Re-Inventions: Essays on Hellenistic and Early Roman Science edited by Philippa Lang

Apeiron 37.4. Kelowna, BC: Academic Printing and Publishing, 2004. Pp. vi + 153. ISBN 0–920890–89–9. Paper $22.95

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In October 2003, Emory University (Atlanta, Georgia) hosted a conference organized by the editor of the present volume, Philippa Lang: 'Reinventions: Hellenistic and Early Roman Science' (http://www.classics.emory.edu/events/reinventions.htm). The conference, which I attended as an audience member, provided the opportunity—too rare in the United States—for the gathering of scholars working on the history of ancient science. This conference was of particular value, as it encouraged research in a rather under-studied period that was crucial in preserving older knowledge and in formulating new. Thus, it was in this period that the ancient sciences and philosophy—and their many subfields and sects—re-defined and re-invented themselves in relation to one another and to the authoritative figures and practices of the past. Three of the five essays of the present volume were given at the conference, and two are new contributions by conference speakers.

Sir Geoffrey Lloyd gave the keynote address, which is the first essay of the volume: 'New Issues in the History of Science' [9–27]. As many readers of *Aestimatio* will know, for more than a decade Lloyd has devoted himself to the study of Chinese and of Chinese science. Here he calls for a 'genuinely comparative' and 'ecumenical' approach to the history of science that is alert to the differences in the development of scientific traditions in different cultures. It is only by this means, Lloyd contends, that scholars can test their accounts of how and why science developed as it did in their 'home' culture, and avoid the temptation to view such developments as inevitable.

ISSN 1549–4497 (online) ISSN 1549–4470 (print) ISSN 1549–4489 (CD-ROM)
Aestimatio 3 (2006) 76–89

But what is science, anyway? It is hard to define even in the modern world. As Lloyd points out, the 'hypothetico-deductive experimental method taught in schools' rarely plays a part in how scientists carry out their work [11]. For instance, it may be a tenet of the scientific method that results should be reproducible, but such verification is seldom conducted, as journals will not generally publish negative results, and scientists cannot afford to devote time producing what is unlikely to be published. Nevertheless, the potential of a given discipline to conform to the ideal of the scientific method plays a role in how scientific it is considered to be. Thus, psychology is frequently not considered a science (or not a 'hard'—i.e., quantifiable—science), nor is medicine; in fact, I once overheard a chemist remark that biology was 'not really a science'.

So, if even the scientists among us are not practicing science as they themselves have conceived of it, how are we to define 'science' with respect to the theories and practices of ancient cultures? Which of their enterprises—if any—are we to call 'scientific'? And are we condemned to committing the cardinal scholarly sins of positivism and anachronism if we do? Moreover, if we are to be alive to the differences in approaches, methods, and goals of such enterprises in different traditions, can we legitimately call all of them 'science'? And, if they are so very different, are they still commensurable? Does genuine ecumenicalism preclude comparison?

Lloyd addresses these broad and fundamental questions at the outset, though necessarily briefly [9–12], before narrowing his focus to the studies of mathematics, astronomy, and harmonics in the Chinese and Greek traditions [12–24]. He agrees with the strictest and most modern conception of science that the data of the phenomenal world are the object of scientific study, but notes that the phenomena are always multidimensional; by implication, then, the purposes of their systematic study can vary and still be scientific. Provided that we avoid measuring early science by a modern yardstick, as was notoriously done in the early years of the history of science, we will remain untainted by teleology and anachronism. As for commensurability, Lloyd argues that there is sufficient common ground in divergent traditions for fruitful comparison. An eclipse is still an eclipse, even if the styles of inquiry concerning it vary.

Lloyd turns first to mathematics where, as he says, 'our expectations of cross-cultural uniformity are at their highest. Two and two make four wherever in the world you are and at whatever period in time' [12]. Nevertheless, Chinese and Greek mathematics developed very differently. In direct contrast to their Greek counterparts, Chinese mathematicians had no interest in axiomatization, and so they have been dismissed as being concerned with mere practicalities [14]. Lloyd disputes this conclusion, though he agrees with the premise: Chinese mathematicians may be 'innocent of any drive towards axiomatization' [14], but inquiry into abstract mathematical questions is not absent [14–15], nor are attempts to systematize, though this is done on an analogical—not deductive—basis that establishes conceptual links between categories of problem [15].

Lloyd then steps back to provide the broader conceptual frameworks in which mathematical studies developed in China and in Greece. Chinese cosmology centers on the processes of change called the five phases [16–17]. The Chinese focus not on the essential natures of the substances associated with each phase (fire, earth, metal, water, and wood), as those of us imbued in early Greek philosophy would expect, but on what brings about the destruction and generation of each phase (in fact, the five 'substances' are viewed as processes: e.g., fire is 'burning upwards,' water is 'soaking downwards') [16–17]. Moreover, the assumed conflict between the intelligible and the perceptible that is at the heart of so much Greek philosophy and science—and which generated so much of the heat in the sectarian conflicts of the Hellenistic period and later—appears to be absent in Chinese intellectual traditions, where the senses play a positive role in furthering knowledge. There is no unchanging hidden or higher truth that can be apprehended by reason alone. As Lloyd says, '[T]he Dao may be hard to fathom, but it is not located on the far side of an epistemological or metaphysical gulf' [17–18]. As a result, the Chinese are free to use mathematics to investigate cosmological questions [17]; in fact, in one source, the studies of the heavens and of the five-phase theory are considered to be sub-categories of 'numbers and methods' [17]. In the Greek tradition, however, the place of mathematics in speculations about 'the nature of nature' (*φυσική*) is contested: is mathematics, being abstract, closer to the objects of reason (in Plato, 'mathematical intermediaries' are midway between the perceptible world and the Forms), or is it properly the study of the mathematical properties of physical objects, as in Aristotle [17]?

Can mathematics aid in the apprehension of true knowledge, or not? These would not, it seems, have been sensible questions in China.

Lloyd's next *comparanda* are astronomy and astrology, where China and Greece appear to share a great deal, with scientists in both traditions observing the skies to record the periodicities of planetary movements, and the courses and eclipses of the Sun and Moon [18]. But, Lloyd cautions, the purposes to which the observations were put are strikingly different: the Chinese wished to predict such phenomena as eclipses; the Greeks, to explain them [19]. The Greeks developed planetary models that were used first to reduce apparent irregularities to regularities, and only later for prediction [19], with teleologists claiming that they revealed the order of the universe [19]. The Chinese, despite their focus on prediction, did not have an interest in teleology [20].

Harmonic science, too, provides common ground, with both traditions concerned to express the main concords as ratios between simple numbers [20]. But in Greece, competing theories obtained in harmonics as in so many other intellectual and artistic pursuits. And, as elsewhere, the assumed dichotomy between reason and perception was the basis of the dispute. As the opposing methodologies were acknowledged to be incompatible with one another, analysis could not be undertaken until decisions on certain methodological questions had been made [20–21]. Chinese theorists reveal no such overriding concern with methodological or epistemological purity; in fact, they apparently had no compunction about rounding off to make their analyses work in the case of very complex ratios [21].

In sum, science should be defined, in Lloyd's view, fundamentally by its aims, not by its methods. Those who seek to understand, predict, and explain the phenomenal world are scientists and, by this definition, we can see some ties between very ancient and the most modern science [22]. If there is no single method that is 'science', and if the objects of scientific study are multidimensional in their meaning, there is no inevitable course for science to take, though judgments can be made about success [24]. Lloyd is calling upon historians and philosophers of science to set aside explanations that rely upon inevitability as an *a priori* assumption, and to take up instead the question of 'why the investigations that were undertaken took the form they did in different ancient societies' [21]. It is only by working comparatively, Lloyd argues, that scholars can test 'which features of which types of inquiry can be correlated with what other aspects of the intellectual, cultural and political situation in which the investigators worked' [22]. Greek scientists and philosophers, for instance, developed their views in a highly competitive marketplace of ideas, while their Chinese counterparts were concerned to persuade powerful rulers of the right course of action [21–22]. The former context, Lloyd and Sivin have suggested, may have fostered an interest in foundations, theories of knowledge, and a proclivity for axiomatic-deductive demonstration; the latter, by contrast, would have required discretion and persuasion [21–22].

Lloyd is perfectly correct, in my view, to warn scholars away from unwarranted *a priori* assumptions, and to urge us to rethink certain basic definitions and questions. I am also persuaded that to do the sort of comparative work that Lloyd proposes has the potential of being fruitful in the ways that he suggests (and probably in other ways, as well). I do not see, however, that the examples that he has provided make his case for such fruitfulness. As fascinating as it is, for instance, to gain a nodding acquaintance with Chinese mathematics, astronomy, and harmonics, and the intellectual and cultural contexts in which they developed, I do not see that any specific hypotheses concerning the development of those same disciplines in Greece have been strengthened or disproved. Moreover, the very vigor of Greek intellectual debate makes challenging specific hypotheses on a comparative basis difficult. Chinese scientists may have been fortunate to develop in a tradition in which empirical evidence was not thought to war with reason; but Greek scientists of course had an empiricist tradition, too. The Platonic eclipse was not a total one. Lloyd in fact points to the Greek propensity for debate and, indeed, for the utter refutation of opposing views, and contrasts it with the greater decorousness of Chinese scientific rhetoric, for which he suggests state control of Chinese science may have been responsible. But Greek science followed its course first under oligarchy, then democracy, and then imperial rule; and the vigor of intellectual debate does not seem to have waxed and waned in any predictable way with these phases. How, then, does the Chinese situation elucidate the Greek? It seems to me that we learn that Chinese rulers were more acutely aware than their Greek counterparts of the potential power of knowledge, and I find myself wondering why the Ptolemies, for instance, did not make more extensive political use of the research at Alexandria. Perhaps this is the sort of question Lloyd hopes comparative work will raise, though it is arguably more in the realm of political history than history of science.

Karin Tybjerg's chapter, 'Hero of Alexandria's Mechanical Geometry' [29–56], is a fascinating examination of the work of this relatively under-studied mathematician who flourished in the first century AD. Tybjerg argues that Hero's work bridges the divide, deep in both antiquity and now, between the 'lower form' of applied mathematics used for such practical applications as land measurement and architecture, and the 'higher' theoretical mathematics of Euclid, Archimedes, and Apollonius.

Hero was thoroughly educated in the Euclidean-Archimedean tradition: he wrote a commentary on Euclid's *Elements* (preserved now only in fragmentary form in an Arabic commentary), and refers frequently to the works of Archimedes and of other theoretical mathematicians [30–31]. But he also takes on practical problems, such as land measurement and instrument construction; and so his work offers, as Tybjerg sees it,

> a rare view of the interaction between geometry, mechanics and professional mathematics; it shows that these enterprises were closely related in the ancient world and that some demonstrative procedures combined elements from several traditions. [31]

Tybjerg deals at length with several of Hero's treatises (*Metrica* [31–41, 43–44, 46–48, 53], *Mechanics* [41–44], *Dioptra* [46–48, 51–52], *Catoptrics* [48–49]) and makes reference to several others. She demonstrates Hero's skillful adaptation of the methods and proofs of Euclidean/Archimedean geometry to practical mechanics and geometry, including to irregular figures (a certain sign that he was interested in practical applications). The result, in Tybjerg's view, is the creation of a new theoretical discipline, mechanical geometry [54].

Ian Mueller's 'Remarks on Physics and Mathematical Astronomy and Optics in Epicurus, Sextus Empiricus, and Some Stoics' [57–87] is a detailed and thorough account of how certain Hellenistic thinkers differentiated physics and mathematics in the course of discussing astronomy and optics. Mueller begins with Epicurus' vehement rejection of astronomy (Epicurus refers to the 'mad, inappropriate behavior of those who esteem the emptiness of astronomy' [60]), which is based on the unverifiability of its explanations [59]. Physics, for Epicurus, is the study of the principles of atomism; since these principles cannot be accurately applied to 'the things in the sky', it is useless to speculate about them; multiple explanations are possible, and there is no basis for making a decision about which one is correct [59].

Mueller then takes up the topic of *paideia*, and of the disdain for it shared by Epicurus and the Sceptic, Sextus Empiricus [61–64]. Among the subjects of a liberal education were ἀστρολογία/ἀστρονομία. Epicurus rejects the typical curriculum *tout court*, as it is not the study of physics, famously advising his student Pythocles to 'flee all *paideia*' [62]. Sextus withholds criticism of mathematical astronomy and weather forecasting, reserving his criticism for that part of ἀστρολογία that has to do with casting horoscopes. (His attack proceeds on practical and epistemological grounds: it is difficult to determine the time of birth or of conception, or which zodiac sign is on the horizon; and one is hard pressed to account for the differences among people born at the same time [64].)

The major section of Mueller's paper discusses mathematics and physics in five Stoic texts that are—or could be—related to Posidonius/Geminus. In Diogenes Laertius, mathematics shares with physics the investigation into such things as the size and revolutions of heavenly bodies, but physics alone asks about the nature of the cosmos (e.g., the substance it is made of, whether or not it is generated, and whether or not it has a soul) [65].

Mueller looks next at a passage of Posidonius/Geminus found in Simplicius' commentary to Aristotle's *Physics 2* [66–72]. Here the distinction between astronomy and physics is similar to that found between mathematics and physics in the Diogenes Laertius passage already discussed: astronomy is concerned with size, shape, motion, speed, eclipses, and so forth; physics, with knowing the substance of the heavenly bodies, and their coming to be and ceasing to be, and so on [67]. Here, however, both disciplines might offer proofs on the same subject (e.g., that the Sun is huge, or that the Earth is spherical) [67]. But the ways in which the two carry out their demonstrations will differ: the physicist will proceed, apparently, by logical argumentation and will offer causal explanations, but will not use mathematics; the astronomer will never give a causal explanation, but will offer hypotheses that have no physical justification, and will use mathematics [67–71].

Mueller analyzes passages in Strabo and Proclus that may be traceable to Posidonius/Geminus, and that tell a broadly similar story [72–82]. In Strabo, physics is self-dependent and unhypothetical; it carries within itself its own principles and justifications; it investigates the general characteristics of the heavenly bodies and their underlying natures. Astronomy relies upon physics, and is relied upon by geometry (in the sense of Earth measurement); as above, astronomy calculates the orbits, eclipses, and other particulars of the heavenly bodies [72–76]. Proclus' characterization of astronomy (ἀστρολογία) is much the same as in the accounts above in dealing with the size and movements of the heavenly bodies [76–82]. Proclus, however, says nothing about the use of mathematics in astronomy, and little about astronomy's relation to physics; he does, though, emphasize the use of astronomical instruments in the calculation of elevations, distances, and positions. And Mueller, reasonably enough, sees this as acknowledging the practicality and precision with which astronomy is characterized in the other sources he analyzes.

Mueller also introduces us to a little-known anonymous excerpt on optics that conforms in some respects to the ideas on optics expressed in Diogenes Laertius and Proclus/Geminus [cf. 65–66, 79–80] and that may be a source for the latter [82–85]. For present purposes, the chief point of similarity is the attribution of the capacity to provide causal explanation to optics. The excerpt also mentions theories and hypotheses in optics—elements absent from the discussion in Proclus [83]. Little is said about the theories, but the author elaborates upon the hypotheses, which appear to have a mathematical basis [83–85]. The author then takes pains to distinguish optics from physics along much the same lines as with mathematical astronomy and physics: optics deals with the particulars and is based on mathematics; physics investigates the larger, broader, and more abstract questions. Optics differs from astronomy, however, in having the capacity for providing causal explanation—something usually reserved for physics [85]. Mueller proposes that optics enjoyed this more elevated status because, although it 'pays no attention to physics', unlike astronomy, its hypotheses are compatible with Stoic physics [85].

James Allen's 'Experience as a Source and Ground of Theory in Epicureanism' [89–106] is a fascinating investigation of the ground shared by Epicureanism with both empiricism and rationalism. Allen first defines the terms used by the medical Empiricists: '*peira*' refers to one observation and to the knowledge that arises from it; '*empeiria*' to repeated observations and to the knowledge or memory that arises from them; '*historia*' is the knowledge acquired from the observations and knowledge of other people [91]. The understanding of causes has no place here, and it is unclear how one would become a doctor, or practice any other art, with only *peira*, *empeiria*, and *historia* at work. Most Hellenistic philosophers and scientists followed Aristotle in supposing that causation was understood by a separate rational faculty that based its insights on experience [93].

The Epicureans, says Allen, took a stronger position even than this, asserting that knowledge 'either consists in or arises out of a grasp of the evident', opinions about which could be assessed by attestation and non-attestation [93]. But what of the non-evident? With a physics based on atoms, the Epicureans enter the realm of the rationalists, who claim that we have a rational faculty capable of grasping the non-evident [89]. Opinions about the non-evident are assessed for their truthfulness by contestation and non-contestation: an opinion about the non-evident is contested when its observable consequences are shown by observation to be false, and is not contested when its observable consequences are not shown by observation to be false [93–94].

The obvious imbalance in this position, whereby a weaker test—mere non-contestation—is all that is required to prove the veracity of an opinion or theory about the non-evident, permits the Epicureans to pass well beyond the usual framework of empirically-based theory outlined above. This position seems to have been required by Epicurean physics. Allen observes that

> ...Epicurus seems to have regarded all the theories compatible with the phenomena as objectively possible. Indeed, he seems to have held that they are true in the sense of being

> realized either at some time in our world or in some other world in the infinite universe. [95]

In other words, if we cannot show an opinion or theory to be false, then it must be true at some time or somewhere. That is why non-contestation is sufficient to prove veracity.

Allen proposes, moreover, that Epicurus goes a step further: the phenomena, being signs of the non-evident, are analogues of the non-evident. To the degree that a theory is similar to the phenomena, it is in agreement with them; this is the guarantor of a theory's being true in the sense of its being possible somewhere or at some time. Allen suggests that the tests for claims about possibility may be different from those for universal theories:

> When put forward as universal explanations, holding of all times and places, [theories] qualify as true if they are merely not contested by the phenomena, but when reformulated as claims about possibility, each has a contradictory, viz., the proposition that it is not possible, which is in conflict with the phenomenon that it resembles and which was the basis of the analogy that is its source. This would mean that theories—conceived as claims about objective possibility—follow from the phenomena to which they are analogous. The grounds that the phenomenon on which an analogous theory is based furnish for accepting the theory would then complement the grounds furnished by the fact that theory is not contested by the phenomena quite generally. [98]

Allen notes that the Epicureans did not push this line of thinking as far as they might have. If, in grasping the phenomena, we grasp how things can and must be, are we not some way towards having a causal explanation? And, if we are, have we not put a foot on either side of the rationalist-empiricist line [98–99]? There is no extant Epicurean text of our world, however, that acknowledges this among the possible truths.

In the last section of his essay, Allen takes up the question of how, in the Epicurean view, conclusions could be drawn from the phenomena about the non-evident [101–105]. He begins with a discussion of *epilogismos*, which is used very differently by Empiricists and Epicureans. Among the former, it is the everyday reasoning of ordinary persons about evident, or temporarily non-evident, matters; for the latter, it seems to be a pre-condition for inferring a non-evident conclusion from the phenomena: it is not the inference itself [101]. The two schools are in agreement that, on its own, *epilogismos* cannot lead to conclusions about the non-evident, but only about the phenomena [103]. But what sort of knowledge can be derived about the phenomena *via epilogismos*? The Empiricist will know the order, patterns, and frequency of the occurrence(s) of the phenomena, and so will be able to reason about them and form expectations about similar unobserved or future phenomena [104]. The Epicurean will gain knowledge, even if incomplete, of the natures and powers of the phenomena, and so will be able to infer that unobserved, and even unobservable, items are necessarily the same or similar [104]. In sum, experience, for the Epicureans, 'prepares the way for the more than empirical grasp of the phenomena that in turn supports rational insights about non-evident matters' [105].

The last essay of the volume is the editor's innovative contribution 'Medical and Ethnic Identities in Hellenistic Egypt' [107–131]. Lang proposes that Greek medicine was a distinct cultural artifact, and so played a role in maintaining ethnic identity among Greek immigrants living in Ptolemaic Egypt. She is well aware of the problems consequent upon her topic and sets them out from the start—e.g., How do we establish ethnic identities? What is the evidence for the blurring of identities through intermarriage and other forms of cross-cultural exchange? How do we define 'Greek medicine' and 'Egyptian medicine'? [107–109].

Lang identifies certain traits as being characteristic of, or exclusive to, either Greek or Egyptian medicine [109–117], though she is generally careful not to overstate her case, and acknowledges a fair degree of overlap [125–129]. She maintains, however, that there were enough sufficiently sharp distinctions between the two traditions that Greek medicine could serve as an identifiable artifact and expression of Greek culture [109]. Egyptian medicine, Lang asserts, was far more institutionalized than was Greek medicine; in fact, it was entirely enmeshed in civil and religious power structures, and so came to value tradition and authority [110–111]. While there was change and innovation over time, we see with Egyptian medicine nothing like the intellectual rivalry that we find in Greek medicine [111–112]. There is a hint here of a false assumption, common among Hellenists, that the well-known vigor of Greek intellectual life would necessarily bring about positive change in a given discipline. But one should bear it in mind that while the 'marketplace of ideas' has the potential for culling out flawed theories and practices, it is also capable of promoting them if they are couched in persuasive speech. Indeed, many erroneous theories and practices espoused in the Hippocratic corpus, for instance, probably owed their survival largely to rhetorical defenses of the sort launched by the author of *On the Art*. Egyptian healers, on the other hand, were apparently assessed at least in part on the basis of their training and expertise:

> Differences between [Egyptian] healers were overwhelmingly due to variation in their training and consequent expertise, their social status and their personal skill and preferences, rather than to competing and explicit differences in theory and methodology. Status and acknowledged expertise were derived from a high degree of medical-magical knowledge, preserved in written form in the temples. [111]

I do not take it as a given that evaluating a doctor based on his education, skill, and expertise, rather than on his ability to articulate competing theories and methodologies is necessarily the inferior choice. There are also two particularly noteworthy exceptions to Lang's view: the Egyptian Smith Surgical Papyrus reveals little or no trace of dependency on religion, while the widespread Greek cult of Asclepius is, of course, a religious healing cult. All that said, I am generally in agreement with the view that Egyptian medicine was more entwined than was Greek with magic and religion, and with the social and political apparatus of magic and religion.

The other key distinguishing features of Greek medicine that Lang proposes are anatomical investigation, naturalistic explanations for physiology and illness, and internal surgery for non-traumatic illness [112–117]. The Egyptians, familiar with internal human anatomy through mummification, had no need to carry out further exploration, and the enmeshing of their medicine with religion and magic precluded the need for naturalistic explanations, and discouraged the development of invasive surgical practices. Patients of both ethnic groups, Lang contends, would expect healers to practice medicine in accord with their respective traditions [117].

Lang proposes that the ethnographic portrayals of Herodotus, Hecataeus, and others, encouraged the attribution of socio-cultural characteristics to ethnicity [117]. Accordingly, she suggests that

> Greeks and Egyptians of the Ptolemaic era perceived differences, real but un-nuanced and exaggerated, between Egyptian practices and Greek medical discourse. This fostered an explicit definition of Greek medicine, particularly in the form in which it was practiced by the intellectual elite of Hellenistic society, as specific to Greek culture, especially in the wider context of an immigrant society inserted into a foreign country and culture. [117]

Lang derives her view from a careful analysis of certain relevant tax policies [117–125]:

- exemption from the obol-tax for residents labeled 'Hellenes',
- exemptions from the salt-tax for 'Greek physicians' and others whose occupations would be useful to the Ptolemaic civil and military authorities, and
- the imposing of the *iatrikon* (the medical tax).

The exemptions, she argues, tended to privilege Greek language and culture, and so all those who could 'sound and act Greek' [119] 'whether through birth, Hellenization, or some combination of the two' [118]. The *iatrikon* was levied on certain categories of Greeks—details are not clear—for the purpose of paying for physicians' services when needed [119]. Lang suggests that this was a Ptolemaic innovation that was loosely based on pharaonic precedents and on the system of public physicians in many mainland Greek cities [121]. The primary purpose, she carefully argues, was to encourage the presence of Greek physicians in the Egyptian *chora* (they were far more plentiful in the cities), where there was a growing presence of Greek immigrants [124]. As Greek physicians, they would, of course, be able to offer their Greek immigrant patients care in their own language—an inestimable advantage that Lang certainly recognizes [124]. But they also, she suggests, represent a 'distinctive part of Greek cultural experience and expectations' because their medical practices were clearly identifiable as Greek [125], though there will have been overlap with Egyptian practices [125–130].

The conference that Lang organized and the volume that has grown out of it are valuable contributions to our field. Lang is to be applauded for her role in bringing to the light scholarly work that is at once thorough-going, innovative, and provocative. I hope readers of this review will be spurred to give each of these articles the time and attention it deserves.