ARE CHINESE SCIENCES SCIENCE?

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Abstract: In this paper I look at Chinese sciences from a historical and comparative perspective. The main concern of the paper is to find a sensible characterization of science that can help us capture the common nature of all scientific inquiries, ancient or modern, Chinese or Western. With such an understanding of science, we can justify Chinese sciences as genuinely scientific, and appreciate some unique styles of inquiry in Chinese sciences.

I. Introduction

ARE CHINESE sciences science? The answer seems so obvious that the question looks trivial. First, must Chinese sciences be science by definition? Second, even if there are any concerns before, works like Joseph Needham's multi-volumes of "*Science and Civilization in China*" should have put out any doubt about the existence of Chinese sciences. Why is there a need for writing a new paper on this topic?

Behind its deceptive simplicity, this has been a quite contentious problem in recent years. First, Chinese sciences cannot become science simply by definition. Look at the meaning of the term "Chinese science." The notion of science we use today is a Western one. Ancient Chinese did not have a corresponding category to the modern Western conception of science. The current Chinese term *kexue* (科學) was introduced to China from its Japanese translation of Western science. So, when one combines the terms Chinese and science (*kexue*) to form a new term "Chinese science", it is possible that 'Chinese science' is an empty term with no reference.[1] In most contemporary discussions of Chinese science, the term is a placeholder for a set of subjects that resembles modern Western sciences in various degrees, such as astronomy, mathematics, physics, chemistry, medicine, agriculture. The issue whether the Chinese studies of these subjects are indeed scientific is often not addressed. But we cannot take it for granted that Chinese sciences must be science. Fool's gold is not gold; American Indians are not really Indians; and many people have argued that creation science is not science. I am not saying that Chinese sciences are like these cases, yet these examples show that the names alone cannot tell us about the nature of the things they refer to. We need to examine the nature of the subjects that are called Chinese sciences, and to decide whether they are truly scientific.

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[1]This is actually the case with the notion of Japanese science. In Japan, science simply means Western science. For Japanese, there is no *Japanese* science, though there are many Japanese scientists today.

This seems to be exactly what Joseph Needham and his team have done with their impressive studies of sciences and technologies in ancient China. After Needham's work, is there any doubt about the legitimacy of Chinese sciences? Here we encounter a real issue: behind the impressive scope and unprecedented depth of Needham's studies of Chinese sciences, there are some serious concerns with his methodological assumptions.

The key issue is how to characterize what science is. If science is understood in terms of modern science established since the period of the Scientific Revolution in 17th century, then there was no science in ancient China. Ancient Chinese sciences had never reached the height of modern sciences with respect to the scope and depth of knowledge. But this is nothing surprising, and by the same standard we have to say that there was no science in ancient Greece, India, Egypt, or any other ancient cultures. Needham's approach is to see whether ancient China has anything resemblant to modern Western sciences. In such an approach, modern sciences are used as a reference point to judge previous scientific attempts. Adopting this methodology, Needham claims that Chinese had made a lot of achievements in many different scientific subjects such as mathematics, astronomy, chemistry, and physics. Needham argues that Chinese made significant contributions to the development of Western sciences and technology. Such discoveries fit Needham's general understanding of science quite well, since to him science is one great river where different steams converge. In such a picture, there is no essential difference between Western and Chinese sciences. In his optimistic tone, Needham says:

> …ancient and medieval Chinese secular texts are always sensible, rational and comprehensible, if not too corrupted by copyists. … For philosophers of course we would hardly dare stand guarantee, but where the practical men were concerned, the reckoners and star-clerks, the leeches, the miners and the ironmasters, there can be no possible doubt. If one cannot be sure of the details of the Mohist specification of crossbow-artillery, if some of the mathematical and astronomical methods of the Chhin and Han escape our penetration, it is because age has almost irretrievably jumbled the words. Even then, if one can once be quite sure what the ancient author was talking about, the whole pattern becomes clear and emendations may follow of themselves (Needham 1959, xliv) .

Needham's approach is typical among scientists and scientific-minded philosophers such as logical positivists. Such an approach takes modern sciences as the paradigm of rationality, and aims to understand the history of science in a pattern of accumulative progresses. Science is an objective, value-free, and universal enterprise that is independent of any particular culture. Though modern science was first discovered in the West, it does not imply it could not have developed in the East. It is unfortunate that modern science did not emerge in China, yet that seems to be only an unlucky historical incident. As Needham has argued, Chinese have made many great scientific discoveries, which were equal or better than what their Western contemporaries had at the time.

Needham's approach assumes that ancient scientific achievements in China should be rediscovered or at least reinterpreted in terms of modern Western sciences. This is the central if implicit methodology in his grand project on Chinese civilization. In such a process, Chinese sciences are defined by the modern scientific standard and are integrated into modern sciences: the parts that fit modern standard or resemble modern sciences become scientific and are classified accordingly.

As Kuhn shows, this methodological assumption is typically reflected in scientific textbooks and philosophical discussions about science. It is presumed that our contemporary sciences provide the best theories of the world, and the historical accomplishments have to be understood in terms of contemporary sciences. A historically important theory (such as Phlogiston Theory) may get no mention in a contemporary science book because it does not fit the current picture, while a little-known theory at the time (such as Mendel's Gene Theory) may enjoy a prominent place in later sciences. In a word, the history of science is constantly rewritten in reflection of the advances and interests of contemporary sciences. Despite its efficiency and convenience for modern scientific researches, such an approach often distorts the history of science and fails to illuminate what was really going on. G. E. Lloyd comments: "To talk of the ancient's chemical theories, for instance, is bound to distort what they were doing, since chemistry as we know it today is a product of the eighteenth and nineteenth centuries … But teleology is even more pernicious, in that it assumes that the ancients aimed to approximate to modern ideas – and as they did not get there, they must have failed miserably" (Lloyd 2004, 1).

When historical contexts are neglected, some extraordinary claims can be made about Chinese sciences. People from different fields have claimed to find modern sciences in ancient Chinese texts. For examples, John Gribbin discovered that the theories of relativity were already present in ancient Chinese theory of cosmology, and Carl Jung identified elements of psychoanalysis from the *Book of Changes*.[2] This seems to imply that ancient Chinese already knew these modern sciences, which seems absurd. These claims reinterpret the ancient Chinese texts with no regard to their historical contexts. Other cases are more complex. For example, Needham studied Chinese alchemy and rewrote many Chinese alchemists' discoveries in terms of modern chemistry. Yet it is quite clear that Chinese alchemists did not really understand the underlying chemical principles, and did not even try to do chemistry as a scientific subject; instead they tried to find life-extending pills, on which they failed miserably most of the times. Similarly with Chinese astronomy or geomancy, quite a few claims can be interpreted in contemporary astronomy or physics, yet ancient Chinese had very different understandings of such phenomena from today's scientists. For example, in 1054 AD of Song dynasty, Chinese astronomers observed the supernova explosion, which gave rise to Crab Nebula today. Yet Chinese astronomers had no idea about the nature of their observation, and they interpreted the

[2]See John Gribbin [1975], and Carl Jung, *Foreword* to *The I Ching or Book of Changes*. [1950/1967].

phenomenon as the visit of a guest star (which stayed for more than one year).[3] From such an observation, no one should draw the conclusion that Chinese had conceived modern astronomical theories.

These concerns are not limited to interpretations of Chinese tradition. It seems that we have to address the issue how ancient people understood their practices before we decide what they were doing are scientific or not. Birds can fly really well but they don't have the science of flight; similarly, ancient people might have displayed some practices that can be understood as scientific, but it does not imply that they had such sciences. For example, most cultures had some kind of incest taboo, though few if any of them knew the genetic reasons behind such practices. With any scientific tradition in consideration, we must ask the following questions in order to have a true understanding: 1) what are the goals of their pursuit? 2) What are the issues that they were concerned about? 3) What is their methodology?

We need to settle a conceptual question first: what is the definition of science? In order to decide whether the subject is a scientific one, we have to clarify the criteria of science. This is a complex issue, which is made more difficult by the facts that different scientific traditions often have different goals of pursuit. As Kuhn argues, even theories from the same tradition may not share the same set of goals or issues. This will be explored in great detail here.

There are two related questions in comparative studies of science. The first one is about cross-culture understandings. Can Westerners or contemporary scientists really understand Chinese science? There are two kinds of understanding in play. A Westerner could learn Chinese medicine as a traditional Chinese doctor did, and master all the details of its theory and practice. Yet this is only understanding in original Chinese terms. In order to explain Chinese medicine in the framework of Western medical system, one needs another kind of understanding, which connects the Chinese conceptual system to the Western conceptual system. But this kind of understanding faces a dilemma, as Lloyd puts it: "We cannot, on pain of distortion, impose our own conceptual framework. Yet we have to" (Lloyd 2004: 2). One horn of the dilemma is that it is hard to avoid distortion when we force our conceptual framework onto the other, and the other horn is that we cannot make sense of the other framework if it is not interpreted in our own. In the case of learning Chinese medicine purely in the traditional Chinese way, what one gets is not an interpretation but at best a replica of the other conceptual system.

The other issue is about comparison and evaluation of scientific theories from different traditions, which is a more complex issue. As Kuhn shows, it is difficult to compare and evaluate different paradigms, even in the same scientific tradition. But the questions must be answered: how can we tell which theory is a better one? Which theory should we accept? Can we ever compare and evaluate these theories in a rational manner? Kuhn and others rejected the cumulative picture of logical positivism, based on their discovery that all observations are theory-laden and as a result there is no pure observational base that serves the epistemological foundation.

[3] Xi Ze-zong was the first to point out that Chinese had observed supernova 1054. See Xi [1966].

Yet what is an alternative? Social constructivists believe that reality is socially constructed, and claim theory choice is not free from social and political factors. Cultural relativists further argue that there is really no objective truth anymore, and as a result theories from different scientific traditions cannot be compared at all. But these are not viable options. Intuitions about scientific progress and scientific objectivity are so strong that the extreme relativist view simply does not fly. The detailed discussion of this topic is beyond the scope of this paper, which focuses on the criteria of science.

II. Criteria of Science

We need to find an understanding of science that can make sense of scientific inquiries of different cultures and at different times. We need to leave out peculiar modes of separate scientific inquiry and focus on more essential elements. In particular, we need to be aware of the explicit or implicit bias that only modern Western sciences are truly scientific.[4]

There are many attempts to characterize what science is, yet most of them are not fit for our inquiry. Such attempts can be classified into three camps: sociological, philosophical, and historical. Sociologists of science (e.g. Robert K. Merton) tend to characterize science in terms of institutional structure of science in a society, such as universities and scientific organizations, and their relations to other parts of society. However, such an approach can only apply to modern sciences that have developed since 17th century in Europe. In the ancient societies, there was no scientific community in today's sense, and there was little institutional support for science per se. Many scientific discoveries were made as a result of personal interests rather than out of professional needs. There were no scientists in today's sense who earned a living by aiming at attaining knowledge of nature. So the sociological approach to science does not work for our purpose, since by this criterion, there would be no science in all ancient civilizations. Philosophers have also been deeply concerned about the criteria of science. Karl Popper's proposal that genuine sciences must be falsifiable sets up the stage for later philosophical discussions on how to separate proper sciences from their pseudo-scientific counterparts. The recent debate concerning the scientific status of creation science underlines the importance of the problem. It is important to see whether such philosophical approaches can be useful for our inquiry. Even if they fail to deliver, we may learn some valuable lessons that are helpful to our investigations.

In his 1953 talk, Popper contrasted falsification with confirmation. What he found is that some well-confirmed theories have little scientific value. The examples he examined are Freud's theory of psychoanalysis, Adler's individual psychology, and Marx's theory of history. These theories are well-confirmed by many successful

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[4]It is not impossible to argue that only modern sciences are genuinely scientific, though such an approach faces serious objections, and has no use for cross-culture understanding of science. For a more detailed discussion, see Lloyd's objection to the Great Divide in chapter 2 of his 2004 book.

cases, yet there seems to be something wrong with them when compared with Einstein's general theory of relativity. Popper's insight is that those three theories cannot be falsified, since whenever they are threatened by some false predictions, some ad-hoc explanations are introduced to account for their predictive failures. The theory itself is never in doubt and so can never be falsified. On the other hand, Einstein's theory could be easily falsified by Eddington's eclipse observations (though it was in fact confirmed by them). So the criterion of falsifiability explains our intuition that such theories are not genuine scientific theories.[5]

Popper's demarcation criterion received many discussions inside and outside the philosophical community. One major complaint is that Popper's picture of scientific practice is so naïve and distorted that it makes his criterion irrelevant to real scientific debates. It is reported that many eminent scientists were as dogmatic about their scientific beliefs as religious believers, including Einstein himself.[6] Many great scientific theories also introduce apparently ad-hoc explanations to avoid their predictive failure. A famous example is failed predictions of the orbit of Uranus from Newton's theory of gravity, which leads to the postulation (and eventual discovery) of another planet, Neptune. Popper's falsifiability criterion does not capture the real distinction between science and pseudo-science. As Imme Lakatos commented, "Popper's criterion ignores the remarkable tenacity of scientific theories. Scientists have thick skins. They don't abandon a theory merely because facts contradict it" (Lakatos, 1980, 3-4). Instead, Lakatos uses his notion of research programme to solve the demarcation problem. First, he explains the notion of research programme and its functions: "the typical descriptive unit of great scientific achievements is not an isolated hypothesis but rather a research programme. Science is not simply trial and error, a series of conjectures and refutations" (*Ibid.*, 4). Besides core assumptions, we need auxiliary hypotheses, and "even more importantly, the research programme also has a 'heuristic', that is, a powerful problem-solving machinery, which, with the help of sophisticated mathematical techniques, digests anomalies and even turns them into positive evidence" (*Ibid.*, 4) Second, the science/pseudo-science distinction should be drawn at the level of research programme, rather than at the level of hypothesis (as Popper did). According to Lakatos, science is marked by its progressive nature: "All the research programmes I admire have one characteristic in common. They all predict novel facts, facts which had been either undreamt of, or have indeed been contradicted by previous or rival programme" (*Ibid.*, 5). To put it more generally, a true scientific research programme is progressive in the sense that it can correctly

[5]This finding led Popper to regard the criteria of falsifiability as the most important feature of a scientific theory, and used it not only as the criterion of demarcation but also as a criterion of evaluating scientific theories. For example, Popper claims that the easier a theory is falsifiable the better the theory is. Such applications of falsifiability in theory evaluation are more controversial and less plausible. They are not related to our main concern in this paper, which is more about the issue of demarcation.

[6]When asked about what he would do if Eddington's observations failed to match his theory, Einstein replied: "Then I would feel sorry for the good Lord. The theory is correct." (see Rosenthal-Schneider, 1981)

predict novel facts. A pseudo-scientific one is degenerative as it fails to predict novel facts, though it may find a way to explain away their failures. For example, Newton's theory and Einstein's theory are greatly successful at their predictions of important novel observations, while Marxists of the later 20th century could provide explanations to significant events only after they have happened but failed miserably at their predictions.

Lakatos's proposal is not without its problems when it is understood as an attempt to define science. The definition would be too narrow, since a long-established research program may be so successful that it has little significant novel problems to solve, yet that certainly doesn't imply it is not scientific anymore. Even with a research programme that has lost its momentum, such a lack of progress should not deprive its scientific status. For example, medical sciences in the past often went through a long period without significant progress, but it seems absurd to say that they were pseudo-scientific. The definition would also be too broad, since a pseudo-scientific research programme may still get some novel predictions right. Confirmation is cheap, as Popper would say. Lakatos likes to focus on the ability of a research programme to handle its anomalies, yet serious anomalies often accompany progressive theories for a long time. In conclusion, Lakatos's definition seems to be more concerned about whether a research programme is good or bad, but less about the demarcation problem whether a research programme is scientific or not.

In this interesting analysis of whether astrology is a science and why, Paul Thagard went further with Lakatos's approach. After reviewing several failed attempts at the definition of science, Thagard claims: "A demarcation criterion requires a matrix of three elements: theory, community, historical context." Pseudo-sciences are defined as the following:

> A theory or discipline which purports to be scientific is *pseudoscientific* if and only if:
> 1) it has been less progressive than alternative theories over a long period of time, and faces many unsolved problems; but
> 2) the community of practitioners makes little attempt to develop the theory towards solutions of the problems, shows no concern for attempts to evaluate the theory in relation to others, and is selective in considering confirmation and disconfirmations (Thagard, 227-8).

According to this criterion, today's astrology is pseudoscientific, since not only does it face many unsolved problems, its practitioners also care little for the solution of these problems. However, this may not be the case in the past. In particular, "astrology should be judged as not pseudoscientific in classical or Renaissance times, even though it is pseudoscientific today" (*Ibid.*, 229).

Thagard's definition is also criticized, especially for his requirement of a more progressive alternative theory. Thagard later modified his proposal, and gave up the search for definitions of science or pseudoscience. Yet Thagard's original proposal has some interesting aspects. Go back to the initial question "what is science" and examine what the term 'what' means. Suppose we're concerned about whether X is science or not. What kind of thing is X? X may be a claim or a statement; X may be a theory, a paradigm in the Kuhnian sense, or a research programme; or X may be a kind of practice committed to by a group of people. Popper's concern is whether a hypothesis is falsifiable or not. Apparently it seems to be concerned only with a statement, yet whether a statement (especially a theoretical one) is falsifiable depends on the structure of a theory. When auxiliary hypotheses are considered, there is often no straightforward way to decide whether a hypothesis is falsifiable or not. Compared with Popper's focus on hypothesis, Lakatos's attention to research programme is more appropriate.[7] A research programme includes the systematic structure and mechanism of a theory, and more interestingly, it includes a temporal aspect that reflects the program's historical success of problem-solving. This temporal feature is not present in the ordinary understanding of a theory, such as the analysis of scientific theory from Logical Positivism. Following Lakatos's path, Thagard's approach considers one more layer of the issue: the community of practitioners and their attitude toward a research programme. Scientific inquiries cannot be separated from their practitioners. I believe that Thagard's approach is a promising one. For our purposes, it is very helpful to understand science as an activity rather than as a theory. A research programme may be dormant for a period of time due to reasons other than internal struggles with anomalies. These causes may include shift of political interest, lack of institutional or economical support, or a significant loss of talents. Even so, as long as its practitioners are still sincere about resolving anomalies to the programme, it seems reasonable to say that such practices remain scientific.

Thagard seems to identify progress with science, that is, whatever is progressive is scientific, and vice versa. This is a popular assumption, yet it is problematic. As Kuhn points out, even the subject of painting was regarded as progressive in Europe for a long time (Kuhn 1996, 161). More general, within a paradigm, any subject can be progressive. If every discipline becomes scientific by such a standard, it cannot illustrate the unique nature of scientific inquiries.

Lloyd and Sivin, in their book "The Way and The World," aim to look at the issue from a holistic view that includes historical, cultural and social contexts.

> We are not comparing things or concepts but whole processes. We look at ideas, their uses, the social interactions that elaborated them, and their adaptation to state power as dimensions of a single phenomena. We try to reconstruct how people at the time understood their own practices and concepts, rather than how authors of modern textbooks would evaluate their work (Lloyd and Sivin 2002, 9).

They believe such an approach is able to better tell us what science is, at least in ancient times. In particular, they are looking at the following questions:

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[7]The same can be said about Kuhn's notion of paradigm. It actually has richer conceptual resources than Lakatos's notion of research programme, which was not further articulated due to Lakatos's untimely death.

> What did it take to become a philosopher, scientist, or physician in ancient China and Greece? Did it depend on what stratum of society one came from? How did those who took up these endeavors m ake a living? Did that affect the inquiries that pursued and the way they pursued them? What part did their technical work play in their careers? Do the answers to all those questions vary according to the period or the discipline? (*Ibid*., 16)

There is no doubt that these questions are important and valuable, yet it is not clear that the answers to them can help us find out what is science. Actually this approach must rely upon some basic assumptions about science in order to classify ancient practices as scientific ones, so it seems to be circular. In order to identify either a scientist or a scientific idea, you need to know what is a scientist or a scientific idea, which goes back to the original issue.[8] There were many different ideas or concepts. Political, moral, and religious ideas were abundant in ancient cultures and were often emphatically debated by the learned, yet they are not scientific ideas.[9] There were also different disciplines in ancient cultures, even according to Lloyd/Sivin's classifications. So we need to figure out what is science before we can search it in these cultures.

In his 2004 book *Ancient Worlds, Modern Reflection*, Lloyd suggests that "we should delineate science rather in terms of its goals or aims," instead of defining science in terms of results which are always changing (Lloyd 2004, 14). Science has a set of constitutive goals of "understanding, explaining, predicting (and many would nowadays add controlling, by exploiting the knowledge gained from human ends)" (*Ibid*.). For Lloyd, not all kinds of understandings will count as science: only those about natural world are: science should be defined as "a matter of the ambition to arrive at some understanding of the phenomena of the external, non-social world – of the natural world" (*Ibid*.). Such an approach has many virtues. First, this definition is broad enough to include many scientific attempts in the history and in different cultures. Almost all known cultures have made serious attempt to understanding the world surrounding them. In this sense, scientific pursuit is a universal attempt of human kind. Such a definition also allows some failed attempts in the past to be scientific: "those failures still rank as science (I should say) if they meet the basic requirement of aiming at understanding, explaining, and predicting 'natural' phenomena" (*Ibid*. 2004, 15). So even the theory of phlogiston is proven to be wrong, it was a scientific theory. We cannot guarantee our contemporary sciences won't become false in the future, but this does not lead us to question their scientific status today. Further, such an approach helps us delineate different fields of sciences, by locating the specific phenomena or issues that human beings tried to understand

[8] This is similarly the case with Kuhn's dependence on scientific community: what differentiates scientific communities from other communities? Kuhn eventually answers this question directly, in a way similar to Lloyd's later proposal.

[9] Llyod and Sivin focused a lot on the general learning class (like their discussion of Confucian school), but that does not shed much light on scientific ideas or scientists. Many scientific/technological advances in ancient China were made by the anonymous technicians or little-known scholars. They were often transmitted secretly within a family or a clan.

and explain. Anatomy and astronomy are different because of the issues they aim to investigate. Other territories can be similarly carved.

There is another virtue of such an approach: it makes the comparative studies of different scientific traditions possible. Given the common goals of understanding/explaining/predicting/controlling, we can compare how well different theories accomplish these goals if they are dealing with the same domain of phenomena. First, prediction and control work only at the observational level. All scientific traditions face the same challenge of predicting what is going to happen empirically. Such a power of prediction gives human beings better control of nature and provides great freedom to our life. Second, even though theories may need to have higher level understandings and explanations, at the fundamental level, what need to be understood or explained are those phenomena that we observe.

Lloyd has some reservations about the prospect of cross-culture comparisons. One lesson we learned from the fallout of logical positivism is that all observations are theory-laden. So there is no pure observation basis that is the foundation of comparison. It is further argued that the basic cognitive tendencies are different in different cultures. Also, what is observed or at least recorded and studied is often determined by pragmatic interests and social needs. So there is often no common base for comparative studies. These themes are further developed in Lloyd's 2007 book *Cognitive Variations*. I think these challenges can be met, though I will only give an outline of replies here. First, Van Fraassen (1982) offers an ontological way to define the observable sphere, which can help sidestep the problem of theory-laden observations. Second, as Lloyd admits, cognitive variations across cultures are not significant enough to shatter the observation base. The basic cognitive abilities are essentially the same across races and cultures. Lastly, differences in pragmatic interests won't have an impact on the possibility of comparative studies – it just adds another layer of differences across cultures.

Some problems remain with Lloyd's definition of science. It may be too narrow and too broad. It is too narrow because Lloyd restricts sciences to the studies of natural world, and excludes social affairs from the scope of scientific inquiry. Yet in many ancient cultures, Chinese culture in particular, there is no sharp distinction between matters of Nature and matters of human society. There is also no reason to think that studies of social phenomena such as social structure, government, and economy, cannot be scientific. Though he is aware of such problems, Lloyd worries that social phenomena are often unique to a society (for example, the celebration of Christmas), and as a result it makes cross-culture comparison meaningless. I think Lloyd's worries are not well grounded. First, many ancient cultures share many common concerns about social issues (e.g. how to govern a state and how to deal with social relations), and the similarities in social affairs between societies outweigh the differences. So some variations on social issues across cultures are not sufficient to exclude studies of social sciences from being scientific. Also, as Lloyd points out himself, even with natural phenomena, different cultures may focus on distinct aspects of the natural world and so accumulate different kinds of scientific knowledge. So differences in the focus of study alone do not warrant the separate treatment of natural and social phenomena. Finally, even if there were no shared issues that two cultures both aim to understand, this wouldn't disqualify studies of such issues in each culture non-scientific. It certainly makes cross-culture comparison almost impossible, since they are really dealing with different fields,[10] but this does not make the study in each field non-scientific.

In his 2004 version, Lloyd's definition of science does not require any further characterizations other than the aims and goals of scientific community. This seems to make the definition too broad. One objection is that this definition is so generous and permissive that it includes pseudoscience (such as astrology) as scientific theories. Lloyd's reply is that astrology aims at understanding and predicting human affairs (such as the fortunes of individuals and states). So it has a different set of goals from astronomy, and since it deals with human affairs instead of natural phenomena, astrology is not scientific by Lloyd's definition. This reply is not effective from the above considerations. Lloyd further explains that astrology might have led to development of true sciences, such as astronomy. Lloyd argues that astrology, as it was practiced in ancient Mesopotamia, Greece, and China, investigated the regularity of heavenly phenomena (such as eclipses), and eventually such studies became a subject (astronomy) independent of astrology. Such an explanation attributes astrology some values derived from astronomy. Yet this does not seem fair to the ancient practitioners of astrology, who did have a clear set of goals on their own, and had accumulated a significant amount of data that were often useful (though not completely true). A better reply is to admit (following Thagard) that astrology, as it was practiced in the ancient world, was a scientific inquiry, and it was a different subject from astronomy since its goals are concerned with the fortunes of human beings and societies. The same analysis applies to similar subjects like alchemy. What about modern astrology? They are clearly not scientific, so where to draw the line? One can follow Thagard again and argue that modern astrology is degenerative and is not scientific. Yet a better argument can be made that modern astrologers have a different set of goals: they don't aim at the true understanding of the relation between stars/planets and human beings, but rather aim at profit. These modern astrologers pretend they have true understanding of what they are doing, and use it as a tool to make money. In this sense, they are not scientists at all.

There is a more serious challenge to the attempt to define sciences merely in terms of its goals and aims. A religious community may aim at true understanding of the world, but if their fundamental beliefs cannot be shaken by any empirical findings, then their practice is hardly a scientific one. So in order for a practice to scientific, the practitioners need to have a scientific attitude. What is a scientific attitude? One important element is that practitioners of a scientific subject must respond to empirical pressure that is forced on their theories by observations. Though Popper's picture of constant threat of falsifiability may exaggerate a little bit, any scientific theory has to meet the challenges from the failed empirical predictions. Normal sciences, as Kuhn describes, attempt to "force nature into the performed and relatively inflexible box that the paradigm supplies" (Kuhn 1996, 24). Once

[10]For example, it is pointless to compare the study and understanding of snow by Eskimos with the study and understanding of rainforest by Amazon tribes.

anomalies accumulated and crisis emerged, it is inevitable that new paradigms are introduced to relieve the mounting empirical pressure.

In his 2009 book, Lloyd reaffirms his approach to define science "primarily in terms of the ambition to understand the world around us" (Lloyd, 2009, 160), yet he also noticed: "There can be no society that does not use what we may call trial and error method to extend their knowledge" (*Ibid*., 164). Lloyd further claims: "On one view, then, the practice of experimentation may be seen as just a more systematic and controlled version of those methods" (*Ibid*..). In this way, Lloyd connects ancient scientific practices with modern sciences. The difference between them is not an essential one, but is a matter of "degree of systematicity and self-consciousness" (*Ibid*.). Lloyd's interests in this chapter seem to be more focused on the historical and social contexts of scientific practices, and on how to resolve the tension between the narrow and broad definition of science. Assuming that Lloyd's definition of science includes a broad understanding of scientific method, e.g. the trial and error method, is his definition a satisfactory one?

It is not exactly clear what the trial and error method means and what roles it plays for Lloyd. From his explanations and examples, Lloyd seems to take the trial and error method as a kind of conscious and active way to attain knowledge through empirical tests. The emphasis is that a method of trial and error is not random trial or random observations, but is guided by particular interests and theories. This is in principle no different from modern experiments, which are designed and interpreted within a theoretical framework, though it is more general than the standard method of experimentation, and can cover the subjects that cannot be experimented upon, such as astronomy. But this is not a necessary condition, since random observations may also lead to meaningful discoveries. Also, Lloyd did not clarify the consequences of failed trials, and how the scientists should respond to such failures.

I will now clarify the notion of scientific attitude and argue that it is the missing component of the definition of science. I think there are two basic elements to scientific attitude. One is concerned with how to understand the relation between theories and observations, and the other is concerned with the metaphysical assumptions about nature (including both the natural world and the social world). We have seen in the above discussions that a scientific community must take empirical challenges seriously. The primary goal of scientific inquiry is to explain and predict everything at the empirical level. If a theory makes a false prediction, then the theory is put under pressure to resolve the issue. If the theory cannot successfully resolve the issue after repeated efforts, then the pressure starts to mount. This does not imply such a theory must be abandoned – a flawed theory is not abandoned until a better alternative emerges, since it is often better to have a flawed theory than to have nothing. But this says that the theory is not quite adequate and needs to be revised. In the history of science, the demand of empirical adequacy is the driving force for scientific development. Compared with other disciplines such as art, law, religion, and philosophy, science is unique in such a requirement for empirical adequacy.[11]

[11]For example, mythological stories may offer great understanding of and give explanations to empirical phenomena. They may even give predictions and help control the nature, but they are

Second, a scientific practice requires some metaphysical commitments. For example, scientists believe that there are inherent stability and regularity in nature, even though things may look pretty random and chaotic. Such stability and regularity is independent from both human caprice and arbitrary divine intervention. The ancient Greek concept of 'logos' and the Chinese concept of 'Dao' reflect such stability and regularity of nature in their different systems. Also, such stability and regularity are known to human beings, at least in principle. Such commitments seem to be common in all scientific traditions we are interested in, and they are essential to any scientific inquiry. Today we have a much more sophisticated picture about the science and its relation to the world, yet, using Lloyd's term, the difference between today's sciences and ancient sciences is a matter of degree of systematicity.

To summarize, the criteria of science can be characterized in the following ways. First, at least for the purpose of cross-culture comparisons, it is necessary to look at how science is practiced in a society. We need to know what the community of practitioners aim at, and how their practices look like. Second, science is defined by a particular set of goals that involve understanding, explaining, predicting, and controlling the world around us. Particular subjects of science are classified by the specific issues that are targeted by such goals. Third, the community needs to take a scientific attitude toward their practices, which means that they are willing to take up empirical challenges to their theories and that they assume nature behaves in an objective and stable way that is knowable to us in principle. Together they constitute the essential conditions for scientific inquiries. From the above discussions, I think that this definition is broad enough to cover scientific practices from different cultures, and is also narrow enough to distinguish them from non-scientific ones.

III. Chinese Sciences

Given the above criteria, it is easy to see why Chinese sciences are indeed science. In the history of Chinese civilization, we can see clear and conscious efforts to understand, explain, and to predict natural and social phenomena. Such efforts are obvious in many different fields, including mathematics, astronomy, agriculture, physics, chemistry, and many applied areas of technology. Needham's studies of Chinese science and technology provide a nice window to showcase what Chinese scientists had accomplished. Chinese scientists also had a scientific attitude toward their inquiries. Using Sivin's study of Chinese astronomy as an example, we can see how empirical observations put a tremendous pressure on Chinese astronomy, as the calendrical systems were repeatedly revised in light of new observations (Sivin, 1995a, II). Also, even though Chinese astronomers were sometimes greatly frustrated by the inaccuracy of their calendrical systems, most of them never gave up the objective regularity of the heavenly movements.[12] Such an assumption about

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not *scientific* theories if they don't aim for empirical adequacy and cannot be challenged by empirical findings.

[12]Sivin (1995b, V) gives a detailed analysis on this issue, and he concludes that "despite the crisis in astronomy that began in the Later Han, the urge to make astronomy a science again

objectivity and regularity in nature is prominent in the writings of Chinese philosophers, and is ever-present in empirical inquiries of Chinese scientists. So by the above definition, Chinese indeed had sciences.

The fields of study are characterized by the empirical problems its practitioners set up to understand, explain, predict and control. For example, astronomy is concerned with the behaviors of heavenly objects and the regularities of their movements. Astrology, on the other hand, is concerned with the relations of heavenly objects and human affairs.[13] Even though the two subjects were not as clearly cut in China as it was in Greek, we have enough evidence to show that Chinese were aware of their differences and Chinese astronomers were conscious of what they were studying. Similarly, despite the huge conceptual difference between Western and Chinese medicine, it is easy to identify this subject given its obvious field of inquiry, in which we also witness the scientific attitude of its practitioners.

Sivin once made an interesting claim about Chinese science: "Chinese had sciences but no science, no single conception or word for the overarching sum of all of them" (Sivin 1995a, VII, 48). From his studies of Shen Kua, a Song scientist who had wide interests and great abilities, Sivin found that there was no unified theme in Shen Kua's studies. Shen studied not only physics and astronomy but also "pseudo-sciences" such as divination and astrology, and did not note much difference in their scientific status. If something common can be found from such studies, such generalizations will be too broad to be of any use. Sivin explains: "Words for the level of generalization above that of the individual science were much too broad. They referred to everything that people could learn through study, whether of Nature or human affairs (*hsueh* 學), or even more broadly to any pattern that could be apprehended through any form of cognition (*li* and *tao*)" (*Ibid*..).

Two replies can be made to Sivin's arguments. First, in the above discussions Sivin seemed to use modern sciences as the reference point for his judgment about what is science. This actually violates his own research spirit which emphasizes the historical and contextual approach to science. Such "pseudo-sciences" as astrology and divination were actually scientific attempts to gain understanding about the world and man. By the broad definition of science, they were scientific. Secondly, Sivin, like Lloyd, excludes studies of human world from the realm of scientific studies. Yet Chinese scientists endorsed a philosophical tenet that man and nature embody the same principle. So there is no essential difference between studies of human affairs and studies of natural events. If we look at Chinese sciences with this assumption in mind, then there is a unifying theme for Chinese sciences. The same *Dao* was believed to govern all things in the world, including heavenly matters, earthly matters, and human affairs. The ultimate goal of scientific inquiry is to understand the *Dao*.

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never entirely subsided. It became a strong motivation from the eleventh century on, as impulses from philosophy stimulated astronomers, and vice versa" (183).

[13]Details may differ on what kind of relations it sets up to discover. It may be a causal relation that the heavenly objects exerts on human affairs (in the Western case), or it may be merely a sign to indicate human affairs (in the Chinese case), or it may be taken to be a correlation explained by other causes (in some modern theories of astrology).

Different scientific subjects, whether it is geometry, geomancy, divination, astronomy, or astrology, explore different aspects of the *Dao* in an empirical manner. The Chinese framework is more holistic than the modern Western sciences, yet it is not significantly different from the approaches we encounter in ancient Greece.

We should also notice that Chinese sciences have some unique aspects. The uniqueness is reflected both at the general level and in the individual sciences. Even when Chinese science and Western science were dealing with the same kind of questions, the styles of inquiry were often dramatically different. For example, Chinese logic is essentially analogical, which is based on inference about kinds. This is very different from the deductive Aristotelian logic, and it had a huge impact on the direction of Chinese sciences. Chinese mathematics is basically an empirical science. It does not aim to prove its statements, but aims at giving algorithmic solutions to paradigm examples. Ancient Chinese math books consist mostly of such solutions to exemplary questions. For Chinese mathematicians, the need of demonstration is never a big concern. If a statement is known to be true, there is no need to further prove its truth. The proof itself does not add anything more to its truth. There are many unique features present in other Chinese subjects, such as Astronomy, Medicine, and Chemistry. One common feature to all Chinese sciences is its lack of theoretical structure. Chinese sciences have theories, yet such theories are not well connected to the empirical observations. In contrast, theories in Western sciences have a deductive structure that connects theory to observations. This is certainly the most prominent feature of modern sciences (which is elegantly analyzed by the logical positivists), but it is also the case with ancient Greek sciences.[14]

In conclusion, in this paper I have offered a detailed analysis of the criteria of science, and proposed a reasonable definition of science that does justice to different styles of scientific inquiries present in ancient cultures. By such a definition, Chinese sciences are genuine scientific inquiries with some unique features. This result is certainly no surprise to anyone who is familiar with Chinese sciences, and I hope I have made it clear why it is the case. Also, I hope this study can be helpful to our contemporary dialogues between different cultures in this more and more globalized world.

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[14] For a more detailed discussion on Chinese sciences and their lack of theoretical structures, refer to Sun (2009).

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