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THE IMPERIAL EXAMINATIONS AND EPISTEMOLOGICAL OB-STACLES

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ABSTRACT

In this paper, my aim is to provide a partial answer to Needham's Grand Question, by arguing that the imperial examinations were 'epistemological obstacles' which hindered the development of modern science. I further argue that these obstacles were present in the European universities as well, after which I elucidate the role of competitive patronage in overcoming these obstacles.

1 Introduction

Over the course of his career Joseph Needham devised several formulations of what has become known as 'Needham's Grand Question' While each of those formulations share a common background, they are all subtly different questions: why modern science failed to arise in China (Needham 1972a), what the inhibiting factors in Chinese civilization that

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prevented such a rise were (SCC, I), or why modern science was developed in Europe rather than in China, despite the latter's superior technology. (Needham 1972b)

Each of these questions is of interest, but all things considered, an answer to any of them will always be incomplete. The fact that a Scientific Revolution has only occurred once in history, and the sheer scope which the investigation requires, render it unlikely that a single cause will ever be pinpointed as the sole responsible factor – or even as the primary responsible factor.

This does not mean that there is reason for cynicism. Needham's Grand Question does not need to be entirely abandoned. One can consider the various causes invoked in its solution; one can investigate factors in Chinese and European society that allow for local comparison. By dividing the question into various subquestions, and scrutinizing them, one might on the long run develop an outline of an answer to the larger question. For the purpose of this investigation, I shall consider Needham's Grand Question in its comparative form: I shall consider the social and educational backgrounds of scholars in both Europe and China, and consider whether there are any factors that may have made a significant difference in the development of science.

The imperial system of examinations has often been held responsible for hampering China's development of modern science. In fact, it has often been claimed to be the sole or primary inhibiting factor in that regard. The eminent historian of Chinese science Nathan Sivin has responded quite viciously to such a claim (cfr. infra) – and not unduly. Often, the inhibiting nature of the imperial examinations has been taken for granted, without consideration of the situation in Europe. In this paper, I shall provide arguments for the inhibitive nature of the examinations rather than taking it for granted. By identifying a number of ways in which the examinations institutionally embedded so-called 'epistemological obstacles', I hope to shed light on their inhibitive nature towards natural science. Three such obstacles can be identified: an inclination towards the reading of books (over the direct investigation of nature), an administrative-generalist focus and an inclination to conform to philosophical (and scientific) orthodoxy. After discussing these obstacles, I shall argue that, in many ways, European intellectual circles embedded the same obstacles. However, I also argue that one significant factor was present in Europe that was lacking in China: a competitive system of patronage, which proved a key method of social legitimation for innovating European scholars.

2 Epistemological obstacles

Before beginning with the argument proper, the concept of an 'epistemological obstacle', which was developed by the French philosopher of science Gaston Bachelard, must be introduced. The term is used to describe inhibiting ways of thinking that must be overcome if science is to progress. Bachelard identified many such obstacles: a conception of the unity of nature, overgeneralisation and even ontological realism. (Bachelard 1989) Most of these identifications are irrelevant to this paper, but I shall reference one particular obstacle. Despite the fact that I will only draw upon it later, I shall describe it here, as it might shed light on the concept.

Bachelard argues that a pragmatic attitude towards knowledge is an epistemological obstacle. Pragmatism is concerned with knowledge that can be applied; therefore it concerns itself with so-called 'common knowledge'. For Bachelard, 'common knowledge' is the form of knowledge that (a) is instrumental, (b) is wholly empirical, and (c) barely evolves. He construes scientific knowledge as the exact opposite of this formulation. Scientific knowledge (a) is not concerned with instrumentalism, (b) is theoretical, and (c) changes rapidly. These two forms of knowledge are separated by an 'epistemological rupture'. In a sense, common knowledge must be overcome in order to arrive at a scientific way of thinking. (Bachelard 1975, ch. 6)

Although this example clarifies the concept of an epistemological obstacle somewhat, it is rather radical. It could easily be debunked by a pragmatist. However, with some modifications, the argument is still forceful. A form of pragmatism that requires all knowledge to have an immediate impact in order to be worthwhile is indeed a hindrance to scientific thought. It is possible that the instrumental value of a scientific theory is only discovered centuries later. Therefore, a 'naïve' form of pragmatism can still be considered an epistemological obstacle.

Later on, I shall argue that this particular epistemological obstacle was institutionalized in the imperial examinations. Identifying such institutionalized obstacles was also part of Bachelard's programme. For instance, he complained about the passive way children acquire knowledge in schools: science is an active process, and this must be exemplified in the school system as well. (Bachelard 1989, 12.2) Thus, epistemological obstacles are not only found in abstracto: the ideological tendencies present in institutions such as the imperial examination system can be investigated as well.

When I use the term 'epistemological obstacle', I take it to mean a *negative causal factor* for the development of modern science. I do not consider causation in terms of necessary or sufficient causes; instead, I treat it probabilistically. I define causal factors in terms of Ronald Giere's theory of probabilistic causation on the level of populations. Although the theory only considers binary variables (i.e. the presence or absence of a particular trait), it can be extended to other variables. In the definition, the two variables are C and E, with respective values C and Not-C and E and Not-E.

> **C** is a *positive causal factor* for **E** in the population U whenever $P_X(E)$ *is greater than* $P_K(E)$.
> **C** is a *negative causal factor* for **E** in the population U whenever $P_X(E)$ *is less than* $P_K(E)$.
> **C** is *causally irrelevant* for **E** in the population U whenever $P_X(E)$ *is equal to* $P_K(E)$. (Giere 1997, p. 204)

U is the population under consideration. X is a hypothetical population obtained by changing the value Not-C into the value C for every member of the population U which exhibits the value Not-C. K is the hypothetical population obtained by changing the value C into the value Not-C for every member of the population U which exhibits the value C. The probabilities in the definition are the relative frequencies of the effect variable in the populations X and K.

In order for claims about the Scientific Revolution to be understood in this sense, they must first be reduced to claims about populations, but this feat is relatively easily achieved. As an example, consider the claim that the imperial examinations formed an epistemological obstacle for the development of modern science. Translated into Gierean terminology, the claim is that, if one were to construct a hypothetical population in which all Chinese scholars were immersed in the imperial examination system, there will be fewer Chinese scholars who develop a modern-scientific mindset than in the case obtained by constructing the hypothetical population in which no Chinese scholar is immersed in the imperial examination system. Necessary and sufficient factors therefore do not enter into the picture.

3 The imperial examination system

As mentioned before, there are (at least) three facets of the imperial examinations that may take the role of inhibiting factors in the development of scientific thought: their consumption of a scholar’s time, their administrative-generalist focus and their enforcement of orthodoxy. By not only considering the examinations as a whole as a stumbling block, but instead distinguishing several facets that served as epistemological obstacles, a comparison with the European situation shall prove to be possible. However, before one can appreciate the prevalence of these obstacles, it is necessary to review the curriculum of the imperial examinations and emphasize their status as an instrument of social advancement. After all, it is the high status of the examinations which allowed the epistemological obstacles to have such a great impact.

3.1 The curriculum

Since the Yuan dynasty (1279-1368), the curriculum primarily consisted of the so-called Four Books (*Daxue*, *Zhongyong*, *Mengzi* and *Lunyu*) and their interpretation by Zhu Xi (1130-1200), whose commentaries constituted orthodoxy until the abolition of the examinations in 1905. The orthodox status of his philosophy had a significant impact on how the examinations were corrected: every answer had to conform wholly to Zhu's orthodoxy. Showing not more than a sparkle of original interpretation in the answer to a question automatically implied failure, even if the candidate displayed flawless logic or brilliant ideas. This was not the only danger for a candidate: even a minor 'spelling' error had the same result. As if these dangers weren't threatening enough, a sufficiently inadequate answer even lead to the degradation of the candidate. (Cressey 1929, p. 256)

Aside from the Four Books, the Five Classics (*Yijing*, *Liji*, *Shujing*, *Shijing* and *Chunqiu*) were also popular material. Questions on these two sets of books generally involved both reproduction and commentary. The demands for reproduction were extremely high. The previous paragraph already indicates that the reproduced text should match the original completely. However, there was an added difficulty: the passage that had to be reproduced often was described very vaguely, so realizing what passage had to be copied already was an endeavor on its own. In one question, for instance, the examinee was asked to specify where in the *Lunyu* (better known as the *Analects* of Confucius) a specific series of three characters was found. In another question, the student was provided with a single sentence from a classic work; he then was expected to write the sentence that followed upon it (and explain the section.) (Miyazaki 1976, pp. 20-21)

Under the Ming dynasty (1368-1644), the government issued a more varied curriculum, adding fields of study such as horsemanship, archery, calligraphy, law and music. Particularly this last field is relevant, given the involvement of mathematics in the study of music. Questions in this field asked for the right length a pipe should have in order to produce the appropriate tones. (Elman 2000, p. 41 & pp. 477-481) Astronomical questions were asked as well, as this period was also a time of crisis for the Ming calendar, which had been accurate for many centuries, but was then increasingly deviating. (Elman 2005, 2) The questions range from the general to the specific: one question asks why the calendar had to be revised frequently; another asks why solar eclipses recorded in the Five Classics only occur on the first day of the month, while those recorded from the Han dynasty onward only occur on the last day of the month. (Elman 2000, pp. 468-469)

Not just any answer would do, however: even scientific questions like these had to be answered based upon the Dynastic Histories and Zhu Xi's philosophy. The political import of the calendar always had to be kept in mind. As a bureaucrat was supposed to be a moral and ritual generalist, he had to know how astronomy and mathematics as well as calendar studies and musical harmony fit within ritual orthodoxy. Of course, the other side of this coin meant that he only had to know them as far as they fit into this orthodoxy. (Elman 2000, pp. 472-473, 482-483)

3.2 The examinations and social status

The imperial examinations were central to Chinese society: they were the ideal manner for acquiring a higher status. Paul Cressey compares the successful graduate in Beijing with the Olympian victors of ancient Greece, and states that the honors received by the latter are nothing compared to the honor of a *jinshi* or palace graduate. (Cressey 1929, p. 254) After graduation, a student dined with high officials and received permission and finances to construct a triumphal arch in front of his house. His promotion was declared by imperial edict and inscribed upon a stone column on the terrain of the Imperial Academy, the *Guozijian*. (Miyazaki 1976, pp. 84-87)

If a student reached the palace examinations, the emperor himself would address him respectfully, as indicated by the introduction to the questions he (at least nominally) had prepared for the students:

> You graduates are talented men who have qualified in repeated examinations and now, facing the palace examination, are about to answer My questions. I am the Son of Heaven, responsible for governing the Empire. Night and day I rack My brains so that the people will be able to live in tranquility. Fortunately I have this opportunity to pose questions to you graduates and I wish to hear your well-considered opinions upon the following. (Miyazaki 1976, p. 77)

While these examples all refer to the final examinations held at the imperial palace, earlier examinations were also seen as very important. One can recognize their special status from many aspects in society, not the least of which being folk tales. The examinations were seen as a situation where men suffered bad karma or suffered the revenge of abandoned women. There are numerous tales about women returning from the dead as ghosts to haunt the examinees during their trials. These ghosts were reputed to cloud the minds of the examinees, or to hide their writing equipment, reducing their chances at passing. (Spence 1997, p. 45) The actions of such ghosts were considered to be just. In this view, failure on the examinations was seen as a result of past immoral behavior.

The high social status accorded to the examinations is noticeable in the context of marriage as well. Powerful families exerted pressure on palace graduates to divorce their wives and marry a member of the family. (Miyazaki 1976, p. 90) In *The Scholars* (*Julin Waishi*), a satirical novel about the examination system, this vast impact seeps through to the lower levels of society: a butcher who regularly assaulted his son-in-law refused to do so after he had graduated, claiming that to assault a graduate would cast him into the deepest hell for all eternity. (Miyazaki 1976, pp. 58-62)

Even in the context of Confucianism, which emphasizes the respect of the young towards their seniors, it was possible for elderly men to humble themselves before a young man with a higher degree. (Elman 2000, p. 286) An ancient Chinese proverb states that while "ten thousand occupations are low-graded, only scholarship ranks high." (Qian 1985, p. 107)

It should not surprise us that Benjamin Elman calls the imperial examinations a *conditio sine qua non* to acquire prestige for the family in the long term. (Elman 1991, p. 21) Not only did positions in the bureaucracy come with more prestige than any other career, they also came with greater power and higher income than any comparable position in trade or in the military. (Elman 1989, p. 381)

Not only the graduates themselves were rewarded for possessing a degree: aside from the increase in prestige, a licentiate's[1] *family* also gained several financial and legal benefits. (Elman 1991, p. 15)

Given these conditions, it is no wonder Elman observes that careerism often overtook idealism when young men were faced with the choice of serving the family's interests (which were valued very highly in Confucian spheres) or serving their personal aspirations. In general, those who had sufficient time and wealth focused their attention on the examinations. (Elman 1991, pp. 12-15)

[1] A licentiate or *shengyuan* was a student who was allowed to take part in the examinations that granted access to the bureaucracy. In order to be allowed to take part in these examinations, one had to pass the school examinations first. (However, one should not see these schools as actual pedagogical institutions; in general, they were only schools in name.)

3.3 Time consumption

Evidently, to be done properly, scientific studies require a great deal of work. Not only is it necessary to experiment (or to observe systematically), there is also a need for elaborate note-taking and correspondence. Such endeavors require a significant investment of time. However, the imperial examinations stimulated scholars to spend all of their time on other matters, primarily the thorough study of ancient texts.

Scholars participating in the imperial examinations dedicated a great deal of time to studies one would now consider trivial, such as the learning by heart of very large amounts of characters. In order to indicate the scope of these studies, it suffices to point out that each character of the Five Classics and the Four Books had to be known. These two sets consist of a total of 431,286 characters.[2] (Miyazaki 1976, p. 16) Earlier discussion of the curriculum clarifies the painstaking detail to which they were to be known. The Dynastic Histories were also part of the curriculum. During the Song (960-1279), there were already seventeen works of this nature; during the Qing (1644-1911), this number had grown to twenty-two.

As all these works are written in classical Chinese, it was necessary for a student to learn another language. After all, the differences between classical Chinese and the contemporary vernacular are not to be underestimated: classical Chinese uses quite different grammatical forms, as well as significant amounts of unusual characters. Aside from all this, the students were forced to learn Mandarin, the dialect common to the bureaucracy. (Elman 1991, p. 16)

Under such conditions, students were required to start their education quite early, as well as being forced to spend almost all of their available

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[2] This number represents the total number of characters, as opposed to the number of unique characters.

time wading through ancient texts. From the viewpoint of scientific progress, this time could easily have been spent better on other ventures, such as the unmediated study of nature.

3.4 Administrative-generalist focus

Confucian literati[3] strived to be generalists, in both the sphere of officialdom and ritual – two domains which were closely connected in Chinese culture. As ritualists, the literati needed sufficient knowledge to perform the appropriate rites; as officials, they needed sufficient knowledge to guide specialized laborers in their duties. This section will review this second element, namely the fact that Confucian officials were strongly focused on solving social problems by overseeing specialist labor. As Michael Lackner writes, “[t]echnological performance was left to petty specialists, or at best to second-rate intellectuals, whereas the men who saw their main task in preserving the core of Chinese knowledge contended themselves with condescendingly guiding and supervising the needed practical efforts.” (Lackner & Vittinghoff 2004, p. xiv) Mary Wright describes the Chinese view of the ideal official as a “well-rounded ‘universal man’” who calls upon members of a lower, non-bureaucratic social class for specialized services. (Wright 1957, pp. 91-92) Confucius’ proverb “[a] gentleman does not behave as an implement” (Analecta, p. 7) was considered to justify this attitude.

Two distinct aspects can be identified in the position of these officials: firstly, a pragmatic attitude and, secondly, a position of leadership. Both of these elements can be identified as an epistemological obstacle.

The pragmatic attitude has already been discussed in the introduction to the concept of an epistemological obstacle: an overtly pragmatic ap-

[3] In a Chinese context, the term ‘literati’ refers to the class of scholar-bureaucrats in charge of the administration.

proach, one that focuses only on the use of knowledge rather than on its inherent value, supports only common knowledge – and in order to transcend that level of knowledge, in order to arrive at scientific knowledge, one must break away from immediate pragmatism. Yet this is exactly what the Chinese literati did not do: for them, research in natural studies such as medicine, but particularly astronomy, served an immediate purpose. Natural studies needed to have an impact on society immediately. The pragmatic results of modern science, however, might not be found until centuries after new theories were developed. This does not fit well within the framework of the utilitarian sciences usually found in administrative societies such as China. (This utilitarian framework in these societies has been described by Harold Dorn. A brief overview can be found in Cohen 1994, p. 482). In fact, Chinese philosophers called into doubt the very possibility of knowledge outside the domain of human affairs. (Cullen 1990, p. 315)

The fact that Confucians were accustomed to a position of leadership formed a second obstacle. As they were expected to direct others, they only required some basic knowledge on scientific disciplines. They were not required to have any specialist knowledge; their awareness of the sciences was quite minimal. (Sivin 1973a, p. 41) While limited knowledge of arithmetic was appreciated in an official, more thorough studies in this discipline were associated with the merchant class. To give an example of what the literati focused on, one can compare encyclopedias from the 1590's. Encyclopedias for the elite contained information on the imperial examinations, classical studies and elite family ritual. Encyclopedias for other circles (including merchants, artisans and *shengyuan*) contained knowledge on medical prescriptions, divination, astrology, et cetera, spheres which are historically associated with the sciences. (Elman 2005, p. 19) Science and technology were ever more delegated to the working classes. (Miyazaki 1976, p. 14)

This state of mind is clearly present in many historical situations. For instance, one of the arguments used to convince the rulers of the Yuan-dynasty to reinstate the examinations was the claim that without them, ambitious people would take to a lesser profession, such as that of merchant or artisan. (de Bary 1981, p. 39) The profession of artisans, those responsible for producing technology, was inferior because it was *specialized*. While Nathan Sivin has emphasized that this inferior status does not imply that the labor of artisans was not appreciated, he also notes that literati appreciation of fine craftsmanship did not imply recognition of those who produced it. Even the scientist and politician Shen Kuo (1031-1095), who was in many ways exceptional due to his admiration for the qualities of technicians, always kept this social distance in mind. (Sivin 1973a, p. 27)

In such circumstances, Chinese scholars were unlikely to engage in the study of the mechanical arts, as Galileo[4] did. Despite a number of exceptions such as Shen Kuo, Chinese who were both scholars of science and philosophy as well as trained inventors were never very influential socially.[5] (Sivin 1973a, p. 27) It simply wasn't the type of generalism Confucians aspired to.

Therefore, Chinese intellectuals who were capable of coupling their abstract theories to technology (thus arriving at a form of modern science) were neither sufficiently numerous, nor sufficiently influential. Given the typical Confucian pragmatism, it is ironic that Chinese society effectively embedded a gap between theory and praxis.[6] According to

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[4] I shall often reference Galileo, as he is one of the central figures in my later argument considering patronage.

[5] Never, of course, is an exaggeration. If one goes back to Chinese antiquity, one can identify Later Mohism as a tradition that combined both of these fields.

[6] Arun Bala argues against this split between theory and practice, but his argumentation is primarily aimed against the idea that the Chinese correlative worldview only hindered science, and not technology. According to him such a narrow limitation is unlikely; on the contrary, a correlative worldview is supposedly more efficient for building mechanical contraptions because every element has to be seen as part of a greater whole. (Bala 2006, pp. 127-130)

A.C. Graham, this gap meant that completely different methods were used for cosmology and philosophy than for technology and practice. (Graham 2003a, pp. 317-319) Examples of this abound, as one can observe in the case of astronomy, where astronomers gave no heed at all to the philosophers who developed cosmology. Likewise, the philosophers paid no attention to the astronomers who made the observations and calculations. (Sivin 1973b, p. 11) It was possible to bridge the gap, of course; there is, for instance, Shen Kuo, who was not only interested in mathematics, but also in mathematical harmony, astronomy, magnetism, cartography, metallurgy, medicine and more. In all these cases, Shen showed remarkable technical insight. Unfortunately, his insights remain quite superficial – because of his bureaucratic career, he was too busy to investigate any of these fields of natural studies more thoroughly (which illustrates the time demands of a bureaucratic career.) (Sivin 1973a, pp. 41-42)

Joseph Needham describes the situation similarly: according to him, the largely illiterate (but sometimes very talented) artisans were separated from the literate scholars by an invisible wall:

> During all this time the masses of the people remained illiterate, having no access to the manuscript books which the government commissioned, copied and distributed to the various nodes of the administrative network. Artisans, no matter how greatly gifted, flourished upon the other side of an invisible wall which separated them from the scholars of literary training. (SCC, III, p. 153)

While these artisans are not to be underestimated (Needham compares them to Da Vinci), they could not succesfully couple their practical developments to abstract theories as Galileo did. There were several Chinese equivalents of European figures such as Da Vinci, Agricola or Tartaglia. Needham mentions Song Yingxing ("the Chinese Agricola") (1587-1666) and the pharmacologist and botanist Li Shizhen (1518-1593). (SCC, III, p. 160) One can also add the musicologist Zhu Zaiyu

(1536-1611) to this list. (Qian 1985, p. 78) The problem, according to Needham, is that these artisans do not rise above pure empiricism: an abstract theory is required to link observations by an overarching theoretical principle – to be more precise, the mathematical formulation of hypotheses is required. Given that these artisans didn't study abstract mathematics, such a requirement posed a problem. (An illustration is the tale of Cao Chong, which shows some similarity to the discovery of Archimedes' law. Cao Chong tried to weigh an elephant by placing it on a boat; the assumption is that a certain weight causes a boat to sink in a proportional fashion. Despite this useful insight, it was not generalized further – otherwise one could actually consider it as identical to Archimedes' law. (Qian 1985, pp. 51-58)) Needham claims that this problem was solved in Europe due to social changes that allowed scholars to respectfully interact with artisans ("the Galilean innovation may best be described as the marriage of craft practice with scholarly theory"), while these changes never took place in China. (SCC, III, pp. 154-159)

Needham's judgment has been criticized by Qian Wenyuan, who argues that Galileo did not stand out because of his use of mathematics. After all, Nicolo Tartaglia, Leonardo Da Vinci and Simon Stevin already used mathematics. Qian remarks that the crucial step isn't mathematisation, but *axiomatisation*:

> Needham insists that a crucial step of scientific progress has been made by Galileo, and not by any of the previous practicioners. Why Galileo? Because of his mathematics? (...) But his predecessors also had mathematics. (...) I think we ought to be aware that mathematisation could not provide the true 'magic touch', but 'axiomatisation' did. Galileo and Tartaglia both did mathematisation, but one did it in the realm of basic physical science, the other in the realm of technology. (Qian 1985, pp. 64-65)

Despite this critique, Needham's point isn't undermined: the problem is still the relationship between theory and practice. However, this refinement allows for recognition of the fact that the practice of mathematics, like the crafts, were part and parcel of the lower classes, just as artisanal production was. By virtue of sharing in the social status of craftsmanship, mathematics also shared the condescending attitude of literati.

Cultural resentment towards the crafts is mentioned by Matteo Ricci as well. Ricci was a member of the Jesuit mission to Late Ming China, and he was trained in the Aristotelian sciences. Among other things, he was responsible for a partial translation of Euclid's elements into Chinese. After having observed the relatively developed mathematics and astronomy in China, he remarks that nobody in China would aspire to a career in mathematics or medicine, if he were to have even the smallest of chances of becoming a philosopher. As such, he remarks that almost nobody engages in these studies, except for the less talented or otherwise constrained. Biased though these views may be, the general cultural image of China they create is largely correct. (Elman 2000, pp. 462-464)

Needham's (partial) answer to his Grand Question described above seems based on the theory of Edgar Zilsel. This Marxist historian was active during the first half of the twentieth century and focused on explaining the Scientific Revolution. According to him, the Revolution could only come to pass after the class of scholars had united with the class of artisans. These artisans wielded a form of mathematical rules of thumb, which were converted to scientific laws after the unification of the two groups.

Floris Cohen, a historian of the historiography of the Scientific Revolution, applies some nuance to Zilsel's thesis: it is a dubious idea that the rules of thumb used by artisans are as closely connected to scientific laws as Zilsel claimed. While these rules no doubt played a role, they have never approached the concept of a law of nature as closely as Zilsel suggests. Cohen identifies another problem in Zilsel's thesis: by positing that the unification of the classes of scholars and artisans caused the Scientific Revolution, one does not explain that unification. (Cohen 1994, pp. 336-342, pp. 345-351)

One needn't worry too much about Cohen’s first critical remark: neither Needham’s nor Graham’s claims are as radical as Zilsel’s. I shall (partially) address Cohen’s second remark in a later section, after having described the third epistemological obstacle that can be identified in the imperial examinations. When one approaches Zilsel’s theory in this manner, it becomes less powerful, but it does seem very plausible (particularly in the case of the Baconian sciences, which are focused more on experiment and less on on mathematisation.) (Cohen 1994, p. 349)

To conclude: Confucians assumed a position of leadership, a position which came with a contemptuous attitude towards those working beneath them. This contemptuous attitude was one of the reasons that artisanal knowledge wasn't subsumed into the Confucian curriculum, and thus one of the reasons why the knowledge required for practicing science remained absent from the minds of the great majority of Confucian intellectuals. In this situation, one can identify the Confucian administrative-generalist focus as an epistemological obstacle.

3.5 Orthodoxy and indoctrination

The indoctrination caused by the imperial examinations wasn't absolute; it did, however, have a large impact. Scholars could entertain various ways of thought, but such tendencies were limited by overwhelming contact with a single strict and orthodox interpretation of centuries-old books. The examination system caused the examinees to internalize the orthodox patterns of language, thought and observation. (Elman 1991, p. 20) In fact, Benjamin Elman believes producing unity of thought to have been one of the primary goals of the examination system:

> late imperial dynastic educators prized orthodoxy and the rote reception of that orthodoxy by insiders and outsiders alike. Repetition as a habit of learning was the key to developing the memory as a pedagogic tool to produce uniformity by education. (Elman 2000, p. 64)

Not only was this the intended purpose – it actually succeeded, as Elman confirms elsewhere:

> Cultural construction of neo-Confucian orthodoxy through the required educational curriculum for examination candidates guaranteed the long-term dominance of neo-Confucianism in intellectual life. (Elman 1991, p. 8)

Both the public schools and a number of private schools focused wholly on entering the bureaucracy, and as such, on orthodoxy. The small amount of schools that didn't abide by this particular programme, the so called *shuyuan*, were increasingly placed under state control, because they were seen as breeding places of heterodoxy. This was not an unreasonable belief, because the influential heterodox philosophy of Wang Yangming was developed in such institutions. (Engelfriet 1998, p. 91)

I have already noted earlier that orthodoxy was enforced on students taking the examinations. This didn't only have an impact on purely philosophical and political matters. It also played a role on the scientific level. If a candidate were to answer an astronomical question undesirably (possibly because of empirical observation of the heavens), then this could be problematic. After all, an answer that could be interpreted as a negative omen for the ruling dynasty was equivalent to heterodoxy. (Elman 2000, p. 482) Now, it is precisely such astronomical questions that lead Benjamin Elman to argue that the humanist nature of orthodoxy was not limiting literati knowledge of science and technology. (Elman 2000, p. 473) However, it seems that he fails to realize that *knowledge* of science and technology doesn't imply a scientific attitude or method. The science studied for the examinations is a form of science Gaston Bachelard calls *dead*: it is information, not scientific practice. (Bachelard 1975, p. 102) The technoscientific knowledge Elman mentions is present, but the type of questions doesn't stimulate further investigation of the world. It is merely orthodox knowledge. The questions ask for information that can be found in books, not in nature.

4 The universities

At first sight, the aforementioned obstacles might be an important counteracting cause for the occurance of a Chinese Scientific Revolution. However, it is possible to counter this claim by denying any relevant cultural difference between the Chinese and European intellectuals. Nathan Sivin has formulated this claim quite impressively:

> Exactly what does "inhibiting factor" mean in such contexts? Consider one of these often adduced to explain the failure of China to beat Europe to the Scientific Revolution despite an early head start, namely the predominance of a scholar-bureaucrat class immersed in books, faced towards the past, and oriented towards human institutions rather than toward Nature as the matrix of the well-lived life. But in Europe at the onset of the Scientific Revolution we are faced with the predominance of the Schoolmen and dons, immersed in books, faced towards the past, and oriented towards human institutions rather than toward Nature. (Sivin 1982, p. 57)

Even when allowing for the small differences that would no doubt emerge if one were to compare European universities and the Chinese imperial examinations more thoroughly, it is not unreasonable to claim that the attitudes promulgated by both institutions are very similar.

As in China, the study of additional languages was essential. Like Chinese literati culture, Scholastics focused on ancient books, particularly Scripture and the works of Aristotle.

The Chinese administrative-generalist focus finds its equivalent in the traditional hierarchy of the universities. Like the Renaissance humanists, the schoolmen loathed artisans (as Galileo, Bacon and Gilbert loathed the forms of argumentation used by humanists and schoolmen). (Cohen 1994, pp. 338-339) The sciences in general and mathematics and astronomy (then not yet wholly distinct) in particular were required to take over elements from (natural) philosophy without questioning them. (Westman 1980, pp. 108-109) In comparison to prestigious fields like law, medicine and theology, astronomy had a low status. The position of professor in mathematics or astronomy was a stepping stone on the way to a more prestigious position as a professor of law or medicine. (Westman 1980, p. 119) Scholars didn't frown upon mathematics in China alone: the rupture between theory and practice can also be found in Europe.

The enforcement of a philosophical orthodoxy was present in Europe as well. Nakayama Shigeru remarks, not without reason, that most universities resisted Copernicanism, because it undermined the Aristotelian philosophy that was taught there. (Nakayama 1984, p. 112) To undermine Aristotelianism was to undermine the universities and the scholars working within them. The structure of the universities was also quite rigid. As in the case of the imperial examinations, it was very difficult to fight the dominant culture, which granted the sciences a lower social status than philosophy, theology, medicine and law. All in all, Sivin's claim that the European and Chinese educational contexts are very similar is quite plausible.

5 Patronage

5.1 Socio-professional legitimation

Despite the similarity between the Chinese imperial examinations and the European universities, the broader social systems in which intellectuals thrived were still distinct. After all, Europe offered a second way of acquiring social status as a scholar: the institution of patronage, which had become commonplace during the Renaissance.[7] While it had its own rituals and etiquette, the system was far less rigid than the university sys-

[7] There were other circuits external to the universities in early modern Europe, such as the *Accademia del Lincei*, founded in 1603. However, I shall not discuss the role of these cirtuits here.

tem. These universities did operate under some form of patronage (Westfall 1985, pp. 12-13), but there is no doubt that the patronage of universities differed radically from, for instance, Cosimo II's patronage of Galileo (1564-1642). This latter form had Galileo as beholden only to a single person, while he owed responsibility to many during his time at the University of Padua. By virtue of cunning preparation and the cultivation of well-selected social relations, it was possible to bind oneself to the right patron and thus acquire a high social status. The appropriate patrons were generally not rulers of large empires, but of smaller principalities such as those of Denmark, of the Holy Roman Empire (Westman 1980, p. 122) and of Italy (Biagioli 1990).

Not only an *individual* could rise in social status by binding himself to a patron. He could also grant this social status to an entire discipline as the patron's status became reflected in it. (Biagioli 1990, p. 5), (Westman 1980, p. 122) Patronage allowed mathematical astronomers such as Galileo to debate with philosophers, although philosophy traditionally had a significantly higher status than mathematical astronomy. Philosophers were usually not required to respond to any cosmological claims made by astronomers:

> Philosophy, it was held, dealt with the real causes of natural phenomena, while mathematics could only deal with their "accidents," that is, with their quantitative aspects. Consequently, mathematicians were not entitled to produce legitimate *physical* interpretations of natural phenomena. (Biagioli 1993, pp. 105-106)

However, by accepting a scientist as their client, patrons essentially forced their philosopher clients to respond. While the challenges of mathematicians as private persons were not significant enough for philosophers to respond to, the challenges of mathematicians with titles such as "Imperial Mathematician" or "Philosopher and First Mathematician to the Grand Duke of Tuscany" could not be trifled with. Such challenges were the scientific equivalent to dueling; one did not turn down a worthy opponent’s challenge to a duel. To deny the judgment of a great patron by still considering such a mathematician unworthy of response would deprive a philosopher who took part in the economy of patronage of all his support. (Biagioli 1993, pp. 72-73)

Astronomy’s evolution from an inferior discipline to that of a fully respected science only began with Copernicus (1473-1543), who no longer accepted the idea that astronomy was to start from the framework laid down by natural philosophy. Such a tendency was met with remarkable resistance. Neither Copernicus’ heliocentrism nor his claim that the earth moved were popular among the astronomers of his time. A popular geocentric interpretation of Copernicus, the Wittenberg-interpretation, held that his theory could accurately predict the angle under which a planet appears. Especially his replacement of the equant by epicycles was appreciated. (Westman 1975, pp. 165-166) As can be seen, Copernicus was not ignored altogether: elements of his theory that didn't have cosmological implications were not off limits. (Westman 1980, p. 117) Clearly, Copernicus did not revolutionize the practice of astronomy; breaking out of the constraints imposed by the governing culture was left for those who followed in his footsteps.

The increased social status granted to astronomers and mathematicians by patronage connections allowed such philosophical constraints to be broken. The first to break out of the metaphorical chains of philosophical orthodoxy was Tycho Brahe (1546-1601), a Danish noble under the protection of the Danish king Frederic II and of Rudolph II, Holy Roman Emperor. Johannes Kepler (1571-1630) was under the protection of Rudolph II as well, while Galileo’s patron was Cosimo II de' Medici, Grand Duke of Tuscany. It were *these* astronomers who bridged the gap between the development of abstract (cosmological) theories and the practical observation of reality:

> That right came into existence as a social norm primarily because it was asserted by a new claimant to knowledge about physical reality, the court astronomer. By conferring the status of noble privilege on the activities of

> astronomical investigation and cosmological dispute, Tycho Brahe freed them from the old guild-like divisions of the academy. Tycho's example became a role model for others, such as Kepler. (Westman 1980, p. 134)

Patronage made it possible to practice this reformed type of astronomy and remain a respectable scholar. The universities only accepted the new discipline later on. (Westman 1980, pp. 127-133) The presence of many powerful nobles with sufficient wealth to 'buy' such amounts of prestige thus seems an important factor in the development of modern science.

5.2 The motivations of patrons

While it is clear what scientists had to gain by associating themselves with great patrons, it is less clear why the patrons themselves would be interested in employing such men. (Biagioli 1993) describes the processes involved in this institution quite thoroughly. Patrons had two things to gain from scientifically minded clients: material or immaterial gifts on the one hand, and debates on the other hand.

If a client engaged in debate, a patron gained prestige. Precisely the acceptance of a challenge to a debate implied an acknowledgement of the patron's high status, and thus increased his prestige. Scientific debates were a method of expressing a patron's power. (Honesty compels us to admit that patrons did not seek a final resolution to the debates – in fact, associating with one particular side of the debate was dangerous to them: it put their honor at stake. Patrons demanded debates; they did not choose sides unless not choosing sides was an even greater problem for their economy of honor. However, this attitude was not necessarily shared by their clients.)

Even greater expressions of a patron's power were the gifts a client dedicated to him. Taking Galileo as an example, two significant examples of such gifts immediately spring to mind. For one, there is the lodestone gifted to Grand Duke Cosimo II, the power of attraction of which stood symbol for the evidence of Medici power. Galileo's own commentary on the motto "[v]im facit amor", which was written on the magnet, speaks for itself:

> [This motto suggested] the dominion of God conferred upon the just and legitimate prince over his subjects, which should be such that with loving violence it draws to itself the devotion, loyalty, and obedience of the subjects. (Westfall 1985, pp. 14-15)

One of Galileo's other gifts was even more prestigious: his dedication of the moons of Jupiter to the Medici. This dedication was particularly impressive given the mythology that they had developed around themselves. Jupiter and the cosmos had been symbols for Cosimo I, founder of the Medici dynasty, since the beginning of the sixteenth century. Mario Biagioli makes an appropriate statement when he says Galileo "was able to present them [the stars] as perfectly fitting the Medici discourse of the (problematic) legitimation of their absolute rule." (Biagioli 1989, p. 48), (Biagioli 1990, p. 41) Scientific discoveries were thus presented as monuments indicating the power of the patron: "Galileo presented [the Medicean Stars] as a kind of object that, while displaying some of the features of our notion of scientific discovery, also participated in the economies of artworks and monuments." (Biagioli 2006, p. 3)

Such gifts were not only flattering, but *required* in order to be accepted as a client: "Galileo needed to produce or discover things that could be used as gifts to his patrons". (Biagioli 1990, p. 25) This stimulation by discoveries went as far as Richard Westfall suggesting that in the case of the telescope, Galileo's attention was focused more on ensuring his own future rather than on the investigation of Copernicanism. (Westfall 1985, p. 12)

Both reasons for why patrons desired scientific clients can be seen as boons for the development of modern science. No doubt, that form of science had not yet shown its face; the institutional culture was still completely alien to that of modern science. People like Galileo spoke the language of a courtier, not that of a contemporary science professor. Nevertheless, it was a step in the right direction: there is no doubt that these mechanisms (that is, the demand for ever more discoveries to be presented to the patron and the demand to defend oneself against criticism in debates) have stimulated scientific discussion in Europe. (Biagioli 1990, p. 32)

5.3 Patronage in China

As discussed earlier, the mechanism of acquiring prestige by virtue of gifts and debates was the main reason why great patrons accepted clients. Particularly central is the idea that a scientist was able to increase the prestige of his patron - whether this occurs through gifts, debates or otherwise is less important. However, such a practice was not commonplace in China, as it only finds fertile soil in times of competition between various courts. In general, in the centralized Chinese state structure, the Chinese court did not have a cultural opposition and was widely acknowledged as highly prestigious.

During times of internal division, however, there are traces of such competition in Chinese history. During the Warring States Period (481-221 BCE), China knew an efflorescence of (natural) philosophy – an efflorescence that did not really end until after the Han (206 BCE-220 CE) had come to power. Even in those Early Han days, individual feudal princes competed with one another culturally and politically, and continued to function as patrons. (Lloyd & Sivin 2002) (A similar situation is found in the Arab world, where the sciences flourished under court sponsorship. At first, this was the court of the caliphs in Bagdad, but as more and more regions became independent, each of these wanted to acquire a high cultural prestige. As such, the fragmentation of the Islamic world opened more options for scientists. (Cohen 1994, pp. 386-387))

Naturally, none of this implies that patronage no longer existed in Imperial China. The difference lies in the motivations of patrons, and in the differences in institutional culture that such motivational differences imply. Chinese imperial interest in the sciences was pragmatic. The usefulness of medicine is evident; the usefulness of astronomy lay both in the development of a workable calendar and the age-old belief that heavenly omens about the ruling dynasty could be discerned in the stars. However, as I have already remarked earlier, astronomical information could threaten the dynasty if it were to fall into the wrong hands. Therefore, the court was often benefited by secrecy, rather than by publicized debates or monumental gifts. This secrecy was institutionalized by several policies, such as the ban on promoting officials of the Astronomical Bureau and their children to positions outside of that Bureau. (Deane 1989, p. 357)

Patronage began to play an important role in the socio-professional legitimation of scientists in the aftermath of the Ming calendar crisis. The crisis had been recognized long before the arrival of the Jesuits, but these scientifically trained missionaries were central to its resolution, after the introduction of `new' methods (at least to the Chinese). Jesuit Ptolemaic astronomy allowed solar eclipses to be predicted to the nearest minute, rather than to the earlier standard of a quarter of an hour. Because of the existence of such a highly improved method, the older method was considered unacceptable for use. (Elman 2005, p. 68) In effect, because prediction to a higher accuracy became possible, predicting with a lower degree of accuracy came to be seen as not predicting accurately at all, and thus as a bad omen.

When the Rites Controversy had made the Qing Kangxi Emperor (1654-1722) aware of the dangers of relying too much on the Jesuits, he saw the need for the development of a class of Chinese mathematicians-astronomers. Imperial patronage lead to the development of a new social position: the literatus-mathematician, a type of scholar that might still have somewhat lower prestige and a lower status than the literatus-official, but was ever more accepted as a necessary element of the hierarchy. (Elman 2006, p. 66)

The iconic beneficary of this patronage is Mei Wending (1633-1721), who fused the traditions of Chinese and European mathematical astronomy. Mei met with the Emperor frequently, who realized that it might be possible *not* to rely on European mathematicians for his astronomical requirements. It was the Kangxi Emperor's canonization of Mei Wending that lead to the change in status of mathematical practicioners. (Elman 2005, pp. 153-160)

Following this canonization came the formation of an Academy of Mathematics, in which over a hundred scholars were recruited. The most influential scholars, such as Mei Juecheng (1681-1763) and Wang Lansheng, were named `palace graduates in mathematical astronomy', increasing their status in a parallel way to Galileo's being named 'Philosopher to the Grand Duke'. (Elman 2005, pp. 177-180), (Elman 2006, p. 42)

However, these evolutions remained limited to mathematics and astronomy. These Chinese were not alone in using patronage to resolve particular matters of importance. European monarchs were often interested in astrological matters as well. (Westman 1994, p. 100) It is important to realize that there were many incentives for initiating patronage relations. However, these differed strongly from the *cultural competition* found primarily in early modern Europe. The princely need to compete with other princes and establish one's status stimulated and legitimated scientific enterprises. While these dynamics of legitimation can be recognized in early Qing China as well, they were initiated less often, for different reasons and in a different form.

6 Conclusion

The imperial examination system most definitely entrenched a number of epistemological obstacles, and as such formed an inhibiting factor for the development of modern science in China. However, similar obstacles were present in the European university system. Therefore, a comparison limited to this level is doomed to fail as a partial answer to Needham's Grand Question. However, after taking into account the system of patronage in Western Europe, the situation changes. Clients could spend their time on whatever they thought would impress their patrons, rather than on the study of ancient books. It was possible for a client to bridge the gap between theory and practice: gifts were both of technological and scientific nature. While patronage cannot be taken as an explanation for the bridging of this gap, it did not artificially maintain it, as the university system and the imperial examinations did. Finally, patronage had an easier time escaping orthodoxy: it was simpler to convince a single ruler of the value of a research program than to convince an entire community of scholars, when that research program conflicted with an orthodoxy – particularly when those scholars owed their position to that orthodoxy.

Given the role of patronage in the careers of major scientists it is not unreasonable to consider patronage as one of the factors that allowed Western Europe to overcome the epistemological obstacles institutionalized in its university system. In China, patronage did not take the same form it took in Europe, and the local patronage system was not as conducive for breaking free of these epistemological constraints as the European system. I do not claim that patronage was the only possible way by which the identified obstacles could be overcome. However, only a limited number of paths are plausible, and the path of competitive patronage is one of those. On that ground alone, the connections between Chinese patronage and Chinese science deserve to be investigated, just as they have received attention in Europe.

This argument rests on the presupposition that the system of patronage common among the major scientists of the Scientific Revolution did not exist in China at that time. My review of the literature confirms that view: while there is a great deal of literature about imperial patronage, there is very little information on any possible competitive patronage as it existed in Europe. Perhaps this means that such a system did not widely exist – if so, what I have argued will remain valid. If not, then a lot of research remains to be done into the systems of Chinese patronage. Questions then need to be asked about the social class of patrons and clients, how systematic it was, the activities that were sponsored, and so forth.

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