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NILSSON, M. P., 'Early Orphism and Kindred Religious Movements' (193: *Opuscula selecta*, ii (Lund, 1952), 626-83.

STADEN, H. von,
'Experiment and Experience in Hellenistic Medicine',
BICS 22 (1975), 178-99.

STENIUS, E., 'Foundations of Mathematics: Ancient Greek and Modern',
Dialectica 32 (1978), 255-90.

(A) TARAN, L., - 'Proclus on the Old Academy',
in J. Pepin and H. D. Saffrey (eds.),
Proclus: Lecteur et interprete des Anciens (Paris, 1987), 227-76.

Westenholz, L. G.
Proclus et les presocratiques
p 105-112
Mueller, J.
Mathematics and Philosophy in
Proclus commentary on book I
- of Euclid's elements
p 305-318

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EXPERIMENT AND EXPERIENCE IN HELLENISTIC MEDICINE

by Heinrich von Staden

When Francis Bacon, in the year 1620, launched his famous attack on ancient Greek science and philosophy,¹ he claimed that one of the reasons for the 'failure' of Greek science was the absence of genuine experimentation in antiquity. This assertion triggered a debate about the nature and methods of Greek science which continued to smoulder and erupt for many years and which even now, three and a half centuries later, does not seem to have reached its terminal point. The controversy became increasingly heated in the nineteenth century, particularly after the philosopher William Whewell, in his influential *History of the Inductive Sciences* (1837), tried to buttress Bacon's negative verdict with a vast array of arguments and historical data.² Whewell's attack in turn provoked a further series of defences of Greek science, notably that of the brilliant physicist and philosopher, Ernst Mach. In 1883, for example, Mach stated in one of his most important works, *Science of Mechanics*: "The opinion, until recently in vogue, that the Greeks were especially neglectful of experiment, cannot be maintained to-day."

In this century the debate has intensified. Among those who argued that ancient Greek scientists did in fact actively use experimentation were John Burnet, Ludwig Edelstein, Benjamin Farrington, Albert Lejeune, A. C. Crombie, and Vassili P. Zubov.³ On the opposite, more or less Baconian side, the most illustrious names have perhaps been those of Samuel Sambursky, J. O. Thomson, H. D. P. Lee, Jean-Pierre Vernant, W. J. Verdenius, Kurt von Fritz, and Arnaldo Momigliano.⁴ Lord Russell too offered his negative verdict in his *Unpopular Essays* (1950), suggesting that the Greeks were capable of forming speculative hypotheses but were incapable of sustained observation and hence of experimentation: "Aristotle could have avoided the mistake of thinking that women have fewer teeth than men by the simple device of asking Mrs Aristotle to keep her mouth open while he counted. He did not do so because he thought he knew. . . ." (p. 135).⁵

In the last decade the most valuable contribution to this debate has been that of G. E. R. Lloyd.⁶ Dr Lloyd argued persuasively that global generalizations of the kind often implicit in the debate do not further our understanding of the issues. Instead, he differentiated carefully between *branches* of ancient science in which an experimental method was used and those to which it was largely alien, often for practical reasons. Lloyd's sober caveats have not been heeded by all. Thus, in a recent issue of the

American Journal of Physics, N. E. Eaton cited the Greeks as a horrible example of failure to experiment, while H. L. Armstrong, in the same issue, claimed that the validity and, in fact, modernity of ancient Greek views on observation and experiment are beyond doubt.⁷

In short, from Bacon's attack on Greek science to Armstrong's defence, enthusiasm for the achievements of Greek science, and criticism of its methods, have alternated; ridicule and admiration have clashed, and more often than not the concepts 'experiment' and 'empirical' have become pivotal points of the dispute.

The nature and difficulty of some problems associated with this controversy might be illuminated by applying a fresh approach to a limited segment of Greek scientific history. This approach will involve, first, not merely listing or describing some experiments, as has often happened in past chapters of the dispute, but examining them more critically, without ignoring flaws which they might exhibit. It will further involve distinguishing clearly, within *one* branch of science, between periods more favourable to experimentation and those that were less so (rather than offering — as does even G. E. R. Lloyd — generalizations about the use of experimentation in a single branch of ancient science).⁸ Finally, in the third and last part of this paper I shall attempt to determine the role, if any, assigned to experimentation in theories of scientific method from the period under consideration, and to discuss their possible significance for the controversy.

The segment to which I wish to apply this approach is the study of human physiology in the first two post-Aristotelian centuries. An analysis of experimentation in this particular period and in this branch of science seems quite promising for at least three reasons. First, in post-Aristotelian scientific literature, it is not until one gets to Heron's *Mechanics* (perhaps first century A.D.?) and Ptolemy's *Optics* in the second century A.D. that one finds again as many descriptions of experimental tests as in this period. In particular, the development of anatomy and physiology reached an unprecedented pinnacle in the third century B.C., and this progress seems to have been accompanied by a certain amount of experimental testing. Second, this segment provides a useful illustration of vacillating extremes in the use of experimentation in antiquity, for by the end of this period the conduct of experimental tests seems to have vanished almost entirely from the study of physiology. This flourishing, and then rapid withering away, of the experimental method within less than two centuries is representative of some of the paradoxes encountered in the history of experimentation. Third, concepts that have often dominated the debate about experimentation in antiquity are widely used and discussed in scientific and philosophical literature of this period. These concepts include experience, observation, test, inference, confirmation, cause, analogy, hypothesis, proof.⁹

I

I have singled out five well-known scientific tests for closer scrutiny. The first of these is recorded in a famous papyrus of Peripatetic provenance, the *Anonymus Londinensis* of the British Museum. It is an attempt to test the hypothesis that continuous, invisible emanations or evaporations of the finer elements within the body occur from the entire body without any external cause.¹⁰ Such emanations, as the author of the treatise points out, are known — though contested by some — from everyday events outside the human sphere. Thus, juices and other liquids become less in volume when

they are exposed, fresh aromatic spices ‘emanate’ more odour than (lighter) stale ones, freshly cut lettuce or flowers are heavier than when they have become withered.¹¹ From plant life the author passes on to “irrational animals” before turning to man himself: the scent in the tracks of an animal is introduced as evidence of “certain emanations” (τινὲς ἀποφοραί) given off by “irrational animals”.¹² At this point a corroborative test is introduced.

The medical scientist who set out to test the hypothesis by going beyond common observations was Erasistratus, one of the most distinguished physicians of the period under consideration.¹³

πρὸς δὲ τούτοις καὶ Ἐρασίστρατος πειρᾶται κατασκευάζειν τὸ προτεθέν. εἰ γὰρ λάβοι τις ζῷον οἷον ὄρνιθα ἢ τι τῶν παραπλησίων, καταθοῖτο δὲ τοῦτο ἐν λέβητι ἐπὶ τινὰς χρόνους μὴ δοὺς τροφήν, ἔπειτα σταθμῆσαιτο σὺν τοῖς σκυβάλοις τοῖς αἰσθητῶς κεκενωμένοις, εὕρησει παρὰ πολὺ ἔλασσον τοῦτο τῷ σταθμῶι τῷ δηλονότι πολλὴν ἀποφορὰν γεγενῆσθαι κατὰ τὸ λόγῳ θεωρητόν.

“Erasistratus too tried to prove the proposition. If one were to take some suitable animal (a bird, for example), and were to set it down in a cauldron for some period of time without giving it food, and then were to weigh it along with the excreta that visibly have been passed, one will find that it is far less in weight because obviously a considerable emanation has taken place, perceptible (only) to reason.”¹⁴

One might question whether or not this test is an experiment. I should maintain that it does in fact merit the label ‘experiment’, even by the fairly stringent standards that prevail in currently accepted definitions. If a scientific experiment is understood to be an attempt to test an hypothesis that has been construed as an answer to a problem under study; if it is conducted under unnatural or artificial conditions designed by the scientist; if a theoretical analysis of the conditions under which the test procedures must take place is necessary; if it involves directed observation and, whenever appropriate, corroboration by quantitative analysis; if it is expected to be repeatable – then this test of Erasistratus would seem to meet the definitory requirements.

An entirely different question – and one not raised often enough by those who have argued about experimentation in ancient science – is whether this is a successful or conclusive experiment. Its hypothesis does not include the notion of metabolism nor do its test implications (or the completed test) ‘discover’ metabolism; rather, it reduces explanation of a puzzling phenomenon to that which is analogically familiar. Yet to philosophers and historians of science an experiment which, in principle, seems methodologically sound, but whose flaws remain undetected for centuries is nothing novel. ‘Emanation’ in the form of dehydration, for example, is not in itself a *wholly* inadequate ‘explanation’ of weight loss, but while not being entirely false it covers only one aspect of the complex phenomenon being explained and hence is invalid; it cannot be generalized at the causal and nomological level which the scientist claims for it.

If one were to accept Sir Karl Popper’s influential view that only those tests that refute a conjecture or produce an unexpected result can be called *successful* experiments or *true* tests, then by this criterion too Erasistratus’ test, like most ancient experiments, would have to be considered an inconclusive experiment – but, even in Popperian terms, it would still be an experiment. Popper states his view on this more unequivocally than

some of his adherents: “But are not Anaximander’s theories false, and therefore non-scientific? They are false, I admit; but so are many theories, *based on* (i.e. confirmed by) *countless experiments*, which modern science accepted until recently, and whose scientific character nobody would dream of denying, even though they are now believed to be false.”¹⁵

A second test concerns a question widely discussed in antiquity: whether any part of what we drink passes into the lungs. Plato¹⁶ supported this view, whereas Aristotle¹⁷ opposed it. Within the Hippocratic Corpus opinion is divided, as it is, in fact, on many other issues. Thus the author of *On the Nature of Bones* maintains that some liquid enters the lungs through the windpipe when we drink, whereas the author of the fourth book of *On Diseases* adduces numerous ‘facts’ to disprove this proposition.¹⁸ The Hellenistic author of *On the Heart*, probably writing after Erasistratus,¹⁹ seems to have decided to conduct a test that would confirm (or refute) the theory.

πίνει δὲ (sc. ὄνθρωπος) καὶ ἐς φάρυγγα, τυτθὸν δὲ οἶον καὶ
 δόσον ἂν λάθοι διὰ ῥύμης ἐρπύεν· πῶμα γὰρ ἀτρεκές ἢ ἐπιγλωσσίς,
 καὶ διήση μείζον ποτοῦ οὐδέν. Σημήιον τοῦτο· ἦν γὰρ τις κυάνω
 ἢ μίλτω φορύξας ὕδωρ δοίη δεδιψηκότι πάνυ πιεῖν, μάλιστα δὲ σιτὶ,
 τὸ γὰρ κτῆνος οὐκ ἔστιν ἐπιμελὲς οὐδὲ φιλόκαλον, ἔπειτα δὲ εἴ τι
 πίνοντος ἀνατέμνοις τὸν λαιμὸν, εὗροις ἂν τοῦτον κεχρωσμένον
 τῷ ποτῷ· ἀλλ’ οὐ παντὸς ἀνδρὸς ἡ χειρουργία. οὐκ οὐκ ἀπιστητέον
 ἡμῖν περὶ τοῦ ποτοῦ, εἰ εὐτρεπίζει τὴν σύριγγα τῷ ἀνθρώπῳ. . . τὸ
 γὰρ διὰ τῆς ῥύμης ἐρπύεν, ἅτε παρὰ τυτθὸν ἰόν, οὐκ ἐνίσταται τῇ
 ἀναφορῇ τοῦ ἥερος, ἀλλὰ τινα καὶ λείην ὁδὸν οἱ παρέχει ἢ ἐπίτεγξις·

“Some part of what (a man) drinks also enters into the windpipe, but only the small amount that can flow in through the passage without being noticed. For the epiglottis is a cover that fits exactly, and nothing of greater density than liquid could pass through it. Here is a proof (sign): if someone were to stain some water with blue or red dye and give it to one in a state of great thirst — preferably to a pig, since it is an animal that is neither careful nor fastidious — and then, while it was still drinking, were to slit its throat, you would find it (scil. its windpipe) coloured by the liquid being drunk. (But the operation is not one that can be performed by everyone.) We must accordingly not be disbelieved when we claim that what a man drinks also lubricates his windpipe. . . . For that which flows in through the passage, entering a little at a time, does not interfere with the upward movement of the air; on the contrary, the moistening provides a smooth path for the air.”²⁰

Again, by the criteria mentioned above, this test seems to qualify as a scientific experiment. Insofar as the scientist here uses his test as a basis for the erroneous conclusion that some liquid enters the windpipe *whenever* one drinks, it is a particularly interesting case. It is strikingly paradoxical that he arrives at an erroneous generalization by means of a reasonably legitimate, scientifically designed experiment, whereas the author of *On Diseases* IV (see above) reached the correct conclusion through erroneous arguments and distorted ‘facts’. This experiment is inconclusive, at least in part because it exhibits three flaws endemic to many ancient tests — flaws which have not received adequate attention in previous scholarship. First, an inappropriate analogy: “as thirsty pig, so all men”. Second, the scientist makes a general proposition out of an hypothesis which holds in one test, but not, as the author’s explicit emphasis

on the 'felicitous' choice of an unfastidious (οὐδὲ φιλόκαλον) pig suggests, in all instances. Whenever the hypothesis is false in any *single* instance, it is consequently false as a *general* proposition, regardless of how many times the hypothesis has been confirmed (a point made with particular lucidity by Braithwaite).²¹ Third, the fallacy of precipitately affirming the consequent. The latter is a fallacy which can, in fact, be detected in the logical structure of some of the most famous and apparently successful experiments in the history of science.

What Carl Hempel wrote on the basis of his analysis of modern scientific experiments, is also applicable to this Hellenistic test: "...the favourable outcome of an experiment, i.e. that a test implication inferred from a hypothesis is found to be true, does not prove the hypothesis to be true. Even if many implications of a hypothesis have been borne out by careful experiments, the hypothesis may still be false."²² Or, to invert the emphasis, a test that confirms a false hypothesis might still be an experiment.

A third test was conducted in connexion with another very controversial question: whether the arteries, in a natural condition, contain pneuma or blood. The view that they contain pneuma, whereas the veins carry blood, has been ascribed to several people: to Alcmeon of Croton and Plato²³ (not with good reason, as it seems); with greater certainty to Praxagoras of Cos,²⁴ an influential physician of the fourth century B.C., and to his father Nicarchus; also to Chrysippus, a physician who was perhaps a teacher of Erasistratus;²⁵ to the pseudo-Aristotelian *de spiritu*,²⁶ and to Erasistratus himself.²⁷ The contrary view, that the arteries as well as the veins carry blood, is represented by some Hippocratic treatises,²⁸ possibly by Marinus (second century A.D.),²⁹ by Asclepiades of Bithynia (first century B.C.),³⁰ by Galen,³¹ and, of course, implicitly by those who like Plato and Aristotle made no distinction between veins and arteries, simply calling them φλέβες.

The view of scientists like Erasistratus was perhaps prompted initially by their observation that arteries of dead animals (or persons) had contracted and were empty of blood, sometimes also becoming dilated with gaseous substances. There were, however, apparently also more theoretical questions which led Erasistratus and his followers not to accept the fact that arteries carry blood:³² if, as Erasistratus believed, the pulsation of the arteries is due to the pumping of pneuma through the arteries by the heart, then how could the regularity of the pulse remain unimpeded if the arteries contained blood – especially since this pneuma "cannot coexist peacefully with moisture"?³³ On the other hand, there was the obvious fact, as Galen says, that blood flows from the arteries when they are pierced "even by the thinnest of needles" (IV. 708, 721K). Erasistratus explained this by claiming that an artery becomes filled with blood only when a wound of some kind allows the pneuma to escape; blood then enters the artery from the veins through the 'synanastomoses' (openings between the veins and arteries) to replace the escaped pneuma.³⁴ Once the puncture is healed or covered, the heart will again pump pneuma through the artery and thereby restore the source of pulsation.

Galen's allusion to a test apparently conducted by Erasistratus to substantiate this theory is somewhat cryptic, but worth looking at. Galen first describes his own experiment (here ἐγχείρησις):³⁵

"One must expose one of the large arteries near the skin, such as that by the groin. . . , then tie a ligature around, above it, and compress the artery itself with the fingers of the left hand at a distance as far as possible from the ligature but before the artery branches. Then make a straight incision in the artery lengthwise,

long enough to insert a hollow body (a tube) between the ligature and the fingers (sc. of the left hand). Have ready a reed of the thin kind with which we write or some appropriate bronze pipe; a finger's length is sufficient. There will obviously be no haemorrhage from the incised artery in this exercise, since the upper part from which the blood flows is shut off by the ligature . . . Hence you can at your leisure insert the tube under the incision in the wall of the artery, and then ligate the artery along with the reed, all around, with thin linen thread, seeing to it that no part of the tube falls outside beyond the incision. But the reed should be of such a thickness . . . that the arterial coat does not lie slack on it . . . This done, loosen the ligature above and . . . change the position of the fingers compressing the artery to the part around the reed. If the reed . . . was wedged in tightly and ligated with precise care, you will no longer need to control it – rather, you will indeed be able to observe at leisure that the part of the artery above the reed even now is still pulsating just as before, but that the part below the reed becomes completely pulseless. This then is what is truly observed.”

Galen's test was designed to refute Erasistratus' theory of pulsation by proving that the source of the pulse is a *dynamis* carried by the arterial *coats*, not by the contents of the arteries. The reed tube permits the *contents* of the artery to flow unimpeded to the lower parts of the artery, but the ligature of fine linen thread that presses the arterial *walls* tightly against the reed shuts off the *dynamis* of pulsation that is carried in these walls, and hence pulsation below the ligature ceases.

Immediately after the passage quoted above Galen adds: “Erasistratus, however, gave an opposite account *regarding this, saying that the part below the reed is seen moving* (i.e., pulsating). And a few lines later he adds: “Some people mention further experiments (ἐγχειρήσεις) through which they promise to demonstrate that an artery is empty of blood, as though they can do something cleverer, and make more beautiful experiments (ἐγχειρῆσαι τε κάλλιον), than Erasistratus. For he certainly would have thought of it first if there were any method of dissection (i.e. vivisection) at all by which an artery could be proven to be empty . . .” (II.648K). Galen seems to imply that Erasistratus conducted the same test but concluded that (a) the pneuma could be pumped through all of the artery again after the reed had ‘repaired’ the lesion and had thus prevented any further escape of pneuma, and (b) the part below the ligated reed would hence be pulsating again.

In the absence of more evidence it might be rash to try to state with certainty which hypothesis Erasistratus was testing – other than that it had to do with his doctrine about the arteries. It is also difficult to conjecture with confidence about the reasons for the discrepancy in the results observed by Erasistratus and Galen.³⁶ Nevertheless, Galen's description leaves no doubt about the experimental nature of the test: its repeatability, the creation of artificial conditions, the control of variables, the emphasis on precision, and so on. The corroborated hypothesis may well have been false, like that of the first two experiments, but the scientific and experimental character of the test would seem beyond dispute.

A fourth and more conclusive test is recorded in chapter 10 of *On the Heart*. Having described the general structure of the heart, the author turns to its ‘hidden membranes’

(ὕμενες ἀφονέες), the heart valves. He describes with considerable precision the three semi-lunar valves at the base of the aorta and the pulmonary artery and then sets out to investigate the *function* (ἔργον) of these valves by means of a test that involves heart surgery.

καὶ τὴν καρδίην ἀποθανόντος ἦν τις ἐξεπιστάμενος τὸν ἀρχαῖον
κόσμον ἀφελών, τῶνδε (sc. ὕμένων) τὸν μὲν ἀποστήσῃ, τὸν δὲ
ἐπανακλίνῃ, οὔτε ὕδωρ ἂν διέλθοι εἰς τὴν καρδίην οὔτε φύσα
ἐνβαλλομένη· καὶ μᾶλλον τῶν (sc. ὕμένων) τῆς ἀριστερῆς·

“And if someone who is skilled at the old way of doing this should remove the heart of a person who has (just?) died and should push aside one of these heart valves but bend the other upward, then neither water nor air that is pushed against (the valves) would pass through the valves into the heart, especially not through those on the left side of the heart.”³⁷

This test demonstrates successfully the irreversibility of the flow of blood out of the heart through the valves. It is difficult to judge whether it represents a test of an hypothesis or a method of discovery, because — as often in descriptions of ancient scientific tests — there is no reference either to the scientist’s immediate or ultimate goal, or to the exact sequence of steps that led to the test. I agree, however, with those who argue that experimentation is a method of both testing and discovery, that its role in theory formation is often heuristic: to guide a scientist from rough or vague guesses to the discovery of more definite hypotheses or conclusions, which in turn might be verified by repeating the experiment in more instances. This test, which meets the other criteria mentioned above, could accordingly be classified as an experiment, regardless of its specific place or role in the scientist’s procedure.

A further instance of testing was used in one of the most spectacular pieces of anatomical and physiological research in classical antiquity, viz. research on man’s nervous system.³⁸ These investigations were primarily conducted by Erasistratus and his contemporary, Herophilus.

One of the more striking developments in the third century B.C. is the use, apparently for the first time in Greek antiquity, of dissection and even vivisection of human beings in physiological research.³⁹ Previously, religious, social, and medico-ethical taboos — or aesthetic inhibitions — seem to have prevented biologists and physicians from dissecting human bodies. It is well known that Aristotle’s extensive knowledge of human anatomy and physiology was derived primarily from dissecting *animals*, including primates, and from observing wounded and mutilated human beings, sometimes perhaps in surgical operations. Aristotle also refers to the fact that he himself mutilated live animals to investigate physiological questions experimentally.⁴⁰ These efforts remained confined, however, to animals and it was only the third century B.C. that witnessed, for a brief period, the extraordinary results of a scientifically interested ruler’s decision to hand over criminals from his prisons to Herophilus and Erasistratus for medical experimentation.⁴¹ (What follows is disconcerting and, unfortunately, not mitigated by the reminder that these are not the only events from ancient life that illustrate a failure to put the highest value on human life.)⁴²

Detailed descriptions of these tests are not extant but from passages on vivisection in Celsus and Tertullian, and from evidence about Herophilus and Erasistratus’ neurological studies in Rufus, Aetius, Galen, Vindician, and Theophilus, one can piece together a mosaic

which suggests that the following procedures may have been followed by Erasistratus in particular.⁴³ After tracing the nerve ramifications he concluded that the nerves are the vehicles of both sensation and motion. This conclusion was probably discovered and tested by severing individual nerves on living beings and observing the resultant paralysis of certain sensory and motory functions. In particular, incisions on the spinal cord of living beings at various points seem to have provided an effective means of establishing which parts of the body are paralysed by lesions of different sections of the cord.⁴⁴ A clear distinction between motory and sensory nerves was thus established; and the ἀρχή of both was located in the dura mater, cerebrum or cerebellum. Here too discovery might have been at least as significant as hypothesis testing, but some of the procedures involved, to the extent that there is evidence, seem to have been experimental.

Each of the tests discussed above, therefore, seems to meet the criteria established for scientific experiments in modern scientific theory. They satisfy the demand for unnatural or artificial conditions, for what Goethe called "*Eingriff in die Natur*" and Norwood Russell Hanson "tampering with nature". They all involve direct and directed observation; they deal with reproducible phenomena and can be repeated,⁴⁵ they single out test cases from an infinite row of similar cases, their hypotheses, which represent various kinds of explanation, and their test implications are open to corroboration or refutation, they attempt to keep known variables constant, and some of them involve quantitative measurement.

In its way, this is impressive. Yet it would be misleading to conclude this section of the argument with an affirmative generalization of the sort that has even recently coloured the dispute. Not even a generalization covering only the limited segment under discussion here would be legitimate. Instead, it has to be emphasized that these experiments still represent only occasional tests (the number of examples for this segment could at most be doubled); counter-examples of the use of non-experimental procedures in physiological research, even in situations which clearly called for experimentation, are numerous. The experiments are, furthermore, often inconclusive; some of them exhibit excessive confidence in an insidious method of analogy, some are prone to the fallacy of affirming the consequent; at times they lead to erroneous conclusions without becoming self-corrective; the use of quantitative methods is, in fact, minimal and inchoate. Finally, and perhaps most significantly, the use of an experimental method tends to disappear rapidly from medical research after the third century B.C. and only surfaces significantly again in the second century A.D. in the works of Galen.

II

Several explanations of the sudden decline in the use of experimentation in medical research after the third century B.C. have been advanced.⁴⁶ The relegation of science to the care of slaves, the political pressures that began to interfere with the freedom of scientific research, the small number of people who had to carry the burden of scientific investigation, the insecurity of the position of science within the social order as reflected in the apologetic and rhetorical character of some scientific treatises, the reassertion of taboos concerning the human body — these are all among the reasons for the decline that have been put forward, and some of them are indeed significant factors. (The disappearance of human dissection and vivisection has also been advanced as a reason, but this might well have been a concomitant or symptom of the waning of experimentation rather than a reason for it.)

A further explanation of this decline, it has been suggested, can be found in the absence of an appropriate conceptual apparatus, including the concepts 'experiment' and 'laboratory'. This is a significant suggestion, but it raises at least two questions: (a) how then did experimentation, as documented by the five examples analysed here, arise in the first place? (b) perhaps more important, what is the place assigned to experimentation in theories of scientific method of this time?

In answer to the first of these questions it must be affirmed that an adequate though minimal number of concepts was available to the authors discussed above. Thus the *Anonymus Londinensis* specifically states, in apparent reference to Erasistratus' own language, that Erasistratus "tries (πειράται) to prove (κατασκευάζειν) the proposition (τὸ προτεθέν)" by the experimental test he then describes. And the author of *On the Heart* first introduces his premiss ("what we drink also enters the windpipe") and then labels the experiment which will 'prove' its validity a σημήιον — an increasingly popular concept in Stoic and Epicurean philosophy, where it often means "the observable basis of inference to the unobserved".⁴⁷ Perhaps more significant, however, than the availability of these and other concepts which could be adapted to descriptions of the experimental method, is the ready availability of conditional structures. The 'grammar' or 'syntax' of experimentation is almost invariably the condition sequence.⁴⁸ The test implications of hypotheses are usually of a conditional character: they tell us that under certain test conditions a result of a specified kind will be obtained. (If conditions of type A are realised, then an event of the sort B will occur.) In the experiments discussed above it is striking, but not surprising, that this essential structure occurs whenever a continuous description of a test is provided:

	<i>Protasis</i>	<i>Apodosis</i>
<i>Anon. Lond.</i>	εἰ γὰρ λάβοι τις . . . καταθοῖτο δέ . . . ἔπειτα σταθμήσαιτο . . .	εὐρήσει . . . ⁴⁹
<i>On the Heart 2</i>	ἦν γὰρ τις . . . δοίη . . . ἔπειτα δέ εἰ ἀνατέμνοις . . . ⁵⁰	εὕροις ἄν . . .
<i>On the Heart 10</i>	ἦν τις . . . ἀποστήσῃ . . . ἐπανακλίνη . . .	ἄν διέλθοι . . .

The use of conditionals to describe the test implications of a scientific hypothesis is therefore well documented,⁵¹ and, at a grammatical or conceptual level, the scientist does not need much more than this to design or record his experiments.

III

The other question — the place assigned to experimentation in theories of scientific method — concerns, I should submit, a very significant factor in the decline of experimentation in the period under discussion, and it is on this question that the rest of my argument will focus.

Most of the experiments analysed above were conducted by Erasistratus, and the two from *On the Heart* might well have been conducted under his influence. It is therefore interesting to find among the several hundred scattered testimonia about Erasistratus a

few that refer to his theory of scientific method and to his epistemological posture.

First of all, one notices his insistence that the scientist needs also to know things which can be 'seen' only by reason (τὰ λόγῳ θεωρητά).⁵² In his treatise *On Causes*, for example, Erasistratus attacks the Empirics' notion that comprehension of 'hidden' things and causal explanations are impossible. And in a discussion of scientific method in a third century (?) A.D. treatise *On Venomous Animals* (transmitted under the name of Dioscorides Pedanius), the author warmly commends Erasistratus for mocking the Empirics' stubbornness regarding causality and for not conceding to them that the universal, generic cause in a disease is incomprehensible.⁵³

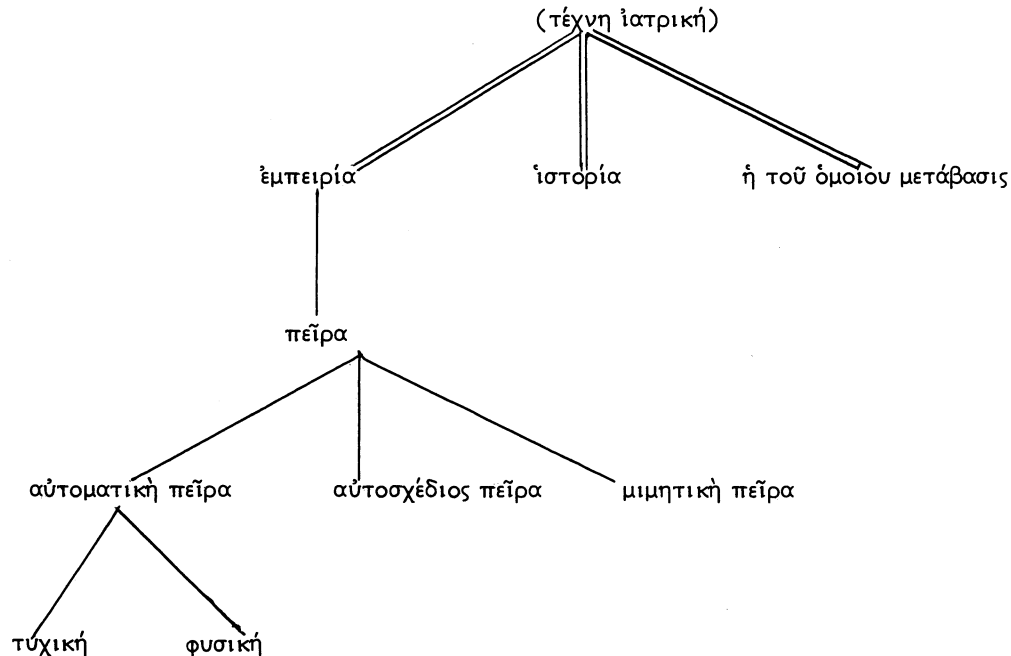
Similarly, Erasistratus is said to have denied that *observation* (παρατήρησις) of individual cases is sufficient and to have affirmed that one must proceed beyond *observation* to an understanding of *unseen causes*; the causes of certain afflictions, said Erasistratus, are in fact comprehensible as a class (κατὰ γένος).⁵⁴ With the Stoics he seems to have in common the concepts of antecedent cause (προηγούμενον αἴτιον) and active, operating cause (συνεκτικὸν αἴτιον).⁵⁵ Given his strong interest in causal explanation, it is not surprising to find Erasistratus formulating numerous hypotheses, as even the vocabulary often associated with him in the testimonia indicates: ὑπέλαβεν, αἴτια τιθεῖς, ὑπολαμβάνων, ὑποθέμενος, and so on.⁵⁶ Add to this the fact established above that Erasistratus clearly considered it legitimate to conduct experiments (πείραι or ἐγχειρήσεις) in order to test and corroborate these hypotheses, and there cannot be much doubt that his theory of method assigns an important niche to experimentation.

As his attacks on the Empirics indicate, Erasistratus' theory of scientific method did not go unchallenged.⁵⁷ Empiricism, in a variety of manifestations, was a significant current in the period under consideration. Thus the fragments of the Peripatetics exhibit an increasing emphasis on empirical examination of individual phenomena.⁵⁸ The Epicureans responded to Stoic criticism by refining their theory of inductive inference. Among the authors of rhetorical theory too there were those who emphasized, in opposition to Plato, that rhetoric has a scientific, empirical method. They stressed, as Philodemus and others report, that rhetoric should be based (a) on empirical observation (αἴσθησις, τήρησις, πείρα), and (b) on probable arguments from 'signs'.⁵⁹ The broader the empirical observation, they said, the more probable the inference. This method they called στοχασμός, generalizing conjecture, and they explicitly compared it to the use of the same method in other sciences such as navigation and medicine.

Not only in philosophy and rhetoric but also in medical theory the emphasis on an empirical method played an increasingly important role in this period (although it was by no means a novel method in medicine). In fact, Erasistratus and Herophilus were barely fading from the scientific scene when the medical school whose representatives called themselves ἐμπειρικοί supplanted them and became dominant.⁶⁰ Not until the so-called Pneumatic School gained currency in the first century B.C. and the Methodic School in the first century A.D. did the Empirics have to contend with any serious rival theory. We thus have the unusual coincidence of two events which, given some popular fallacies about the relation of empiricism to experimentation, might at first seem incompatible:⁶¹ (a) the rapid withering away of experimentation; (b) the rapid rise of a theory of scientific empiricism.

To understand this conflation, a closer look at the empirical theory of the ἐμπειρικοί will be necessary. In particular, the role assigned to experimentation in their theory of method and their use of the concept πείρα would seem to merit attention.

Apparently inspired by Nausiphanes, a pupil of Pyrrho and a teacher of Epicurus, the Empirics developed an epistemological and methodological tripod which looked roughly as follows:⁶²



The first leg of the tripod, ἐμπειρία or cumulative personal experience of the visible, is defined as a form of autopsy, seeing for oneself, to which one is led through an intermediate stage, πείρα, by the senses alone without any reference whatsoever to reason (logos). The senses, they concede, only lead us to experience of appearances (phénomena), not to “the nature of the thing itself” (φύσις αὐτοῦ τοῦ πράγματος). Nevertheless, the senses are the only valid source of ἐμπειρία, which in turn is the only cognitive state of which they approve without qualification.

These sense perceptions, the Empirics say, are only useful as a complex of sense perception in a temporal sequence, which in turn constitutes a πείρα, an experiential state preliminary to ἐμπειρία. πείρα is subdivided into three kinds of experience: involuntary, voluntary or improvised, and ‘imitative’: αὐτοματική, αὐτοσχέδιος, and μιμητική πείρα. The first of these, involuntary experience, is in turn subdivided into chance and natural involuntary experience.⁶³ Chance involuntary experience occurs when an external cause triggers an accidental growth of empirical knowledge. For example, Z. has a headache in the back of his head; he stumbles, cuts his forehead accidentally, and bleeds profusely; the headache disappears — Z. will have learnt, through an involuntary, chance experience (τυχική πείρα) that bloodletting cures headaches.⁶⁴ A natural — as opposed to chance — involuntary experience (φυσική πείρα) would have been gained if no external agent was involved (for example, if Z.’s fever had disappeared when his nose had started bleeding for no apparent reason).⁶⁵ What is significant for my purposes here is (a) that neither of these two kinds of involuntary experience could involve any sort of experimentation;

and (b) that these are exactly the kinds of experience on which the Empirics claim that science should preferably be based.

Improvised experience (αὐτοσχέδιος πείρα), on the other hand, involves volition or intention and a form of testing: ὅταν ἑκόντες ἐπὶ τὸ πειράζειν ἀφίκωνται, “when they voluntarily arrive at trying out something”.⁶⁶ At first this seems very promising in terms of its experimental potential. The semantic spectrum of αὐτοσχέδιος is wide, at least for a word of limited use, ranging from “hand to hand” (battle) over “improvised or extemporaneous” to “at hand”, “wild” (flowers),⁶⁷ but the Empirics clearly use it in the second sense: “improvised out of, and for, what is at hand”. That it does not refer to a passive “experience that lies at hand” but rather to an intentional *act* of testing becomes clear not only in the emphasis on ἑκόντες and τὸ πειράζειν in the phrase quoted above, but also in the designation of all involuntary experience (whether ‘natural’ or ‘chance’), in specific *contradistinction* to αὐτοσχέδιος πείρα, as “coincidence” or “the accidental form of ἐμπειρία”, “since things are encountered involuntarily” (ἀβουλήτως).⁶⁸

As opposed to most other forms of ‘experience’ in the empiricism of the Empirics – which tends to be passive – this one accordingly represents an action involving an attempt or a test designed and executed by an agent. There might therefore have been justification for the authoritative claim that the Empirics’ notion of ‘improvised experience’ includes what we call experiment, and that experimentation is hence recognized as a fully legitimate empirical procedure.⁶⁹ If this were so, little reason could be found in empirical theory for the rapid decline of experimentation. The exact nature of ‘improvised experience’ must, however, be tracked down before such a claim is accepted. The most illuminating tool available for this purpose is a survey of some practical examples of ‘improvised experience’ preserved in the Empiric literature.

A particularly striking example is that of a man bitten by a wild animal on a mountain and, presumably, stranded far from any professional aid.⁷⁰ It occurs to him to apply a herb that happened to be at hand (“hanc herbam”) from which he derives relief. His πείρα was αὐτοσχέδιος. The extant description is almost telegraphic in style, but the principles are clear: a patient acted out of desperation by improvising with what was at hand. Although a therapeutic measure may have been discovered in the course of his improvisation, and a chance idea may have been corroborated, the procedure is different in significant respects from those that were used in the experiments discussed above. The question is: “will this thing that happens to be here help me?” and not: “by what test could I corroborate my hypothesis?”; the agent is not a scientist in search of a tested conclusion that can be generalised, but an afflicted patient (as in the next two examples!) seizing upon *any* accessible medicament as a purely *ad hoc* solution which is not intended to be more than a κατάπαξ.

How tenuously the experimental method is represented in ‘improvised experience’ becomes even clearer in two further examples. First, a case that seems to exemplify the Empirics’ assertion that voluntary, improvised experience is sometimes motivated by dreams.⁷¹ Galen cites, in a discussion of examples of the Empirics’ πείραι, the case of a man who came from central Thrace to Pergamum inspired by a dream (ὀνείρατος προτρέψαντος αὐτόν).⁷² There a god ordered him to drink a daily dose of a drug derived from vipers and to rub (it?) on to his body, with the initial consequence that his disease changed into leprosy after a few days – but his leprosy was in turn cured by drugs prescribed by the god. This πείρα – it is explicitly called an example of an Empiric *experientia*⁷³ – was probably classified under voluntary or improvised experiences, as

Deichgräber suggests, and it indicates how remote from the experimental method examined above this method of gaining experience through improvisation can be.

A final example of this kind of experience again confirms beyond doubt that it does not represent a bastion of experimentation: “autescedia vero experientia fit sicut si iuvatur propter desiderium vel bibendo aquam frigidam vel comedendo malum granatum aut pirum aut quid tale aliud. . .”⁷⁴ Finding relief from illness in a drink of water or in eating a pear or quince at the prompting of desire might produce a useful experiential increment, but it is quite remote from experimentation as defined in the first part of my argument.

A further factor should be considered in any evaluation of voluntary or improvised experience. Even at a theoretical level it is de-emphasized by the Empirics; it is subordinated to accidental involuntary experience; it is ranked with haphazard actions that have no particular cognitive worth; its heuristic role is more or less that of a second-best; it is never granted the preferred status conceded to sheer chance and coincidence. Accordingly, neither the examples nor the theoretical treatment of αὐτοσχέδιος πείρα provides convincing evidence that the experimental method was regarded as legitimate by the Empirics.

The third kind of πείρα that contributes to ἐμπειρία, namely μιμητική, need not detain us. It is not so much imitation as repetition: ‘imitating’ a first observation by repeating it. Since a single observation is unscientific (ἄτεχνον), one needs ‘mimetic experience’ to provide a sum of similar single observations (τὰ καθάπαξ), and thus, in consort with memory, to render the unscientific experiences scientific (ἐντεχνον) by reducing the chance factor of the first observations.⁷⁵ Here too the emphasis is on passive absorption; science becomes represented as the collective positive and negative results of repeated, passive observation, and no role is assigned to experimentation.

ἐμπειρία, then, the first leg of the Empiric tripod, is the sum of these three kinds of experience. A Greek fragment from Galen’s *On Medical Experience* in a Trivultian codex puts it differently but distils essential aspects of this theory of scientific method: ἡ γὰρ τῶν πλειστάκις καὶ ὠσαύτως ἑωραμένων τήρησις καλεῖται μὲν . . . παρ’ αὐτῶν (sc. τῶν ἐμπειρικῶν) ἐμπειρία, συγκεῖται δ’ ἐκ πολλῶν τῶν καθάπαξ.⁷⁶

The other two main legs of the tripod are no more conducive to the use of experimentation than the first. The second leg is *historia*, understood as the transmission of evident data provided by others, of things that have previously been seen and confirmed by observation. Bruno Snell pointed out that the application of the concept ἱστορία, especially when it refers to knowledge rather than to more investigative research, tends not to be extended beyond the sphere of immediately accessible sensibilia.⁷⁷ Here, too, as Deichgräber suggests,⁷⁸ this would seem to be the case. As defined by the Empirics, *historia* is a passive reception of experiential traditions, tested and testable only by its similarity to one’s own observational experiences, by the amount of agreement between traditions concerning the same perceptible data, by biographical criticism (to determine a previous author’s particular emotional, ethical and other weaknesses or prejudices), and by the purity of its empirical content (all the results of purely ‘rationalistic’ research must, according to this principle, be eliminated from *historia*). It has been claimed that the Empirics admitted experimentation too as a means of verifying a tradition, if none of the other criteria of verification succeeded in doing so.⁷⁹ I find no conclusive evidence for this view;⁸⁰ rather, all of the criteria listed above once again suggest an essentially un-experimental, if not anti-experimental, posture, as does the very concept of ‘transmission’.

The third main leg of the methodological tripod is 'transition by way of the similar'. If one wishes to understand the Empirics' concept of *metabasis*, one must divest one's mind of the specific semantic dimensions given to expressions like 'transition', 'analogy', 'model', and so on by some modern scholars (such as Professor Mary Hesse). The Empirics refer to a simple operation by analogy from one medicament to another, from one disease to another, from one part of the body to another, on the basis of as many observed, visible similarities as possible. It has been maintained with firm conviction and considerable authority that this procedure must always culminate in a successful experiment, without which it would be incomplete.⁸¹ And we saw earlier, in the case of an experiment designed to test the hypothesis that liquid enters the windpipe, that the principle of analogy is indeed not necessarily excluded from experimental procedures. Fortunately, clear statements of the principles and circumstances that motivated the use of the Empirics' analogical method survive and we are hence able to judge its relation to the experimental method. Thus, for example (in a Latin translation of the fourteenth century): "similis igitur transitio per se sola fiens, absque quod iudicet ystoriam et etiam quando agit, hoc ad trivicam idest eruditam nos ducit experientiam, non quod certitudinaliter est verum, sed possibilis inventionem promittens; concordie fidedignorum ystorie fidelis existentis et ante experientiam, sed transitioni ad similia nondum credimus, ante trivicam experientiam tanquam vere."⁸² The emphasis on *trivica experientia* (used to render the Greek *πείρα τριβική*) is one element in this text that may have prompted the claim that the Empirics' *metabasis* must end in a successful experiment. Another is perhaps the statement that this method of analogy leads to *trivica experientia* "not because the truth is certain, but because it promises discovery of the possible" – which could suggest a form of testing. This emphasis on the analogical method as a heuristic tool is echoed several times in Empiric literature:⁸³ it is ἡ ὁδὸς ἐπὶ τὴν εὕρεσιν, a way to discovery, or again, an ὄργανόν τι βοηθημάτων εὑρετικόν, a tool capable of discovering remedies. One is reminded of what was said above about the heuristic orientation of some experiments. Also of significance in this connexion is the sentence εὕρεσις δ' οὐδέπω πρὸ τῆς πείρας, the discovery does not occur prior to the πείρα (*τριβική*). Finally, there is the assertion that the Empirics do not grant analogy-to-the-similar credence prior to a *trivica experientia*, apparently indicating that the latter is a test. Cumulatively, these factors could suggest the use of experimentation and they must be discussed briefly.

The concept of *πείρα τριβική* is central to judging whether or not the analogical method always culminated in experiments. Galen reports that this kind of *πείρα* was called *τριβική* "because the person who intends to discover anything in this way (viz. by analogy) must be practised (*τετρίφθαι*) in the science"⁸⁴ of medicine. It is, in short, a test or experience founded on medical *practice* and *expertise*, whereas, Galen adds, the sorts of *πείραι* the Empirics prefer – "those that are discovered prior to *ἐμπειρία*" (involuntary, improvised, and repetitive) – "... can happen to any random person too." Only the practical experience of the agent is emphasized as a distinguishing feature of this *πείρα*, not his use of scientific experiments. That this 'practice' is in fact no less *ἄτεχνος* and *ἄλογος* than the *τριβή* in Plato's *Phaedrus* (260e, 270b), and that the 'test' is no more experimental than many practical measures taken in everyday life is made clear by the definitive examples, cited by the Empirics themselves,⁸⁵ of the use of the analogical method.

One example is that of applying a remedy that is known to have been effective against erysipelas ('St Anthony's fire') to a similar skin disease, namely shingles. Another consists of using the measures known to have been effective in the treatment of the arm to the treatment of the thigh, because of the similarity of these two limbs. A third example

is the use of a remedy (the fruit of the medlar tree) similar to one known to have been effective (quince) in the treatment of the same disease.

Important differences between this means of discovery and the experimental method discussed in the first part of this paper emerge here. None of these examples involves the creation of artificial or unnatural conditions designed by the scientist, as did the experiments discussed earlier (staining the pig's water; putting a bird in a cage without food; trying to force air or water into the heart through the heart-valves). Nor do they exhibit or require any interest in controlling the variables known to the scientist (weighing the excreta along with the bird, using red dye, etc.). They are neither motivated by causal explanation nor by a desire to generalize any hypothesis, but rather by the practical question 'What will work in this particular case right now?' – and the answer is uniformly simple: 'Let us try whatever worked in a similar case.' That is all that this *πείρα* represents: the *ad hoc* 'trying out' of similars, without any attempt at understanding or formulating *why* or *how* similar things either have similar effects or are affected similarly. The only practice or experience required is that of knowing what previously was effective. 'Similar' itself is used in a very broad sense, and its use does not represent any attempt at scientific classification: quince is like medlar, arm like thigh, St Anthony's Fire like shingles – and there is no need to say or explore why these may legitimately be regarded as similar.

Undoubtedly this method can, in practice, be useful and produce a significant increment of therapeutic measures, but the influential claim that it involved scientific experimentation cannot be substantiated. There is, moreover, evidence that the Empirics were not entirely happy about even the limited amount of thought and action required by the analogical method. From the outset they assigned it a role that was subordinate to that of the other two main parts of the tripod.⁸⁶ Furthermore, there are clear indications that successive generations of Empirics became increasingly uncomfortable with some rationalistic implications of this method and therefore modified or abandoned it.⁸⁷

Not only did none of the three main parts of the Empiric theory of scientific method therefore prescribe or involve experimentation, but their views on causal explanation were also in marked contrast to those of experimental scientists like Erasistratus. They were disinclined to engage in hypothesis or theory formation and in causal explanation (οὔτε δὲ πάθος εἰδυῖα οὔτε αἰτίας ἐξετάζουσα),⁸⁸ as I indicated above. Whereas the 'rationalists' tried, on the basis of what was visible, to formulate a causal hypothesis and to prove or verify it (sometimes by an experiment) in order to discover a cure, the Empirics relied primarily on repeated observation.⁸⁹ They were not interested in non-apparent causes or invisible principles, they did not probe into anything that does not lie on the surface, they were not interested in the *physis*, *arche*, or *aitia* of anything. In short, their general emphasis on experiential passivity – which is often characteristic of philosophical empiricism too – smothered any active interest in experimentation.

One might reasonably conclude that they practically proposed empirical data collection in which the only differential appraisal consisted of determining general statistical frequency. They remained unshaken by the infinity of individual appearances and used it in their own favour. Their concessions to statistical confirmation, to probabilism, analogy, and improvisation were not enough to render their theory conducive to experimentation. They firmly established *πείρα* as a concept that was, in fact, inimical to experimentation, and their interpretation of *πείρα* dominated medical science for several centuries. If my analysis is correct, the inhibiting effect of their brand of empiricism on experimentation may have been considerable.

* * * * *

Perhaps it has become clear why I suggested at the outset that one might gain more insight into the problems associated with this protracted dispute, first, by taking a more critical look at experiments that were actually conducted and at the flaws they exhibit; second, by distinguishing as clearly as possible between times that were favourable to experimentation and those that were less so, instead of generalizing even about a single branch or epoch of ancient science; third, by examining more closely the attitudes to experimentation that are reflected in ancient theories of scientific method. It is of course true, as Professor Sabra and others have pointed out, that a scientist's methodological rules and theories often serve as no more than *machines de guerre* which can be directed against the adherents of rival theories but which often have little or nothing to do with his own scientific practice.⁹⁰ Yet in the case of the two centuries dealt with here — and not infrequently in ancient scientific history — there seems to have been an unusual isomorphism of methodological theory and practice.⁹¹ Here some of the vicissitudes in the history of experimentation can accordingly also be illuminated by exploring developments and changes in theories of scientific method, rather than focussing exclusively on those economic, social, political, and religious circumstances which, without question, also are numbered among the determinants of scientific practice.

Like many ancient experiments, some of those examined above exhibit severe flaws, and most are inconclusive; but by closing the door to experimentation the Empirics locked up an important tool of scientific investigation. Like Goethe, they viewed confirmation of hypotheses by experimental tests as a classical case of self-delusion. If nature should not and cannot be known, she will also not be tampered with.

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NOTES

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1 *Novum Organum* I. 73; but cf. I. 63.

2 See especially Book I, Chapter 3, sect. 2 and Book II. Cf. also pp. 68–72 of Thomas Fowler's introduction to Bacon's *Novum Organum* (2nd ed., 1889).

3 Burnet, *Early Greek Philosophy* (4th ed., 1948) 27; *Essays and Addresses* (1929) 253 f. Edelstein, "Recent Trends in the Interpretation of Ancient Science," *Journal of the History of Ideas* 13 (1952) 573–604; reprinted in Edelstein, *Ancient Medicine*, ed. O. and C. L. Temkin (1967) 401–39 (see especially pp. 403, 406–7). Farrington, "The Greeks and the Experimental Method", *Discovery* 18 (1957) 68–9. Lejeune, "La science grecque a-t-elle atteint le stade expérimental?", *Revue des questions scientifiques* 128, 5th ser. 18 (1957) 321–43. Crombie in *Critical Problems in the History of Science*, ed. Marshall Clagett (1959) 81 (the Greeks' "brilliant idea of the generalized use of scientific theory tailored according to the principles of non-contradiction and the empirical test"). Zubov, "Beobachtung und Experiment in der antiken Wissenschaft", *Das Altertum* 5 (1959) 223–32. See also G. E. R. Lloyd's review of Edelstein, *History of Science* 7 (1968) 125–8; F. Kudlien, *Der Beginn d. Med.* (1967) 135–9.

4 This view is represented with varying degrees of differentiation, subtlety and conviction, and the authors listed here are not always in agreement with each other. Sambursky, *The Physical*

- World of the Greeks* (1956) 2. Thomson, *History of Ancient Geography* (1948) 94. Lee, *Aristotle's Meteorologica* (1952), xxvii (Loeb ed.). Vernant, "Remarques sur les formes et les limites de la pensée technique chez les Grecs", *Revue d'histoire des sciences* 10 (1957) 205–25. Verdenius, "Science grecque et science moderne", *Rev. philosophique* 152 (1962) 319–35. Momigliano, *JRS* 31 (1941) 149–57. Von Fritz, *Grundprobleme der Geschichte der antiken Wissenschaft* (1971) 3 (but cf. pp. 73–5, 116 ff., 550–4). See also J. Mittelstrass, *Die Rettung der Phänomene* (1962) 232.
- 5 Cf. A. D. Ritchie's defence of Aristotle against Russell's charges: *Studies in the History and Methods of the Sciences* (1958) 18–19.
- 6 "Experiment in Early Greek Philosophy and Medicine", *Proc. Cambridge Philol. Soc.* 190, N.S. 10 (1964) 50–72.
- 7 *Am. Journ. Physics* 34 (1968) 168–9. Cf. O. Blüh in the same journal, vol. 17 (1949) 384–8.
- 8 Cf. von Fritz, *op. cit.* 550–4, 75.
- 9 ἐμπειρία, τήρησις, πείρα, σημείωσις, ἐπιμαρτύρησις, οὐκ ἀντιμαρτύρησις, μετάβασις καθ' ὅμοιον, ἀναλογία, ὑπόθεσις, ἐνδειξις, ἀπόδειξις, σημείον, and corresponding verbs. (Cf. e.g., the *loci* cited s. vv. in the indices verborum of SVF IV; G. Arrighetti, *Epicuro*; Ph. and E. De Lacy, *Philodemus on Methods of Inference*; K. Deichgräber, *Die griechische Empirikerschule*.) The interaction of medicine and philosophy was considerable in the third and second centuries B.C. but it would be impossible to discuss the relationship properly within the scope of this paper.
- 10 *Anonymus Londinensis*, ed. H. Diels (*Suppl. Aristotelicum* III. 1, 1893), col. XXII. 8 ff., XXX. 40 ff. Cf. also the edition by W. H. S. Jones, *The Medical Writings of Anonymus Londinensis* (1947; repr. 1968). The source of this theory of emanations may have been Aegimius (cf. *RE* VI, col. 339). Diels' views concerning the influence of Strato on Erasistratus (*Sitz.-Ber. Berl. Akad.* 1893, 3 ff.) are in need of reconsideration.
- 11 Col. XXX. 40–XXXI. 25; XXXII. 31–XXXIII. 14.
- 12 XXXIII. 14–43.
- 13 On the date of Erasistratus see P. M. Fraser, *Rend. Ist. Lombardo* 103 (1969) 518 ff.; in the early Hellenistic period his reputation was rivalled only by that of Hippocrates and Herophilus (ca. 330–250 B.C.). Cf. R. Fuchs, *Erasistratea* (1892); M. Wellmann, Pauly-Wissowa's *RE* VI, cols. 333–50; I. M. I. Lonie, *Bulletin Hist. Medicine* 38 (1964) 427–43; L. G. Wilson, *ibid.* 33 (1959) 293–314.9
- 14 XXXIII. 44–51. Cf. also fragment I. See von Fritz' suggestion (p. 75, n. 138).
- 15 *Conjectures and Refutations* (3rd ed., 1969) 141 (italics mine). Cf. *The Logic of Scientific Discovery* (1959) 106 ff., 280, 45–6.
- 16 *Timaeus* 70c1–d6, 91a. (In 70d, 72e, 78a–b, Plato does, of course, confirm that most drink goes with food to the stomach.) Cf. Plutarch's list (*Stoic rep.* 29) of others – among them, Euripides, Alcaeus, Eupolis! – who supported the view that drink also enters the lungs.
- 17 *Parts of Animals* 664b3–36.
- 18 VII. 604–8 Littré. Each of the 'facts', many of which are blatantly erroneous, is called an ἱστορίον (fact in proof).
- 19 Cf. K. H. Abel, "Die Lehre vom Blutkreislauf im Corpus Hippocraticum", *Hermes* 86 (1958) 201 ff. See also Lonie, *op. cit.* Although I agree that *On the Heart* postdates Erasistratus' research on the cardiac valves, and that it shows signs of Stoic influence, the evidence for the argument that it postdates Posidonius seems rather thin (cf. F. Kudlien, *Hermes* 90 (1962) 419–29).
- 20 *On the Heart* 2 (IX pp. 80–82 L).

- 21 R. B. Braithwaite, *Scientific Explanation* (1953) 12–21 (especially p. 14) and *passim*.
- 22 *Philosophy of Natural Science* (1966) 8.
- 23 Cf. J. Wachtler, *De Alcmaeone Crotoniata* (1896) 71–2. It is true that Plato uses *arteria* only in the sense of “airduct” (*Timaeus* 70d2, 78c5–6) and *phlebs* of the bloodvessels, but the “airduct” is the windpipe and its extensions, not an artery. Aristotle too uses *arteria* only of the windpipe and the bronchi, not of arteries, and *phlebs* for bloodvessels (cf. Bonitz s.vv.).
- 24 F. Steckerl, *Praxagoras of Cos* (*Philosophia Antiqua* 8, 1958), fr. 85 (cf. fr. 28–31 and pp. 17–27).
- 25 Cf. Diogenes Laertius VII.186; but see also VIII. 87 and VIII. 89. It is difficult to know whether Erasistratus’ teacher is identical with either of the other physicians by this name. Galen’s references to Chrysippus medicus are informative but do not help to establish his identity more exactly (Galen, *CMG* V.10.2, 2 p. 44 Wenkebach; XI p. 221 and 230 Kühn, etc.). See also Wilamowitz, *Philologische Untersuchungen* 4 (1881) 324 ff.; M. Wellmann, *Hermes* 35 (1900) 371 ff., 379; Fraser, *loc. cit.*
- 26 The author does not always distinguish clearly between *arteria* as “artery” and *arteria* as “wind-pipe”. Cf. *De spiritu* 482b14–15, 484a35. The common and authentic Aristotelian use of *arteria* to signify the trachea alone survives in 483b3, b12, b14–15, and so on.
- 27 Cf. *Anonymus Londinensis* XXVI. 31–XXVIII. 12; Galen III. 492 Kühn; II. 75K, 95K, 104K; XI. 152f.K, and numerous other testimonia. Galen also devoted an entire treatise to a refutation of Erasistratus’ view (*An in arteriis natura sanguis contineatur*, ed. F. Albrecht (1911); IV. 703–736K). A new edition by D. J. Furley and J. S. Wilkie is in preparation. On Diels’ views about Strato see n. 10.
- 28 But see Steckerl, p. 17 n. 1.
- 29 Cf. Galen, *Scripta Minora*, Vol. II (1891) 104 and Albrecht, *op. cit.*, pp. i–ii. This is by no means conclusive evidence.
- 30 Cf. Galen VIII 940K; *Scripta Minora* III 155; Albrecht, pp. ii, 29–30. Again insufficient evidence.
- 31 See n. 6; also Galen II. 641–650K.
- 32 Galen *an in arteriis* . . . IV. 721–2K. The text that follows, especially pp. 723–5, has been restored by Professors D. J. Furley and J. S. Wilkie, *CR* n.s. 22 (1972) 164–7, who also briefly discuss four of the problems that may have led the Erasistrateans to this view; only one of these is immediately relevant here.
- 33 Albrecht, p. 12. 24–25 (corresponds to IV. 722K, which is, however, corrupt).
- 34 *Synanastomosis* is apparently one of Erasistratus’ many neologisms, formed with a characteristically Hellenistic double prepositional prefix. Cf. Galen IV. 709K; VIII. 352K; II. 152K. (See also II. 597K on the origin of the pneuma in the heart.)
- 35 From Galen’s *On Anatomical Procedures* VII. 16 (II. 646–648K). The same test is described in IV. 733–734K, and a similar anti-Erasistratean test with a somewhat different purpose IV. 725K (see Furley and Wilkie, *loc. cit.*). Galen alternates between πείρα and ἐγχείρησις as the word for “experiment”, but generally seems to prefer ἐγχείρησις or the corresponding verb. Cf. M. P. Amacher, *Sudhoffs Archiv* 48 (1964) 177–80.
- 36 Galen’s comment, after mentioning Erasistratus’ account of the test, is: “So great is the rashness of those who make precipitous assertions about things they have never seen” (II. 648K). This general statement is characteristic of Galen’s often abusive and hyperbolic polemics and should not be given much weight. It is more than countered by the statement with which Galen concludes *An in arteriis natura sanguis contineatur* (II. 736K; cf. Albrecht, p. 21): Erasistratus was often badly mistaken, “but Erasistratus was not shameless to such an extent that he tried to record what in fact could not be seen.”

37 IX.88L.

38 Cf. F. Solmsen, "Greek Philosophy and the Discovery of the Nerves", *Mus. Helv.* 18 (1961) 150–197.

39 Cf. Edelstein, *Ancient Medicine*, 247–301. Sound criticisms of Edelstein's views were made by Lloyd, *History of Science*, *loc. cit.* (n.3 above) and F. Kudlien, "Antike Anatomie und menschlicher Leichnam", *Hermes* 97(1969) 78–94, who advances convincing reasons (87 ff.) for the rise of human dissection.

40 Cf. *On Respiration* 471b19 ff., 479a3 ff.; *Progression of Animals* 708b4 ff.; *Hist. An.* 519a27 ff. The vivisection experiment with the pig, discussed above, is further evidence of the persistence of this practice, as are Galen's vivisection experiments with animals (e.g., *On Anatomical Procedures* XIV.7 Duckworth).

41 Celsus, *prooem.* 23 (CML 1.21.14-17): "Necessarium esse incidere corpora mortuorum eorumque viscera atque intestina scrutari; longaeque optime fecisse Herophilum et Erasistratum, qui nocentes homines a regibus ex carcere acceptos vivos inciderint considerarintque, etiamnum spiritu remanente, ea quae natura ante clausisset. . ." *Regibus* probably refers to Ptolemy I Soter and Ptolemy Philadelphus (possibly, in the case of Erasistratus, also to Seleucids). Human cadavers also seem to have been widely available for the first time; Tertullian expresses his outrage at this: "Herophilus ille medicus aut lanus qui sexcentos exsecuit ut naturam scrutaretur. . ." (*De anima* 10.4, p. 13 Waszink). See, however, Fraser, *loc. cit.* 532.

42 I am referring not just to ritual and mythical violence (on which see, e.g., W. Burkert, *Homo Necans* (1972) and "Buzyge und Palladion", *Zeitschrift für Religions- und Geistesgeschichte* 22 (1970) 356–68), but especially to instances such as Alexander's excesses (the Massaga massacre, the murder of Parmenion and Cleitus, the destruction of Thebes, etc.); cf. also Cassius Dio's account of Commodus' murder of invalids (LXXIII. 20.3) and of how this son of Marcus Aurelius sliced off the ears, noses, "and other features" of gladiators in the privacy of his palace (LXXIII. 17.2); Appian's account of the crucifixion of 6,000 followers of Spartacus "along the entire road from Capua to Rome" (*Civil Wars* I. 120); the death of Cicero – or, for that matter, Michael Grant's judgment that only the Nazis slaughtered more human beings than the Romans. Recent chapters in the history of vivisection are discussed in Paul A. Freund (ed.), *Experimentation with Human Subjects* (1972).

43 Celsus, *loc. cit.*; Tertullian, *De an.* 10.4, 15.3, 15.5. Aetius, *Plac.* IV.5.3-4 (*Dox. Gr.* p. 391; cf. 203-13 and ps.-Gal. XIX.315K). Ps.(?) Rufus, *Anat.* 71-4 (pp. 184-5 Daremberg/Ruelle). Galen, *UP* 8.11 (I.482-4 Helmreich), 8.13 (I.488H), 9.6 (II.19H); *Plac. Hipp. Plat.* 7 (pp. 598-608 Müller); *On Anat. Proc.* 9.9 (pp. 9-10 Duckworth); *CMG* V.10.1, pp. 330-1 Pfaff; II. 570-1, 712, 719, 731, 895K; VII.605K; VIII.212-3K. Vindician, *Gyn.* 1-3 (pp. 428-31, 464 Rose). Theophilus Protospatharius, *Corp. hum. fabr.* IV.5.4-5 (p. 135 Greenhill).

44 Galen, *Plac.* 606/7 Müller: ". . . Erasistratus thought that a living thing becomes paralysed immediately as a result of a lesion of the membrane (sc. dura mater). For he observed in the case of oxen that when they are subjected to lesions at the first vertebra, the animal becomes immobile simultaneously with the incision of this membrane. . ." I am inclined to regard Erasistratus as the source of Galen II. 683-4K, since it is documented that Erasistratus distinguished between sensory and motory nerves, that he observed paralyses resulting from various lesions, and that he explored the spinal cord. (Galen often failed to mention the sources of his data and arguments or the originators of experiments which he himself also conducted; thus there is no mention at all of Erasistratus in Galen's long books on the cranial and spinal nerves, and only one mention of Herophilus, characteristically merely in the context of nomenclature: *On Anat. Proc.* Books XIV–XV.)

45 Cf. Stephen Toulmin, *The Philosophy of Science* (1953) 66 ff.

46 Kudlien, *loc. cit.* 90-94.

47 Epicurus, *ad Pyth.* 87, 97; Sext. Emp. VIII. 142; Philodemus *On Methods of Inference*; cf. SVF II p. 73.

48 Cf. Braithwaite, p. 295; Hempel, pp. 19-20.

- 49 The use of εὐρήσει or εὐρήσεις in the apodosis of experimental conditions is widespread. In the Hippocratic Corpus I have noted *Women's Diseases* I.1, *Nature of Embryo* 17 and 29, *Sacred Disease* 11, *Airs, Waters, Places* 8.
- 50 Double premisses, one expressed in the optative, the other in the subjunctive, also occur in other descriptions of experiments; cf. *On Disease* IV.39, 51, 57; *On Semen* 9; *Nature of Embryo* 17.
- 51 G. Senn, "Über Herkunft und Stil der Beschreibungen von Experimenten im Corpus Hippocraticum", *Sudhoffs Archiv für Geschichte der Medizin* 22 (1929) 217–89, esp. 231 ff. has excellent comments on the syntax and style of descriptions of experiments in the Hippocratic Corpus.
- 52 *Anon. Londin.* XXI.23–6. Cf. the conclusion of the first experiment described above. See the judicious comments on θεωρούμενον by D. J. Furlley in *Essays in Ancient Greek Philosophy*, ed. J. P. Anton and G. L. Kustas (1971) 615.
- 53 The authenticity of the authorship is still in doubt. *Medicorum Graecorum Opera* XXVI, pp. 49 f. Sprengel; improved text in Deichgräber, *Empirikerschule* fr.25. Much of the terminology used in this dispute has Stoic and Aristotelian overtones; ἀληπτος or ἀκατάληπτος, κατ' εἶδος and κατὰ γένος, ἡ ἐπαναβεβηκυῖα καὶ καθολικὴ (sc. αἰτία).
- 54 Ps.-Dioscorides, *ibid.*, p. 51 Sprengel.
- 55 Cf. SVF II pp. 264, 268, 273, 120–2; Ps.-Galen XIV.692K. M. Pohlenz, *Die Stoa* vol. II (3rd ed. 1964) 60–61 argues that Chrysippus was influenced by Erasistratus. Cf. Sambursky, *Physics of the Stoics* (1959) 60. Erasistratus' polemics against the concept of 'procatactic' cause should, however, also be taken into account (Galen, *De causis procatacticis*, *CMG Suppl. II*, ed. Bardong, pp. 23–45). See n. 89.
- 56 E.g., *Anon. Londin.* XXI.25; XXIII.9.
- 57 Erasistratus' contemporary Herophilus assumed a much more cautious posture in his views on causality, explanation, and theory formation, ascribing most value to visible appearances and experience. See Kudlien, "Herophilus und der Beginn der medizinischen Skepsis", *Gesnerus* 21 (1964) 1–13. One must, however, guard against seeing too much of a Sceptic (or even Empiricist) in Herophilus; not only was he a very active anatomist but he also believed in four *dynameis*, his pathology was based on a theory of humours, he was willing to talk about things like the *hegemonikon* and the classification of dreams by putative source – and according to the doxographer Aetius (*Dox. Graec.* p. 320) he used, on occasion, the same distinction between τὰ αἰσθητά and τὰ λόγῳ θεωρητά as Erasistratus (see n. 52).
- 58 F. Wehrli, *Die Schule des Aristoteles* 10, pp. 96, 101, 103 (1st ed.).
- 59 Philodemus, *Rhetoric*, *passim*. Cf. P. and E. De Lacy, "Ancient Rhetoric and Empirical Method", *Sophia* 6 (1938) 523–30.
- 60 Excellent collection and evaluation of testimonia by K. Deichgräber, *Die griechische Empirikerschule* (1930, 2nd ed. 1965). Further important considerations were raised in R. Philippson's review of Deichgräber, *Philologische Wochenschrift* 51 (1931) 1201–13.
- 61 It is not an uncommon belief that empiricism and experimentation always go hand in hand. Cf. Paul Feyerabend, "Problems of Microphysics", in *Philosophy of Science Today*, ed. S Morgenbesser (1967) 138–9, on the period of classical physics (Galileo, Newton, Faraday, Maxwell): "The official philosophy is still empiricism – and indeed a very militant *empiricism* it is. Speculation is discouraged . . . *experimentation* and the derivation of observational results are regarded as the only legitimate manner of obtaining knowledge." (My italics)
- 62 Deichgräber, pp. 121–30, 44–51, 65–80, 90–96; R. Walzer (ed.), *Galen on Medical Experience* (1944).
- 63 This is, of course, a residue of many *physis-tyche* debates.
- 64 Deichgräber, pp. 44–45; cf. pp. 94–95.

- 65 *Ibid.*, p. 45; p. 95.
- 66 *Ibid.*, 95.7-8.
- 67 Cf. LSJ s.v. Cf. also αὐτοσχεδιάζειν in Plato, *Crat.* 413d and Thuc. I. 138, as well as σχεδιάζειν in Philodemus *Rhet.* I. 100 (Sudhaus). The pejorative use of αὐτοσχεδιάζειν ("speak or act precipitously or ill-advisedly") found in Plato's *Euthyphro* 5a, and of words like σχεδίασμα ("whim, freak") does not seem to occur in medical literature, and certainly is not represented here.
- 68 περίπτωσις, τὸ περιπτωτικὸν εἶδος τῆς ἐμπειρίας, and ...περίπτωσιν ὠνόμαζον ἀπὸ τοῦ περιπίπτειν ἀβουλήτως τοῖς πράγμασι. . . (Deichgräber p. 95.5-7). As Deichgräber points out, they have this emphasis on the involuntary (ἀβούλητον) in common with the Sceptics; cf. Sext. *Emp. Pyrrh.* I.22.
- 69 Deichgräber, p. 292, with reference to the distinction between αὐτοσχέδιος and αὐτοματική πείρα: "Eine πείρα kann mit oder ohne unseren Willen eintreten, sie kann ein Experiment sein (sc. αὐτοσχέδιος) oder eine hingenommene, nicht gesuchte (sc. αὐτοματική) Erfahrung. . ." Cf. p.293, concerning an example of αὐτοσχέδιος πείρα: ". . .möchte man vielleicht geneigt sein, hier etwas wie das moderne Experiment zu vermuten." Deichgräber is, however, aware of the complexity of the experience called αὐτοσχέδιος πείρα: ". . .das moderne experimentelle Verfahren (ist) nur als Unterart in dieser Gattung der Empirie enthalten" (p. 294).
- 70 Deichgräber, p. 45.4-12: autoscedia vero experientia fit sicut. . .morsus in monte ab aliqua fera advenit ei hanc herbam apponere et abinde iuvari.
- 71 *Ibid.* p.95.7-8: ὅταν ἐκόντες ἐπὶ τὸ πειράζειν ἀφίκωνται ἢ ὑπ' ὄνειράτων προτραπέντες ἢ καὶ ἄλλως πως δοξάζοντες.
- 72 *Ibid.*, pp. 78.26- 79.4.
- 73 *Ibid.*, 79.4.
- 74 *Ibid.*, 45.4-9.
- 75 Cf. R. Walzer, *op.cit.*, Ch.XV. The empirical 'theorems' that result from this repetition are then arranged into four groups according to their relative coincidence (and hence their scientific probability?). The total collection of theorems in turn constitutes medical science: τὸ σύμπαν ἄθροισμα.
- 76 Deichgräber, p. 103.17-18.
- 77 *Die Ausdrücke für den Begriff des Wissens* (1924), 64 ff.
- 78 P. 298, n. 2.
- 79 "Erst wenn alle diese Kriterien nicht ausreichen, soll man den Versuch machen, die Überlieferung durch ein eigenes Experiment nachzuprüfen" (Deichgräber, p.300).
- 80 The only example cited in support of this view (fr. 16, p. 96.29 ff.) is not particularly convincing. It refers only to the legitimacy of corroboration through personal experience, not to any experiments.
- 81 ". . .dieses Prinzip (erhält) seinen letzten Abschluss erst dann, wenn auf diesem Wege die Erfahrung erfolgt ist, das Experiment, hier liegt nun wirklich ein solches vor, gelungen ist" (*ibid.*, p.302; my italics).
- 82 Nicolaus of Reggio's translation (dated 1341) of Galen's *Subfiguratio Emperica*, Deichgräber p.71.11-22.
- 83 Deichgräber, p. 95.30-31, 95.23. Cf. pp.95.32-96.2.
- 84 *Ibid.*, p. 96.2-3,
- 85 *Ibid.*, p. 95.27-30.

- 86 The Empiric Serapion (fl. 225 B.C.) already relegated it to a subordinate role according to Galen: “neque etiam similis transitio equivalens est particula (sc. artis medicativae) per se inspectioni et hystorie . . . et neque Serapio aliter cognoscebat” (*De partibus artis medicativae* 6.6, *CMG Suppl. Orient.* II, p.125; this treatise is extant only in Latin and Arabic translations – the Latin version is confirmed by the Arabic, *ibid.* pp.40, 42). “Per se inspectio” is αὐτοψία, the first leg of the tripod (i.e., ἐμπειρία). Elsewhere too Galen confirms that the role of this analogical method was strictly limited: ἐπειδὴ δὲ καὶ νοσήμασί τισιν ἐνετύγχανον ἔστιν ὅτε πρόσθεν οὐχ ἑωραμένοις ἢ τισιν ἔγνωσμένοις μὲν, ἀλλ’ ἐν χωρίοις ἐν οἷς οὐκ ἦν ἱαμάτων εὐπορία τῶν διὰ τῆς πείρας τετηρημένων, . . . ἐποίησαντο τὴν τοῦ ὁμοίου μετάβασιν (*Deichgräber*, p. 95.20-24).
- 87 Menodotus (fl. ca. 125 A.D.), for example, claimed that Serapion had not even recognized it as the third component of the Empirics’ tripod, conceding only that he may in practice have used it (so Galen, *Subfiguratio emperica* 4; *Deichgräber* p.49, 23-29). Cf. also Galen, *De part. artis med.* 2.1: in constitutivis vero (sc. partibus artis medicativae) per se inspectionem quidem et hystoriam universi (sc. Emperici), similis vero transitionem non omnes enuntiarent esse partem artis (*CMG Suppl. Orient.* II, p.120; corroborated by the Arabic version, p.26). Cf. also *Deichgräber*, pp.303-4.
- 88 *Deichgräber*, p.91.15; cf. 91.31, 94.33-34. There are also less radical statements, for example in Galen’s *De causis procatarcticis* 162 (extant only in Nicolaus of Reggio’s Latin translation): “Quidam enim nil nullius dixerunt existere causam, quidam vero dubitaverunt si est an non, sicut emperici . . .” (*CMG Suppl.* II, pp.41-2); “. . . et qui ab emperia medici observare super aliquos alios ea quae secundum vitam proponentes tamen a sophismate devicti sunt ita ut dubitarent de procatarcticis causis et nichil enunciare auderent de ipsis” (*ibid.*, p.44). Cf. nn.52-56.
- 89 Cf. *Deichgräber*, p.97.17-23. If the Empiric takes into consideration any ‘cause’ at all, it is only the ‘procatarctic’ (see n.55), i.e. the one that immediately and visibly causes a morbid condition, such as a snake-bite as a ‘cause’ of poisoning or a dog-bite as a ‘cause’ of rabies. He does not try to investigate, however, why a dog-bite causes rabies, not even in order to find a cure. Cf. *Deichgräber*, fr.89 and 90 (p.144). And even about ‘procatarctic causes’ – all of which, in the examples cited by the Empirics, lie within the realm of the visible – the Empirics were divided, uncomfortable, and non-committal.
- 90 A. I. Sabra, *Theories of Light from Descartes to Newton* (1967). See L. Laudan, “Theories of Scientific Method from Plato to Mach”, *History of Science* 7 (1968) 1-63. Cf. also Lord Zuckerman, *TLS* No.3689 (17 November 1972) 1393: “Scientists are brought up to believe that there is a genuine antithesis between theory and practice . . .”
- 91 Thomas Kuhn, *Structure of Scientific Revolutions* (1962), argues persuasively that the methodological standards of an epoch – e.g. the criteria of acceptable explanations and the canons for sound experimentation – often affect the practice of science and “can never be dismissed a priori as irrelevant”. Cf. also the influence of positivism on the practice of social scientists in this century.