correction.

The majority of ancient Greek and Latin scientific works were, however, composed in prose, and prose works too display a great heterogeneity of literary forms. These include, for example, comprehensive expository works, brief handbooks for beginners, letters, synopses, doxographies, encyclopaedias, compact aphoristic collections, illustrated works, and commentaries (which often contained original scientific theories, for example Hipparchus' commentaries on Aratus, Galen's on Hippocratic treatises, and Simplicius' on Aristotle's *Physics*). To these forms one could add comprehensive compilations, such as the *Synagoge* attributed to Pappus: a compilation of eight originally separate treatises and commentaries on different branches of the mathematical sciences (but when this compilation was made, and by whom, remains controversial).

Many of these prose forms display their own structural and rhetorical conventions. Furthermore, as in the case of poetry, the individual prose genres display a dynamic instability, rather than a static fixity. They often transform or violate inherited conventions of their own ‘ genre’. Moreover, they tolerate what literary critics know as‘ generic contamination’, i.e., the overt or covert mixing of more than one genre in a single work. I offer two brief examples.

Letters which observe many conventions of ancient literary epistolography often appear in systematic expository treatments of highly technical scientific material. Especially when addressed to fellow-scientists, these epistles sometimes contain personal reminiscences about the recipient or about mutual acquaintances who were also scientists. Unlike formal prefaces addressed to kings or rulers by ancient scientists (for example, Archimedes' *Sand-Reckoner*, addressed to King Gela of Syracuse, or Apollonius of Citium's *Commentary on Hippocrates' On Joints*, addressed to the Ptolemaic ruler of Egypt), these letters offer autobiographical details of a more personal nature. Most of Archimedes' extant works, six of the seven books of Apollonius of Perge's *Conics*, and Hipparchus' *Commentary on the Phainomena of Aratus and Eudoxus* are examples of systematic expositions that are joined to such‘ personal’ letters to fellow-scientists (see below, Part 2).

Very different examples of a‘ contamination’ of literary forms occur in some of Galen's works. His lengthy treatise *On the Composition of Drugs According to Places*, for example, is presented as systematic exposition (*pragmateia* or *hypomnema*), but the systematic exposition is repeatedly suspended while other‘ genres’ take centre-stage. Among the other literary forms accommodated during the suspensions of the expository form are, for example,‘ catalogue’ literature, autobiographical mini-narratives (for which he uses the term *diegesis*), lengthy quotations of didactic poetry, and an extensive exegesis of such quotations from poetry.

Any history of transmission that ignores this multiplicity of often elastic and unstable forms of transmission is likely to overlook a crucial feature of the remarkably rich, energetic, and multi-leveled nature of scientific transmission within ancient Greece and Rome.

2. Some social and cultural contexts of scientific transmission

As in subsequent eras and in other cultures, acts of scientific transmission in Greece and Rome obviously were not confined to written works. In Greek and Latin scientific works there are ample, though often tantalizingly fleeting, references to transmission through oral instruction, scientific debates, public competitions (for example, in surgery), *symposia*, visual demonstrations, public declamations (*epideíxeis*), and the public and private performance of experiments and investigations. At times these non-written forms of transmission served as vehicles not only of the transmission of the author's own theories and data but also of the transmission — critical or uncritical — of the scientific theories of others.

Some of these non-textual forms of transmission serve as a further useful reminder of a point that already emerged in our consideration of literary form, namely that ancient science is not co-extensive with ancient scientific texts. Greek science included a wide range of observational, investigative, social, and cultural practices, some conducted in public and others in private, and some oral but others represented through written language or diagrams or illustrations. At times some of these activities converged. In geometry, for example, a visual demonstration sometimes was immediately afterwards reported in written form, often with implicit or explicit references to the exercise in visualization that preceded the text. But the visual transmission of science was not confined to geometry or to illustration in texts. It also occurred through public performances of science. I offer only one particularly well attested example from the second century of our era.

Among ancient Greeks who understood themselves to be doing and transmitting science, Galen is, as indicated above, by far the best attested author, and we are therefore exceptionally well informed about his practices. We likewise have ample evidence of the scientific self-understanding he wishes to project, thanks to his more than 120 extant works. Overtly acknowledging that numerous predecessors, including Plato, Hippocrates, Aristotle, Theophrastus, Herophilus, Heraclides of Tarentum, Marinus, and other biologists, anatomists, philosophers, and physicians, had made contributions to science, Galen energetically interacted in his own texts with the works of earlier scientists and, in some cases, of contemporaries. The theories and practices of precursors with whom he strongly disagreed are eagerly included in these interactions: for example, Erasistratus of Ceos, the Methodist Thessalus, and the Stoic philosophers Chrysippus and Posidonius. He quoted earlier writers, often at great length, he wrote commentaries on their works (including one on Plato's Timaeus and extensive extant commentaries on thirteen Hippocratic works), and he repeatedly reported, disputed, censured, and praised their theories and practices. Galen thus became responsible for transmitting more biological theories, more medical theories and practices, and more detailed accounts of theories of scientific method (especially those belonging to the period between Aristotle and the second century A.D.) than any other surviving ancient source.

Galen did not, however, transmit this invaluable knowledge only through his writings. To contemporaries he also transmitted it through public and private instruction, public orations, participation in debates, the conduct of experiments in public, and public and private dissections and vivisections of animals. The animals he dissected ranged from mice, birds, and snakes to pigs, goats, oxen, horses, donkeys, monkeys, apes, and elephants.

Galen characterized these public dissections and vivisections as' exhibitions' or' display pieces' (*epideíxeis*, i. e., the word also used of' declamations') presented to large crowds. In other words, he understood them to be not only the public performance and transmission of science, but also rhetorical exercises that aimed at scientific persuasion. Conducted in large auditoria, his anatomical exhibitions had both a visual-performative and a verbal dimension, inasmuch as he delivered a running commentary during each of his anatomical performances. In his oral commentaries Galen often pointed out in what respects his dissections and vivisections confirmed or refuted the anatomical views of precursors. The public performances therefore transmitted not only his own science but also the science of others (more on this below).

The audience absorbing the visually and verbally transmitted information was not always passive: sometimes boisterous, it responded with a mixture of cheers and jeers, of admiring applause and heckling. At times the scientist invited other experts in the audience, i.e., his rivals, to participate in vivisecting apes, only to unveil their ignorance or inferior skill. Those in attendance included not only fellow-scientists and fellow-physicians but also students, masses of ordinary citizens, and a generous sprinkling of the political and intellectual élite, including members of the Roman senatorial class and leading philosophers.

Critical interruptions by skeptical members of his audience sometimes so irritated Galen that he withdrew from the auditorium in a huff. The partly agonal relation between the publicly performing scientist and his audience belongs to a long Greek tradition of contestation in public spaces. The pervasively competitive nature of Greek culture is well attested, and in many spheres the Greek public performer and transmitter of science could expect not only applause but also sharply polemical public responses.

The public display and transmission of science, no less than other public performances, was not only a cognitive but also an affective experience for the audience. Galen was in no doubt about the affects at which he aimed in his public dissections and vivisections: visual astonishment, amazement, a state of marveling and being stunned. The members of the scientist's audience were simultaneously spectators at an astounding visual exhibition and listeners to an astonishing verbal interpretation of a skillful performance, at least if the scientist achieved his goal. The scientific performer, like many ancient orators, thus relied on mutually reinforcing visual, auditory, and affective elements to attain persuasion, while transmitting his science and, even if critically and very polemically, the science of his predecessors.

Public performances of science stood in a close relation to written texts. At times anatomical performances served, for example, to verify controversial claims made in written works previously composed by the performer, particularly when such claims, after their written diffusion, had been challenged by rivals. In these contexts, the works of other anatomists often played a central role. This confirms once again that scientific rivals participated in the process of transmitting one another's works. Galen records an example in his remarkable autobibliographical treatise *On My Own Books*:

> "And when I came forward to display (*epideixon*) myself as having committed no falsehood in my anatomical treatises, *I set up in the middle the books of all the anatomists*, thereby giving each of those present the means to propose whatever part he wished to be dissected. At the same time I announced that I would show [through a public dissection] that all the things that disagreed with my predecessors *had been recorded correctly by me*" (2; XIX.22 K).

At other times a scientist would compose "memoirs" or "memoranda" (*hypomnemata*) which recorded what had been displayed and said by him during his public performances. In *On My Own Books* Galen remarks, for example:

> "Compelled, then, by my friends [to dissect in public], and having shown [through dissections and vivisections] in public (*demosiai*) over many days that I had not committed a falsehood in any respect, whereas my predecessors had been ignorant of many things, I subsequently at the urging of my friends wrote memoranda of what had both been shown and said by me" (2; XIX. 22 K).

This topos of the' reluctant author', compelled by others to write, recurs frequently in Greek scientific writers, and it seems to confirm that they thought of (or at least deemed it important to imply that they thought of) other forms of doing and transmitting science as no less important than writing scientific texts.

Written texts, however, remained of cardinal importance to transmission. The ancient evidence suggests that there were active scientific' communities of readers'. Contemporaries exchanged their new works over considerable distances; they offered one another comments on their works; they asked one another to help diffuse their most recent treatises, and so on. Invaluable evidence of such synchronic' communities of readers' is preserved in the above-mentioned (Part 1) epistolary prefaces to Hellenistic mathematical and astronomical works. Archimedes, for example, appears to have had a lively exchange with the Alexandrian mathematicians Conon, Dositheus, and Eratosthenes, among others. Both books of Archimedes' *On the Sphere and the Cylinder* open with a letter addressed (from Syracuse) to Dositheus in Alexandria, as do Archimedes' *On Conoids and Spheroids, On Spirals*, and *Quadrature of the Parabola* (which grieves over the death of Conon). His *Method of Mechanical Theorems* opens with a letter to Eratosthenes. These prefatory letters include repeated references to works by the Alexandrian and other mathematicians.

The Hellenistic mathematician Apollonius of Perge similarly addresses Books 1 and 2 of his famous *Conics* to Eudemus (perhaps the historian of mathematics and Aristotelian from Rhodes?). In the epistolary preface to Book 2 Apollonius requests Eudemus, who was residing in Pergamum at the time, to share the work with the geometer Philonides (who became a famous Epicurean philosopher and whom Apollonius had commended to Eudemus in Ephesus), should Philonides come to Pergamum, and with other interested mathematicians. In the letter with which Book 1 opens, Apollonius also refers to a lecture by the geometer Naucrates which he had heard in Alexandria. The epistolary preface to Book IV of the *Conics*, addressed to Attalus (possibly the mathematician from Rhodes), laments Eudemus' death and refers critically both to a work by Conon and to Nicoteles of Cyrene's book criticizing Conon (books 5－7 are likewise addressed to Attalus, but they do not offer further evidence of a' community of readers'). Other evidence also suggests that scientists had lively contact with one another and that they and their works enjoyed a lively circulation within scientific' communities of readers'.

Composing and exchanging scientific texts of an enormous literary variety, performing in public, and providing oral instruction at many levels, in larger and smaller settings, thus were among the many complementary ways of transmitting scientific theories and observations, both one's own and those of precursors. Furthermore, visual and affective elements, oral and written communication, private and public spaces, individuals and groups, experts and lay persons, the intellectual and political élite, and more re-active as well as more passive audiences of varying sizes, ages, and socio-economic make-up, all belonged to the social and cultural contexts of transmission.

3. Agents of scientific transmission. Individuals and collectivities.

I have alluded to the role of several individual ancient scientists (for example, Archimedes, Hipparchus, Apollonius of Perge, Conon, Dositheus, Philonides, Herophilus, Erasistratus, Galen) as well as Greek and Roman non-scientists (e. g., individual encyclopaedists, doxographers, philologists, and poets) in the transmission of science. In non-scientific texts—for example in legal texts of the Roman empire—there are also references to professional teachers of various sciences, especially sciences that have practical applications. Numerous professional transmitters remain anonymous and largely invisible to us. They include the many low-level astrologers, who made a living by practising 'applied astronomy' but were paid less for their services than more famous astrologers; teachers of medicine who do not become visible in the texts composed by a literary élite to which we owe almost all of the vast body of extant medical literature from the ancient world; teachers of arithmetic and geometry at less than the highest levels; professional teachers of applied mathematics (for example, geodesy and land-surveying), and so on.

Individuals were, however, not the only agents of scientific transmission. Collectivities also became agents of transmission, particularly in the context of 'schools' (*hairéseis, sectae*) of scientific thought. Characteristic of the Hellenistic epoch are not only fierce debates between rival 'schools' committed to different scientific methods, epistemologies, scientific theories, and medical practices, but also extensive exegetical work within such 'schools'—and not only on treatises by their founders. The astronomer Hipparchus (2nd century B.C.) was not the first Hellenistic scientist to write a commentary on a precursor's work, and the fifth-century A.D. *Commentary on the First Book of Euclid Elements* by the Neoplatonist Proclus was not the last ancient exegesis of a scientific work. Both before and after, as in the intervening centuries, scores of other such exegetical works were written, many of them driven by disputes between scientific collectivities, each of which understood itself—and was perceived by others— to have a clear doctrinal and methodological identity.

I offer only one example, from a relatively early period. In the third century B.C., Herophilus, the revolutionary pioneer of systematic human dissection and of vivisectory experiments on criminals, appears to have initiated a remarkably rich exegetical tradition that lasted until the end of antiquity and beyond, namely writing commentaries on texts attributed to Hippocrates. As is well known, in the first part of the third century B.C. the Ptolemies actively acquired literary, historiographic, philosophical, and scientific texts, including—this is unequivocally attested by ancient sources—Hippocratic texts, for the famous Royal Library of Alexandria. The existence of this extraordinary library undoubtedly contributed to the broad range of commentaries on Hippocratic treatises and of Hippocratic lexica produced in Hellenistic Alexandria. The two Alexandrian 'schools' that became most famous for such exegetical efforts were arch-rivals: the 'school' of Herophilus and the 'school' of the Empiricists (*hoi empeirikoí* who gave themselves this collective label). On methodological, epistemological, and clinical grounds the Empiricists rejected the cornerstone of the Herophileans' scientific medicine, i.e., they rejected anatomy and physiology based on systematic human dissection. Dissection and vivisection, the Empiricists argued, yielded unreliable scientific results and were methodologically vulnerable. Furthermore, they added, human vivisection is morally indefensible. As for physiology, they believed that it is epistemologically suspect and clinically irrelevant. In this protracted battle, which lasted almost three centuries, both the Herophileans and the Empiricists invoked Hippocrates, and both 'schools' tried to buttress the legitimacy of their respective positions by writing extensive commentaries on Hippocratic works.

In the third century B.C., for example, the Herophilean Bacchius of Tanagra wrote commentaries on the Hippocratic works *Aphorisms, Epidemics VI*, and *In the Surgery*, as well as a famous Hippocratic lexicon. The founder of the Empiricist school, Philinos of Cos, quickly responded by writing a polemical work against Bacchius' Hippocratic lexicon. The early Empiricist Zeuxis (ca. 275 -200 B.C.) also joined the exegetical fray with a commentary on *Epidemics VI*. In the second century B.C. the Herophilean Zeno wrote a commentary on Epidemics III, which was soon attacked in counter-commentaries by two Empiricists, Apollonius the Elder and Apollonius Biblas. The Empiricist Glaucias of Tarentum (2nd century B.C.) weighed in with a famous commentary on *Epidemics VI*. In the first century B.C. the exegetical agon continued. On the Herophilean side, Dioscurides Phacas (a prominent counselor and ambassador of Cleopatra and of other Ptolemies) and Heraclides of Erythrae carried the torch. Among the Empiricists, Apollonius of Citium contributed a commentary—still extant—on the Hippocratic treatise *On Joints* (in which he reiterates the Empiricists' rejection of anatomy as a foundation of scientific medicine and attacks some Herophileans by name). Other first-century B. C. Empiricists also wrote several commentaries (Heraclides of Tarentum, for example, on *Aphorisms, Epidemics II, Epidemics III, and Epidemics VI*, and Lycus of Naples on other works).

To the extent that the fragmentary evidence permits a generalization, the purpose of these exegetical exercises was not only to elucidate and transmit the theories and practices of 'Hippocrates', but also to appropriate or expropriate 'Hippocrates' as the true founder of one's own 'school'. This in turn had a profound effect on the subsequent reception and transmission of the original texts: once expropriated as foundational texts of one's own 'school', the originals continued to be transmitted as part of the 'school' tradition. They were used in instruction, explicated and discussed orally, and expropriated in written commentaries. The author of each commentary was an individual, but the doctrinal collectivity to which each commentator belonged was a significant dimension of the exegetical dynamic that produced so many Hellenistic commentaries.

It is important to keep in mind that each commentary tended to include the entire text which it interpreted. The original text was often broken up into lemmata (usually of paragraph length) and included in the text. On each lemma the commentator wrote longer (up to twenty or more pages) or shorter comments. Many, but not all, commentaries thus participated directly in the transmission of the entire original text itself. Indeed, they often offer valuable evidence of manuscript variants; some ancient commentators on scientific texts also discussed the relative merits of textual variants they encountered in different copies of the original. Equally significantly, a cumulative consequence of the commentaries produced within distinctive scientific 'schools' over several centuries was the transmission of, in part, rival versions of the original text. This too confirms the fluidity and instability of scientific texts in the ancient world, not to mention their susceptibility to divergent interpretive traditions that shaped their transmission.

4. Scientific transmission across linguistic and cultural boundaries

Over the last century many valuable contributions have emphasized the importance of Mesopotamian and Egyptian science for the development of certain features of Greek science. As indicated above, in the case of astronomy, for example, the use of Babylonian data in the Hellenistic era contributed to significant and lasting changes in Greek astronomy. In other cases it remains controversial, first, how extensive the affinities between early Greek and non-Greek science are and, secondly, whether any given affinity may be interpreted as 'influence' or 'exchange' or independent developments in different geographic and cultural entities, etc. Affinities are, after all, susceptible to a considerable variety of explanations. But in the case of the transmission of science from Greece to Rome, and from Greek into Latin, we often appear to be on firmer ground. I have referred, for example, to the many translations of Aratus' *Phainomena* into Latin (by Cicero, Germanicus, Avienus, Ovid, and, P. Terentius Varro Atacinus) and to Lucretius' transportation of atomism into Latin hexameter. There are numerous further examples, but I restrict my remarks to a few general observations.

The transmission of Greek scientific knowledge to Rome, and into the Latin language, occurred in many literary forms and was prompted by a variety of motives. Frequently noticeable in these acts of transmission are moments marked by a distinctively Roman sensibility and a distinctive Roman voice (for example, in the uses of Greek scientific material by Cato the Elder, Cicero, Varro, Lucretius, Manilius, Aulus Cornelius Celsus, Scribonius Largus, and Pliny the Elder). In such instances, the crossings of cultural and linguistic boundaries are not only productive moments in the transmission and reshaping of Greek scientific knowledge, but often also moments marked by Roman resistance, ambivalence, and even rejection of the transmitted material. Although they transmit Greek scientific material on a significant scale, Roman authors such as Cato the Elder, Celsus, and Pliny the Elder fault the Greeks on moral and other grounds. Appropriation across cultural boundaries notoriously entails expropriation and misappropriation. And overt Roman resistance to Greek scientific culture often veils a domesticating reception and absorption of the alien by the Romans. Furthermore, within the same culture, different authorial prisms frequently refract the reception of the same scientific traditions or texts in sharply divergent ways. Such patterns become visible in the long history of the Roman reception and transmission of Greek science too.

Roman writers who transmit Greek science sometimes complain about the relative poverty of the Latin language compared to Greek, and about the resulting difficulty of rendering Greek science in Latin. Lucretius offers perhaps the best known example of this lament: ...*nec nostra dicere lingua / concedit nobis patrii sermonis egestas*... (1.831-832; see also 1.136-139, 3.258-260). A number of other Latin writers echo this view, for example Aulus Cornelius Celsus (4.7.1; 5.26.31B; 6.18.1; 7.18.3; 7.18.7) and Quintilian (*Institutio Oratoria* 12.10.34). These Roman self-perceptions seem to be borne out by the fact that, from the time of the Roman Republic to the late Empire, Latin scientific texts contain a much higher percentage of loan words and calques (mostly derived from Greek) than do Greek scientific texts. Such foreign words continually reminded Roman readers that they were reading un-Roman material, and that Roman authors were participating in the Greek scientific conquest of Rome, despite their explicit and implicit acts of cultural resistance.

A further complaint by Latin scientific writers was that they were constrained by Roman aesthetic and moral sensibilities that made the free, unrestricted use of certain Latin words difficult, even impossible. They suggest that the Greeks, by contrast, suffered under no such constraints. A striking example occurs in Celsus' account of the anatomy and pathology of the genitalia. Here he attributes the difficulty of his task to the fact that the Latin words which he is compelled to use give offense to the Romans (*apud nos foediora uerba*, 6.18.1), whereas Greek scientific authors can deploy the corresponding Greek words freely without giving any social, moral or aesthetic offense.

If Greek scientists often depict themselves as reluctant authors, compelled by friends or adversaries to write, Roman writers transmitting Greek science at times depict themselves as facing a daunting linguistic and cultural task: they confront the liminal perils entailed by crossing the boundaries between Greece and Rome, between Greek and Latin. They nevertheless developed an efficacious technical language—or rather, several sets of technical languages—that allowed them to assume an influential role in the transmission of Greek science, both in antiquity and in subsequent epochs. Essential to understanding this important chapter in the history of scientific transmission is, however, also the tenacious strain of Roman ambivalence, hesitation, and plaintiveness that accompanied the Greek conquest of which Latin authors were, in part, prolific agents. Sometimes articulated more aggressively (e. g., by Pliny the Elder), at other times finding more moderate and subtle modulations (e. g., in Celsus' *Artes*), this ambivalence is a recurrent feature of the many interactive factors—social, linguistic, ideological, moral, and aesthetic—that shaped the complex dynamics of the reception, transformation, and transmission of Greek science by the Romans.

5. Scientific transmission and the nature of ancient Greek science.

The modern scientist who turns to ancient scientific texts sometimes is startled by the extent to which the Greeks and Romans quoted and interacted with scientific precursors who often pre-date them by centuries. If being an original scientist means being a pioneer and an author of new discoveries, new observations, and innovative theories, why do so many ancient Greek scientists, unlike their modern counterparts, spend so much time transmitting the views of their oft distant predecessors? An adequate answer cannot be developed in the brief space available here. It would have to include divergent, even contradictory explanations, since the answer would not be the same for every ancient scientific writer. In closing I nevertheless offer four brief gestures toward some of the possible answers.

First, unlike modern scientists, most ancient Greek scientists seem to have thought that being a good scientist entails, *inter alia*, also being a good historian of science. A critical mastery of the theories, methods, and practices of earlier authorities was deemed a necessary condition for establishing one's own scientific identity, authority, and innovativeness.

Second, and closely related, precursors often were selectively invoked to demonstrate that renowned earlier authorities were in agreement with one's own views. Despite the rhetoric of innovation and discovery that is characteristic of much of ancient scientific writing, a selective deployment of the sanction of past authorities at times was a central stratagem in most Greek scientists' quest for legitimacy. It is hardly surprising that this cultural habit was, however, often also marked by manipulative misappropriations of predecessors' scientific work.

Third, some ancient scientists were keenly aware that numerous ambushes for the scientist lurk in the language he or she uses. Turning science into texts entails using language, and language in turn is characterized by syntactic and semantic ambiguity, by polysemy, and by the many indeterminacies inherent in the inevitably figurative use of language by scientists. Tracing the history of the terms used in scientific propositions therefore sometimes became a basis for trying to achieve the univocal use of the terms required by true propositions. In these contexts, too, quoting scientific precursors in order to scrutinize their language became a step in the development of a language apt for one's own science.

Finally, the deeply rooted Greek habit of competitiveness to which I alluded earlier also manifested itself as a competition with revered figures from the past. This agon with history, this competition with, and emulative overcoming of, scientific giants from the past, becomes a further important motor of scientific transmission in antiquity. Among its consequences is a dense texture of agonal intertextuality in many ancient scientific writings — a complex intertextual tension that frequently accompanies the remarkable wealth of quotations, detailed paraphrases, careless as well as meticulous analyses, and highly polemical refutations of predecessors' works.

Cumulatively, these diverse yet not unrelated factors suggest that scientific transmission was understood by at least some ancient Greek scientists to belong to the nature of science itself. From the ancient scientist's self-understanding as both pioneering discoverer and historian of science, from his tendency both to test new frontiers of scientific understanding and to look over his shoulder at yesterday's shadows, to look forward aggressively while constantly looking back, arose an extraordinary benefit that has still not been appreciated adequately: a remarkably rich treasure-house of information about Greek scientists whose works are no longer extant. In both trustworthy and suspect refractions, their theories and practices were remembered, emulated, and criticized by other ancient scientists whose works have survived. Were transmission of past science not viewed as an essential feature of the nature of science itself, were it not for the resulting rich texture of the transmission of science within antiquity itself, and were it not for the active participation of original scientists in multiple literary and non-literary processes of remembering and transmitting the scientific past, our loss —which is immense— would have been even greater, and our understanding of Greco-Roman culture even more fragmentary.[1]

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1 The lecture format has been preserved, i.e., the lecture presented at the symposium in Kyoto here is printed with only minor modifications. It is a pleasure to express my warmest gratitude to Professor Elizabeth Craik, to the organizers of the symposium, and, above all, to Professor Tetsuo Nakatsukasa for their kind invitation and for the extraordinary graciousness and attentiveness I experienced during my visit to Kyoto.