

PROBLEMS AND PROSPECTS IN THE NEEDHAM PARADIGM FOR SOCIAL STUDIES
OF CHINESE AND MODERN SCIENCE

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Introduction. Joseph Needham began his studies of science and civilization in China to determine why modern science developed in Europe and not in China. Early in his studies, a second equally important question was raised by his findings on the state of science and technology in ancient and medieval China: Why was Chinese civilization between the -1st and +15th centuries more efficient, or advanced, than Western civilization in applying knowledge to practical human problems (Needham, 1964: 127)? The rationale for Needham's Problem rests on the conclusion drawn from documentary and archeological evidence that some of the major preconditions of the West's Scientific Revolution were present in ancient and medieval China.

A knowledge of Needham's work is indispensable in social studies of Chinese science, analyses of continuities and discontinuities in the historical relations of science and society in China, and comparative studies of science and society. My objectives in this paper are to (1) outline the Needham Paradigm (including basic queries, rationales, assumptions, hypotheses, and world view), (2) identify and discuss promising and problematic aspects of the paradigm, and (3) briefly consider the relationship between contemporary scientific activity in China and the West, and the future of science. My assumption is that it is not too early for specialists in various fields - with and without competency in the Chinese language - to begin to critically digest Needham's work, and to consider some of the research problems generated by his findings and working hypotheses.

I have adopted the convention for this paper of citing references to Needham's multi-volume Science and Civilization in China (1954-) in terms of volume number, part, and page(s).

The Needham Paradigm: Basic Queries. The two basic queries guiding Needham's work are (1) why did modern science emerge in Western Europe and not in China, and (2) why was China more advanced in science and technology than Western Europe during the nearly two millenia prior to the Scientific Revolution? These two queries are formulated in a variety of ways throughout Needham's writings, and I have collected a sample of these formulations in Appendix A. The queries constitute Needham's Problem.

Rationale and Positive Hypotheses. The basic queries arise because the study of the history of science and technology in China reveals, according to Needham, the presence of many factors which appear to have facilitated the emergence of modern science in Western Europe. These include pre-, proto-, and para-scientific theories (e.g., Yin-Yang, and the notion of the Five Elements), and ideas (e.g., Fan Kuan, "objective observation", and Wu Chi, "omnipresence of the Universal Pattern"), the efforts in scientific logic by the Mohists and Logicians, and outstanding scientific achievements by individuals such as Ko Hung and Chu Hsi.¹ The major facilitative factors discussed by Needham are listed in Appendix B.

Negative Hypotheses. Given the many facilitative factors identified by Needham, why didn't China experience, to borrow Needham's oft used terms, a "spontaneous", or "autochthonous" Scientific Revolution? Needham (Vol. I: 3) argues that China, like Western Europe, experienced primitive and medieval science; why didn't China reach the next stage, modern science? To pose the problem in terms of a specific technology, having developed primitive and then

quantitative navigation (the latter some two or three hundred years before the Europeans), why didn't the Chinese reach the next stage, mathematical navigation (Vol. IV, 3:560)? As in the case of facilitative factors, Needham suggests numerous inhibiting factors, from China's failure to develop a syllogistic logic to the poverty of sounds in the Chinese language. The major inhibiting factors discussed by Needham are listed in Appendix C.

The General Sociocultural Hypothesis. The variety of ideological, philosophical, and theological inhibiting factors is ultimately subordinated to the General Sociocultural Hypothesis, which is stated in various ways and covers a wide range of variables. This hypothesis states that the basic explanatory factors in Needham's Problem are social and economic, and that favorable social and economic conditions, manifested in the transition from feudalism to mercantile and then industrial capitalism in the West, could have overcome any intellectually limiting factors and fostered a Scientific Revolution in China. Three illustrative formulations of this general hypothesis are listed in Appendix D, along with a sample of Needham's more specific sociocultural and environmental-ecological hypotheses.

World View. There are five components of Needham's world view which should be noted in rounding out this paradigm: (1) a universalistic conception of modern science, (2) a view of the relationship between Chinese and modern science expressed in the hydrodynamic, titration, and critical points metaphors (described below), (3) an allegiance to an epistemology rooted primarily in mathematized physics, to a Whiteheadian (organic) metaphysics, and to a dialectical materialist sociology, (4) a socialistic image of

humankind, and (5) a conception of the project on science and civilization in China as a contribution to world understanding.

The hydrodynamic metaphor likens the primitive and medieval sciences of all the world's cultures to "rivers flowing into the ocean of modern science" (e.g., Vol V, 2:xxviii). The titration metaphor describes Needham's method in the comparative history of science and technology: by constantly trying to "fix dates" for discoveries and inventions, Needham sees himself "titrating" Chinese against West European civilization (and, to a lesser extent, other civilizations, notably Indian) in order to (1) give credit for achievements in science and technology where credit is due, and (2) find out why one combination of socio-economic and intellectual factors gave China the lead in science and technology over Western Europe and the rest of the world for nearly two millenia, and why another combination allowed Western Europe to "catch up" and give rise to modern science (Needham, 1969: 12). The critical points metaphor labels the time at which Western science overtook Chinese science as the transcurrent point, and the time at which the Western and Chinese forms fused, melting "all ethnic characteristics" into "the universality of modern science" as the fusion point (Needham, 1970: 397).

The above constitutes, in bare outline, the Needham Paradigm. More details of the paradigm will come into focus in the following discussion which is aimed at an evaluation of the paradigm as a source of research leads, and as a device for generating valid knowledge about science in China.

The Needham Paradigm: Problems and Prospects

Needham's Problem. Three positions on the Needham Problem can be identified in the literature on Chinese and modern science. One is that there is evidence that a Scientific Revolution was, to use Ben-David's terms (1964: 457), "intellectually possible" in China: that is, Needham's Problem is indeed a problem. The second position is that Needham's Problem is a problem, but it cannot be adequately dealt with until we have first comprehended Chinese science on its own terms. Nathan Sivin (1968, 1973, 1975) advocates this position and has contributed significantly to its realization. I will refer to this position as the Sivin Imperative. The third position, championed among some sinologists, notably Arthur Wright, is that there is no Needham Problem. Chinese culture, they argue, must be understood as a whole, on its own terms, and without reference to teleological notions about movements toward a universal world science, and a cooperative world commonwealth (e.g., Wright, 1957, and Hummel, 1955: cf. Gillispie, 1957).

I have adopted the position that the Sivin Imperative and Needham's Problem are not incompatible, and should in fact be worked on simultaneously. I rely on the following discussion to establish the rationale for this position.

Needham's Factors Approach. Needham's approach to his problem has been to identify (a) the defining developments of modern science (e.g., the mathematization of hypotheses, and the wedding of experimental method and theory construction), (b) the necessary precursors of these developments (Euclidean geometry, Ptolemaic astronomy, knowledge about magnetic phenomena, and Paracelsian alchemy: Needham, 1973: 3-4), and (c) the underlying

supportive and correlative factors which on various levels (social, economic, and intellectual) constituted the preconditions for the Scientific Revolution. This has led Needham to the identification of negative or inhibiting factors. The procedure is then to show, through detailed comparative analyses, that the preconditions of the Scientific Revolution (which obviously existed in Western Europe) did not exist in China.

Needham's approach has led to an unending list of facilitative and inhibiting factors. This approach, however, lacks (1) a careful consideration of what "Scientific Revolution" refers to, and (2) a systematic theoretical program for explaining why it occurred in Western Europe and not in China.

The idea that the differences and similarities between science in China and Western Europe are ultimately related to social and economic factors should be appealing to sociologists. In order to work with this idea, however, it is necessary to view the Scientific Revolution as a social fact. Weber (1958: 15-16) and Ben-David (1964: 459) have provided a basis for this by viewing modern science in sociological perspective. Following their contributions, modern science can be defined as the pursuit of scientific activity by persons occupying positions as scientists in specialized settings (e.g., scientific societies, research laboratories, or universities), all of whom regard scientific activity as the source of valid knowledge about reality, submit the results of their activities to the community of scientists for judgment, criticism, and use, and are rewarded (materially and symbolically) for their activities (roles) in a publicly recognized, more or less autonomous institutional sphere. "Autonomous" is used in the sense of a functionally differentiated social activity and process, not of an isolated and independent social system (Karp

and Restivo, 1974: 126).

Needham's General Sociocultural Hypothesis. The sociological conception of modern science leads to a sociological reformulation of Needham's Problem: Why did scientific activity become functionally differentiated and institutionalized in Western Europe and not in China or elsewhere? This reformulation implies that what are usually considered the defining characteristics of modern science - e.g., mathematization, the interaction of theory and experiment, and universalism and rationalism as basic normative orientations - were historically dependent on the continuity in communication and innovation made possible by functional differentiation and institutionalization. This idea paves the way for an eminently Durkheimian sociological explanation of a sociological fact. Needham's General Sociocultural Hypothesis, which encompasses environmental and ecological factors in its broadest formulation, can now be seen to be appropriate to the problem as I have reformulated it. Karp and I have discussed this, in a preliminary way, elsewhere and suggested that theory in human ecology may hold the key to solving Needham's Problem. It appears that only in Western Europe did conditions exist which stimulated scientific attitudes and concepts of a scientific role (as Merton and Ben-David have noted), and allowed for the functional differentiation and institutionalization of science, a fact which has been understressed and to some extent obscured by Merton's "reciprocal influence assumption" regarding the relationship between Puritanism and modern science, and by Ben-David's "utilitarian hypothesis" which emphasizes "needs," "demands," "social value," and "social interests" as factors in the evolution of modern science (Merton, 1970: xxviii; Ben-David, 1971: 31, 45ff, 68). Human ecological

considerations suggest that differences in the interrelations of environmental and social structural factors can help to account for the greater degree of functional differentiation that came to characterize Western European in contrast to Chinese civilization by the 16th and 17th centuries. In this perspective, Protestantism, modern capitalism, and modern science are conceived as parallel responses in different institutional spheres to a common set of environmental-social structural conditions which fostered a highly differentiated exchange-based economy and the decentralization of authority patterns in Western Europe as a whole (Karp and Restivo, 1974).

World View: Modern Science, Chinese Science, and Human Nature. In all of his writings prior to the "Author's Note" which introduces Part II of Volume 5 (in which some tentative qualifications, which I will discuss shortly, are introduced), Needham describes the Chinese scientific tradition as pre-, proto-, or para-scientific. His point of reference is modern science, which he conceives to be the latest stage in the evolution of science. In contrast to the two earlier stages, primitive and medieval science, modern science does not have an "ethnic stamp" (Vol. IV, 1: xxvi). Thus Needham refers to modern science as it emerged in the West's Scientific Revolution in phrases such as "the universality of modern science" (Vol I: 3), "science in the fullest sense" (Vol. II: 60), "perfected world-view of natural science" (Vol. II: 339), and "universally valid world science" (Vol. III: 448). In the Scientific Revolution, according to Needham, "the basic technique of discovery" and "the full method of scientific investigation" were discovered, the "absolute universality of mathematics" was established and the conditions for generating "a body of incontestable scientific truth

acceptable to all men everywhere" based on the "universal language of mathematized hypotheses" set up (Vol. III: 448). Universalistic science, potentially open and comprehensible to all human beings, is the foundation, according to Needham, of a new universalism which is preparing the way for the unification of "the working peoples of all races in a community both catholic and cooperative" (Vol I: 9; Needham, 1970: 417-418).

We are, for the moment, Needham believes, in troubled times. This is not, in his view, because of modern science as some critics of science contend. Needham considers science "neutral" (Vol II: xxvi). The fact that good and evil effects attend the development of natural knowledge is, Needham argues, a fact of human nature (Vol. II: 149). This orientation has as one of its consequences - explicitly expressed by Needham - the fact that in some cases at least scientists must engage in non-benevolent acts in order to insure long-term benevolent results in the pursuit of knowledge: this is a sine qua non of scientific method (Vol. II: 49). This viewpoint is developed further in Needham's criticism of Said Hussain Nasr's argument that modern science never arose in Chinese or Islamic civilization because of metaphysical doctrines and traditional religious structures which prevented profaning nature (Nasr, 1968). Needham stresses the fact, in his view, that science demands working as if Nature is "profane" (Vol. V, 2: xxv). In part, Needham wants to point out that we cannot do science if we are going to divide the world up into things that can be studied scientifically (the profane) and things that can't (the sacred). He succeeds, however, in lending support to three positions - the neutrality of science, the profanity of nature, and the need for non-benevolent acts - which appear to be inconsistent with his socialistic sympathies. I will consider this inconsistency later in this paper.

There is some confusion in Needham's work because of the fuzziness of the concepts "modern science" and "Scientific Revolution" in his work and in the history of science in general. Needham relates Chinese science to three versions of modern science: (1) Galilean-Newtonian science (the mechanistic version), (2) Einsteinian-Planckian science (the field, organic version), and (3) future science (fully and unequivocally organic). Thus, when he relates Chinese science to version I, Chinese science appears to be very different in its philosophical foundations, but pre-, proto-, or para-scientific in terms of scientific attitudes, theoretical orientations, and methods. When compared to relativistic-quantum mechanical science, China's organic perennial philosophy fares well as an anticipation of the "modern" scientific world view. Since future science will, in Needham's view, probably be even more "organic" than relativistic-quantum mechanical science, China's scientific achievements are most notable in this third comparison.².

Following this line of inquiry, it is interesting to note that the "universal science" introduced by the Scientific Revolution Needham eponymizes as Galilean lasts, in one of his accounts, for hardly two centuries. In a matter of 163 years, from the birth of Galileo to the death of Newton, Needham takes us from a Revolution to the seeds of the destruction of the new science introduced by that Revolution, sown by Leibniz. Leibniz, with his ties to the Chinese traditions, is presented as the leading figure in the movement to replace the mechanistic science of Galileo with a more organic science (Vol. III: 157). This confuses the issue of what modern science is and what the Scientific Revolution accomplished. It reflects the lack of careful conceptualization, which I discussed earlier, and the inevitable difficulties that arise when "heroes"

such as Aristotle and Galileo are relied on to explain social facts. Aristotle and Galileo are the two central figures in one of Needham's most confusing exercises in the history of science, the "parallel heroes" question.

Did China produce an Aristotle or not; and if China did not, was this a hindrance to the development of Chinese science on the path to modern science? For Needham, at times, and for some historians of science, Aristotle is an important link in the chain of activities and processes that leads from pre- to modern science. Needham cites Aristotle, for example, as a figure in the trend to experimentation which started with him and "led to Galileo through Leonardo" (Needham, 1972: 35). Aristotle is also portrayed as the pre-scientific polar genius on the theory of impetus, with Nicholas Oresmus the medieval transitional figure, and Newton at the modern science pole (Needham, 1969: 84).

There are dangers in seeking parallel heroes, i.e., looking for China's Aristotles, Galileos, and Newtons. Such an approach imposes specific historical biographies on other people and obscures their individuality, and the ways in which they reflect and reflect on their particular cultural settings. It also expresses a unitary view of science and scientific contributions. Even if there is some heuristic value in this kind of exercise (Cf. Sivin, 1973: xvi-xvii), it is hindered by Needham's equivocations. Thus, he suggests that China produced no Aristotle in one place, and at the same time points out that Aristotle and Aristotelian logic were necessary ingredients of modern science (Vol. I: 18). Needham cannot, however, unequivocally assert that the term fa used by the Mohists did not include all of the Aristotelian causes (Vol. II: 183), nor can he maintain without uncertainty that the Mohists had not in fact developed Aristotelian logic,

or that they were not capable of inventing it, or furthermore that Aristotelian logic does not exist, informally, in Chinese thought.³ In addition, Needham finds discussions in the Chinese literature that are, in his view, as sound from a scientific viewpoint as anything in Aristotle. The discussions in the Pao Phu Tzu (Book of the Preservation-of-Solidarity Master), written in the early 14th century, are exemplary (Vol. II: 439). Furthermore, Needham notes that scholars from Francis Bacon to A. Whitehead considered Aristotelian logic more of a hindrance than a help in the emergence of modern science. Given these problems, it does not appear that the comparative history of science in Chinese and Western Europe can gain much from a search for China's Aristotle (cf. Vol. II: 201).

For Needham, Galileo is the focal point of the Scientific Revolution, the central figure in the mathematization of science (Vol. III: 154), and the developer, in "almost perfect form," of the experimental-mathematical method (Needham, 1972: 29). This view of Galileo as the hero of the Scientific Revolution may, however, create confusion, especially when Needham takes us hunting for China's Galileo. Needham points out, in the first place, that Galileo had "precursors" (e.g., Buridan, Bradwardine, Philoponus, and Nicolas Oresmus: Vol IV, 1: 1). In addition, Needham argues that the theorizing and experimenting components of the Galilean method were possessed by, respectively, the scholastics and the higher artisanate in pre-Galilean Europe (Vol. III: 160ff).

There are at least three points to consider in weighing the place of Galileo in the Scientific Revolution, and the significance of Needham's contention that China did not produce a Galileo. First, historians of science have not abandoned Galileo as a hero; but increasingly, they have made him share the pedestal with other heroes, notably Copernicus, Kepler,

and Newton. Second, historians of science are not unanimous and unequivocal about Galileo's place in modern science. Mittelstrass (1972), for example, suggests that what we see as "new" in Galileo's nuova scienza, depends on what we think characterizes modern science, and in particular modern physics. This includes consideration of the extent to which the mathematization of physics is more an ideal than an accomplishment in Galileo's work (cf. Finocchiaro, 1975: 120). Finally, given Needham's conception of modern science, we can ask, following Feyerabend (1970: 323), whether Galileo is an appropriate representative of that science given his actual methods.

I want to stress that far from being an advocate of the heroic approach to the history of science, Needham is unusually sensitive to social facts in scientific change, even when writing about "scientific heroes" like Galileo (e.g., Needham, 1972: 32-33). This does not reduce the confusion introduced by the elements of the heroic approach that enter into his discussions.

Chinese and Modern Science. In his introductory note for Part II of Volume 5 in Science and Civilization in China (1974), and in answer to criticisms (especially those of his collaborator, N. Sivin), Needham admits that (1) traditional Chinese science should not be viewed as simply "a failed prototype of modern science" (a viewpoint previously adhered to and illustrated by his contention that Taoism retained "unborn within itself, science in the fullest sense," and was oriented in a direction that would have ultimately lead to modern science : Vol. II: 47, 60; Vol. V, 2: xii); and (2) modern science is not the last word, and everything in the past should not be judged in its light nor related to it as a final court of appeal (Vol. I, 2: xxviii). However, there is some

indication that Needham is not fully persuaded by this, and that in fact he misses the point of the criticisms he addresses. The above admissions are immediately qualified: modern science is not the last word, and we must remember its "transitory nature", but it is a "reliable measuring stick" (Vol. V, 2: xxviii); science today is not "all that science will ever be" (Vol. V, 2: xxix), but we cannot deny "the fundamental continuity and universality of all science" (Vol. V, 2: xii). To the extent that he is persuaded by critics of the universalistic approach that characterizes his earlier contributions, it seems to be in terms of envisioning potentials for scientific change that will allow him to assign an even more exalted position to Chinese science in the history of the emergence of world science, which must now be considered a future development rather than a present reality (Vol. V, 2: xxix).

Needham is not ready to abandon his hydrodynamic metaphor (Vol. V, 2: xxi). He does, however, acknowledge that differences concerning how modern science emerged and what its future is likely to be can be entertained (Vol. V, 2: xxviii). He also acknowledges two points of view on the relationship between Chinese and modern science. One is the viewpoint he still seems to cling to, that the Chinese and Western scientific traditions were on paths directed toward modern science. The second, advocated by Nathan Sivin, is that Chinese and Western science might have been, and still be, on separate paths, with their true merger lying in the future (Vol. V, 2: xxviii-xxix).

Needham convincingly argues that he has brought an unusual combination of talents to bear on the documents and archeological evidence of ancient and medieval China. In particular, he has stressed his education in science as necessary preparation for dealing with the Chinese scientific and

technological tradition. This should not be accepted uncritically as a blessing. There is reason to be sceptical of Needham's translations and interpretations. He has an understandably strong - some critics would say "zealous" - commitment to setting the record straight on Chinese achievements in science and technology, long unknown and ignored by Western scholars. He also developed strong intellectual attachments to Whitehead's metaphysics, the Marxian idea of inevitable stages in social evolution, dialectical materialism, and the universality of the modern scientific orientation before undertaking his study of science and technology in Chinese civilization (v. Price, 1973; Nakayama, 1973). Given the widely acknowledged difficulties of translating in general, and of translating Chinese in particular, and the possibility that Needham's linguistic skills are not up to the highest standards (Graham, 1973: 46n), it would be foolhardy in the light of Needham's intellectual biography to uncritically accept his continuing discoveries of Whiteheadianism, dialectical thinking, and anticipatory pre-modern scientific attitudes, concepts, and methods in Chinese texts. These discoveries are even more problematic given the fact that Needham's project is not an in-depth, definitive study but, in his own words, "a reconnaissance" (Vol. I: 5). Warnings and cautions, tempered and otherwise, have been duly sounded. William McNeill, for example, has labeled "nonsense" Needham's claim that the Taoists had the idea of "natural selection," and generalized this by implication to all of Needham's efforts to discover parallel ideas in the light of the formidable difficulties of translation. Sivin has argued that we will be bound to trivialities if we forget that Chinese concepts and attitudes - for all the similarity they may exhibit to concepts and attitudes in science today and in the future - were embedded in disciplines

"drastically different" from our own in aim, approach, and organization (Sivin, 1973: xxvii).

One of the things that is missing in Needham's conception of his project and in the comments of his detractors and appreciators, and which might help to organize the type of critical evaluation aimed at in this paper as well as independent studies of Chinese and modern science, is a sense of the comparative history of science as an exercise in the cross-cultural anthropology of knowledge. I want to explore some of the implications of such a perspective for dealing with Needham's Problem.

History of Science as Anthropology of Knowledge. Let me begin by noting a specific problem in Needham's methodology which suggests the need for an anthropological approach to the comparative history of science. Needham's stress on distinguishing between empirical principles (characteristic of pre-, proto-, and para-scientific activities in China and elsewhere) and systematic theory (characteristic of modern science), and his reliance on a unilinear theory of the evolution of theory through three stages - primitive, medieval, and modern - presents the possibility that the theory-laden nature of all human observations and activities will be obscured. Furthermore, the stress on the distinction between empirical and systematic science, and the unilinear theory of scientific evolution (recall also Needham's hydrodynamic metaphor) insures that we will only be able to understand pre-modern theoretical statements, or infer theoretical understanding, in terms dictated by modern science. We are also likely to view pre-modern theories as "ethnicized" and modern theories as "universal" without being able to show clearly and unequivocally why modern theories are not also ethnicized. Finally, we are likely to conclude that since the

theories we read or infer are "incorrect." it is amazing how often, with what skill, and on what scale great technological achievements can result from "wrong reasoning". Two or three thousand years from now, perhaps, our own technological achievements may appear, from a comparable perspective, miracles of "wrong reasoning."

The pre-modern Chinese, so far as we can gather from Needham and other students of Chinese science, were no more or less theorizers than the people of other pre-modern civilizations. Their pre-modern theories were not quantified, tended to be more integrated into a world view, were independent of experimental evidence in the modern sense, and were not characterized by the generational continuity associated with science from the 15th century on. The question is, is there more to scientific understanding than modernistic theories that can be written down? What about non-linguistic forms of inquiry and understanding? Most scholars would probably accept the idea that non-linguistic forms of knowledge are part of human thought, but what about the possibility that they may be, in some respects, more important than linguistic forms, as Hooker (1975) has suggested? The more conventional issue here is the controversy over the relationship between theory and observation. For some philosophers and other students of science, Feyerabend's, Hanson's, Kuhn's and Toulmin's positions on scientific changes as changes in observables are too strong and destroy the possibility of referring theories to experience (Kordig, 1971). The underlying problems here may, to some extent, be related to a specific aspect of Needham's world view that is related to the problem of dealing with the relationship between theory and observation and which invites critical anthropological scrutiny.

The Psychic Unity of Mankind. The "psychic unity of mankind" hypothesis or assumption is central to Needham's heart and method, and not unrelated to the Sivin Imperative that we work to understand Chinese science in its own terms. This idea, which has had a troubled history in anthropology, states that human beings everywhere and at all times (or, at least, over a period during which we can be relatively certain that no major biological changes - especially involving the brain and nervous system - have occurred which would affect mental potential or functions, say the last 35,000 years) have had similar propensities and abilities. As a general proposition, and as an egalitarian and anti-racist proposition, sentiment, or metaphor it can, in my view, stand unchallenged. There is, however, a chance that if it is accepted uncritically and axiomatically independent of cross-cultural evidence, it might obscure or close access to learned differences which seem to contradict psychic unity, and incline students in cross-cultural and comparative studies to minimize or ignore the difficulties of understanding a second culture in its own terms.

Consider, for example, Donald Campbell's studies of responses to optical illusions. In undertaking these studies, he noted that if different response patterns were found in different cultures, the first place to look for an explanation should be differences in visual environments. He proposed "the carpentered-world hypothesis": the proportion of artifacts that are rectangular (i.e., the degree to which the visual environment is carpentered) varies across cultures; the greater the degree of carpentering, the greater will be the tendency for people to habitually interpret obtuse and acute angles as rectangular surfaces extended in space. Similarly, the habit of interpreting elliptical retinal images as circles extended in the

third dimension might be absent in cultures where the visual environment included objects which were actually elliptical in cross-section (Campbell, 1964: 309).

Campbell (1964: 310) also identified the two-dimensional representation of three dimensional objects as a factor related to illusion responses. Perspective drawing, he pointed out, is a pervasive feature of Euroamerican culture from childhood on, and the techniques or conventions of perspective drawing may be related to the habits of inference which some illusions illustrate. I will refer shortly to the relevance of China's reliance on "parallel perspective", with respect to Campbell's hypothesis.

Campbell's experiments indicated that there are differences in the ways in which people respond to standard (for Westerners) optical illusions. These results could lead to the conclusion that different people perceive and think in radically different ways. The differences Campbell observed, however, were small; and it was because the differences were small that they could be determined (Campbell, 1964: 325). This suggests an optimistic epistemological hypothesis: there are differences in perceptual and thought patterns across cultures, but they are small enough to permit cross-cultural understanding. There is also, however, a pessimistic epistemological hypothesis implied in Campbell's results. If, Campbell writes, we ask how people discriminate between ignorance, truth, and falsehood we can hope to answer this question within certain limits when such discriminations are actually made. Such knowledge, however, may turn out to be possible only under rare conditions, and possibly only under experimental laboratory conditions. Campbell concludes that the achievement of such conditions may be entirely lacking in the

cross-cultural study of philosophy, and by implication in the study of knowledge and science (Campbell, 1964: 326-328). We should, he urges (in line with the Sivin Imperative) strive to achieve an "insider's view", but recognize (1) the impossibility of achieving more than an approximation (Hockett, 1964), and (2) the fact that "a brain", as Mackay (1964) shows, "which has mapped a certain environment becomes a biased machine for mapping another environment" (Campbell, 1964: 330).

Campbell (1964: 331-333) proposes the method of triangulation for approaching the limits of certainty in cross-cultural studies. Basically, this amounts to relying on ethnographers from plural cultures studying plural cultures. It would be enough, he argues, to have two ethnographer cultures focused on one target culture. This, in fact, is what Needham and his collaborators have tried to achieve. However, Campbell is concerned with studying cultures in the present, and his final comment on these matters points out the special (and ultimately perhaps insurmountable) problem faced by students of cultures in the past. Any given cultural item (including a linguistic item, I would emphasize) must be examined in its total cultural context. Obviously, the student of cultures in the past cannot realize this goal in the same way and to the same extent that the student of cultures in the present can. The fundamental problem, however, of special concern for the student of cultures in the past, is that the context dependence of cultural items "removes the possibility of certainty and makes ever present the possibility of erroneously alleging cultural differences as a result of mismatching" (Campbell, 1964: 330-331). This problem is obviously also present in establishing similarities (cf., Quine, 1970-73).

The preceding discussion falls, in general, within the province of the so-called "culture-and-cognition paradox" which I want to consider next.

Culture and Cognition. The culture-and-cognition paradox (following the discussion in Paredes and Hepburn, 1976) is this: on the one hand, there is the psychic unity of mankind hypothesis or assumption; on the other hand, anthropologists such as Campbell have shown that cognitions are dependent on environment and culture. The human mind functions similarly in every culture; but culture determines the behavior of the brain in response to specific stimuli.

The culture-and-cognition paradox is based in part on the attempts of ethnographers to describe and explain different patterns of thought encountered in cross-cultural studies. This has led them to distinguish two basic modes of thought and knowledge, variously referred to as lineal and non-lineal (Lee, 1968), abstract and concrete (Gladwin, 1964), and analytical and relational (Cohen, 1969). In the case of China, a similar distinction has been applied. Wilhelm (1942), Eberhard (1933), Jablonski (1939), and Granet (1934) have referred to Chinese thought as "coordinative" or "associative" and contrasted it with, to use Wilhelm's term, the "subordinative" nature of thought in Western science. They not only note that the Chinese form is distinct in its emphasis on pattern and organicism, but that it has its own form of causality and logic.⁴

It might occur to someone familiar with research on the hemispheric functions of the brain that the culture-and-cognition paradox might have

some relationship to patterns of hemispheric dominance. To put it simplistically, were the Chinese right-brained and the West Europeans left-brained (following the usual association of the left hemisphere with propositional thought and the right hemisphere with appositional thought)? Paredes and Hepburn (1976) have proposed just such an hypothesis to resolve the culture-and-cognition paradox.⁵ Their proposal can be summarized as follows: (1) there are plural cognitive processes, but different matchings cross-culturally between particular processes and particular problems; (2) the existence of neurological bases for plural cognitive processes eliminates the need to explain alterations in brain functions from one situation to another in terms of environment; (3) modes of thought appear to be hemispherically localized, but the hemispheres are interconnected and intercommunicate; (4) cognitive strategies are rooted in combinations of mental processes which can be theoretically represented "as an indeterminate number of outcomes of cerebral interaction, or interhemispheric oscillations, comprised of various 'mixes' of right- and left-hemisphere functions" (Paredes and Hepburn, 1976: 125); (5) the overall "acuity" of right- versus left-hemispheric functions may vary across cultures (as well as subcultures, social classes, and individuals); (6) such variations reflect learning that different cognitive strategies have different survival potentials; (7) habituation to one type of cognitive strategy(ies) does not preclude adoption of another type of cognitive strategy(ies); (8) the two basic modes, or strategies, are evaluated differently across cultures: "...the best example is the tendency of Westerners to regard only what appear to be manifestations of left-hemisphere functions as 'real' intelligence" (Paredes and Hepburn, 1976: 127).⁶

Paredes and Hepburn oversimplify the results and implications of the research on hemispheric functions of the brain, but their suggestions are in line with other attempts to relate this research to problems in the social sciences ranging from cross-cultural philosophical differences (e.g., Ornstein, 1972) to the sociological nature of scientific inquiry (Restivo, 1975). Consider, for example, the extent to which Needham's findings manifest a relational way of thinking rooted in a relatively uncarpentered, agriculturally dominated landscape. To what extent is such a situation suggested in the characterization of Chinese algebra as beautifully "symmetric" (Cajori, 1928, 1929), "rhetorical", and "positional" (Nesselmann, 1842), not to mention the dominance of algebraic overgeometrical orientations in Chinese mathematics? Are the high Phenomenal Regression Index of the Chinese, eidetic artistry, and the use of parallel perspective (Vol. IV, 3: 117-119) further evidence for a Paredes-Hepburn type of hypothesis?⁷ Are these phenomena simply pre-modern patterns of thought which may or may not be significantly related to hemispheric functions in the brain; and if we are dealing with a general pre-modern phenomenon, is there reason to suppose that environmental and cultural conditions in China were peculiar in the extent to which they fostered the development of an appositional mode of thought?

Needham refers again and again to phenomena which seem to make sense in terms of the Paredes-Hepburn hypotheses. Thus, he refers to the interest among Taoists in techniques which could not be transmitted by words (Vol. IV, 2: 47); and to the traditional Chinese shipwrights who depended on the skill and eye of the elder and more experienced shipwright

rather than on templates or blueprints (Vol. IV, 3: 413). These examples have their parallels in Europe and other pre-modern cultures; but the Paredes-Hepburn hypothesis is not thereby vitiated, since the evidence Needham cites suggests a relative not an absolute difference - a small enough difference, perhaps (recalling Campbell), to give rise to Needham's Problem.

The heuristic value of these speculations depends on the extent to which Needham and others have accurately portrayed Chinese culture. They also specify areas of concern for scholars trying to understand human beings in a cross-cultural perspective. In general, there does seem to be some agreement among students of Chinese culture on Needham's characterization of the dominant mode in Chinese thought as "organic." There is, however, a question about whether this mode is organic in the Whiteheadian sense, Needham's label for a phenomenon which other investigators would recognize as pre-modern, or something altogether different.

The culture-and-cognition discussion may provide some clues about problems in comparing Chinese and modern science and the development - or evolution - of science.

Pathways to Science. Is there one unitary science of Nature, and is it the result of a unilinear evolution of scientific inquiry? Needham has consistently affirmed both parts of this query (e.g., Vol. II: xxi), but not without introducing inconsistencies by speculating that if modern science had emerged in China it would have differed from the modern science that emerged in the West. It would, he argues, have been "profoundly organic and non-mechanical" (Needham, 1969: 323). Does this mean it would have reached the Einsteinian-Planckian stage without going through the

Newtonian stage; or that it would have developed a different kind of "organic" science? If the latter, what could this mean if, as Needham contends, Nature is One and the Science of Nature approaches a Unified Scientific World View? Was Newtonian mechanics a necessary preparation for Einstein and Planck? Needham is equivocal on this question. The philosopher Clifford Hooker (1976), by contrast, bluntly proclaimed recently that Newtonian mechanics was a "disaster" which led us off the main track of evolution in scientific inquiry.⁸ On Hooker's view, there would be some justification in speculating that if science had become a functionally differentiated, institutionalized social activity in, let us say, 16th century China, modern science would have emerged there and been closer to our contemporary science to begin with than Newtonian science was. This is a favorite Needham game which I will briefly indulge in.

Suppose we assume a tendency toward appositional thought in a culture otherwise prepared for a Scientific Revolution to the extent that China appears to have been. The functional differentiation and institutionalization of science in such a culture would lead to a form of modern science with a strong appositional flavor. This might make it seem closer to Einsteinian-Planckian physics, or more radically to the bootstrap physics of Geoffrey Chew (1968, 1970), depending on one's point of view. In any case, if such a situation had come about, we might find critics of science challenging the predominance of an appositional bias in science, just as we in fact find them challenging the predominance of a propositional bias in contemporary science -

because modern science emerged in Western Europe. This, it seems to me, is one of the implications of the search for a "new science", especially in David Bohm's (1971b; 1973) orientation to a "new physics". This may reflect the incompleteness of the development of human intellectual capacities. The human experience has perhaps stimulated the dominance of one mode of thought in some cultures, another mode in others. We may have reached the point now where the conditions under which we live are stimulating and requiring the transcendence of hemispheric functions; survival into the next evolutionary stage may depend on "thinking" in a "whole brain" way (Restivo, 1975).⁹.

Some of the inconsistencies in Needham's viewpoint on modern science can be resolved, in part, if he drops the assumption that modern science is universal world science. Perhaps the ethno-adjective "Western" should not be used with the same strength as the ethno-adjective "Chinese" when we drop the world science assumption and view modern science as retaining an ethnic stamp; the civilizational intercourse that underlies modern science seems to require this. Universal world science would have to be the product of a universal world culture; and such a science may emerge after one or more new Scientific Revolutions in increasingly ecumenized civilizational areas. The system of thought that emerges out of world culture will deserve the label universal science - or, inquiry. We must avoid, however, the trap of conceiving either a world culture or a world science as an ultimate unity - that would be an evolutionary dead end. Rather, we can think in terms of a de-ethnicized science, and the beginning of a new series of developments in a theoretically endless evolution of new world views (Cf., Popper, 1972; Bohm, 1971a;

Restivo, 1975). Perhaps this would be our first experience with terrestrial ethnocentrism in a universe of plural planetary civilizations.

I have left open the question of whether neutrality, a profane view of nature, and tolerance for non-benevolent acts in science are (1) necessary attributes of modern science, (2) reflections of an "ethnic stamp", and (3) necessary attributes of a stage in the evolution of science. I also have left open, but set the stage for considering, how the attributes of modern science we tend to take for granted might fare in a Second Scientific Revolution.

Earlier, I noted that Needham's support of neutrality in science, profane nature, and the need at times to engage in non-benevolent acts in the interest of future human welfare appears to be at odds with his socialistic commitments. These ideas, in fact, seem to contradict Needham's appreciation of Taoism in contrast to Confucianism, and his appreciation of the idea suggested by Wheeler (1939) and Bergmann (1933) that "masculine aggressiveness" is being "liquidated" in social evolution (Vol. II: 60; cf. Restivo, 1976a). Experimentation - the manipulation of things under controlled conditions - may be rooted in part in an aggressive orientation that has had survival value for human beings. As we look toward new stages in evolution, and the possibility that the aggressive orientation is losing its evolutionary significance as the cooperative principle takes on increasing importance, we may have to re-evaluate our view of the function of experimentation in stimulating a sense of conviction about hypotheses. It does not appear that, for example, withholding treatments and giving placebos in medical research, lying to or otherwise misleading subjects in social psychological experiments, and the general

reliance on naive subjects are consistent with a socialist society of equals living in a cooperative commonwealth. This idea is not restricted to the social sciences, as ecological considerations illustrate.

It would be absurd to defend the thesis that a new science born in a Second Scientific Revolution in a socialist milieu would be non-experimental; human beings are experimentalists by virtue of being problem-solvers confronted with life and death choices on a daily and epochal scale and on individual and collective levels. Perhaps, however, it would not be so absurd to suggest that a less domineering, manipulative approach to nature would become predominant. This might amount to something along the lines of carrying Popper's idea of letting hypotheses die in our stead to its logical conclusion (Popper, 1972: 244).¹⁰ Human considerations might also lead us to substitute statistical or logical manipulations for the manipulation of material and living things, and to develop much more sophisticated techniques for doing this than are now available. There is, perhaps, a way of encountering nature (including ourselves and others) ecologically without reference to (or by transcending) the sacred and the profane (Cf. Ravindra, 1975-76). Finally, it might not be irrelevant to seek the seeds of a Second Scientific Revolution of this sort in the limitations of proof and rigorous demonstration (which Sivin, 1969, considers a factor in explaining why modern science failed to emerge in China - where the notion of rigorously demonstrating proofs never developed) which have been brought to our attention by developments from Godel's Proof to the recent controversy concerning probabilistic proofs in mathematics. Empirical demonstration and formally rigorous proof may not be the only - nor the ultimate - source of confidence about hypotheses. We may be nearing a

point in the history of science where discussions about alternatives to experimentation in the classical sense will become commonplace, and the possibility of relying on certain mental states - or states of consciousness - as criteria of confidence considered seriously.^{11.}

Continuities in the History of Science and Society in China. The unity of scientific and other activities in China from ancient to modern times is notable but not unique. What may be unique is the extent to which China, while entering into the world ecumene and undergoing the turmoils and transformations of war and revolution, has emerged as a nation-state in which the pre-modern unity of science and society is a basic feature of the sociocultural landscape. Is the unity of science and society in contemporary China merely a matter of the slogans that proclaim science as "a summation of the laboring people's experience", "a tool forged by the people's labor to be used for the improvement of their lives", "a process of thinking and developing rational knowledge through practice", and "one of the three great revolutionary movements" (the other two being class struggle and the struggle for production; SESPA, 1974: 300)? Is this unity, in fact, pre-modern, and will the advances promoted by current policies ultimately recede in the face of a failure to establish modern "basic research" programs as some Western observers have maintained (e.g., Wortman, 1975: 20; Sprague; 1975:63)? Is China, in fact, monolithically developing "socialist science"; or are there pockets of resistance within which "science for its own sake" is being pursued, as suggested in Dedijs and Billgren's (1975) analysis of Scientia Sinica? Are what appear to be pockets of resistance in fact a reflection of a pluralistic policy that supports what outsiders might consider ideologically contradictory activities?

This would appear to be a consequence of adhering to the policy of the three methods which seems to be part of China's orientation to development: Yang Fa, the foreign way of doing things (Western science and technology), Thu Fa, earth methods, the ways of local peoples, and Hsin Fa, new methods being pioneered in China (Cotterell and Morgan, 1975: 304-305).

The most daring possibility is that the concept of a "new science" which is more than a whisper in the intellectual winds that come from such varied sources as the radical science movements, counter-culture critiques of and alternatives to science, and the frontiers of modern physics is trying to find its wings in China. Nathan Sivin, a cautious and sceptical scholar in the best sense of those adjectives, hints that we should be open to such a possibility. "One of the most fertile questions we can ask in view of our contemporary crises," he writes, "is exactly how science and other aspects of culture coexisted in unity earlier"(Sivin, 1973: xxx). Some sort of unity appears to be an imperative of our time in a way and on a scale qualitatively different from anything in the prior experience of the human species. "If there is to be a new unity of custom, belief, and knowledge", Sivin writes, "it will come from new modes of adaptation that we have so far failed to evolve" (Sivin, 1973: xxx). Is the new adaptation a new Scientific Revolution, a new science that is pre-modern in appearance with regard to its unity with other aspects of society, but trans-modern as a manifestation of a new evolutionary stage, a new level of consciousness, and a new moral order?

Those of us who look toward a "new science" cannot be sure that it will happen, nor can we be sure where it will happen. But as we scan the

present for the seeds of the future, we cannot ignore the possibility that China, intent on integrating the three methods, may be the source of a perplexing problem for future historians of science: Why did modern science, as we know it from the 21st century on, emerge in China and not in the United States or elsewhere?

Summary. This paper is a preliminary reconnaissance of Needham's reconnaissance in Science and Civilization in China (1954-) and other writings. I have outlined the Needham Paradigm for social studies of Chinese and modern science, and explicated it in a critical discussion of problems and prospects in the paradigm. I took the opportunity provided by a reconnaissance (Needham has shown the way here) to engage in duly considered as well as speculative hypothesis formulation. I reviewed Needham's Problem, his factors approach, his General Sociocultural Hypothesis, and his world view. The areas considered in the main section of the paper, on Needham's world view, included the relationship between Chinese and modern science, the conceptualization of "modern science" and "Scientific Revolution", the comparative history of science as the cross-cultural anthropology of knowledge, problems in culture and cognition, and the possibility - perhaps inevitability - of future Scientific Revolutions which will upset the taken-for-granted structure of modern scientific inquiry rather than simply result in a Kuhnian paradigm shift.

Every discussion of Needham's contributions, however critical, must if fairly carried out be an appreciation of the man and his work. This reconnaissance has been carried out in that spirit. A fuller appreciation must await publication of further studies by Needham and his collaborators, and the results of research still to come, parallel to and in line with Needham's work.

APPENDIX A. BASIC QUERIES (NEEDHAM'S PROBLEM)

1. "Why should the science of China have remained, broadly speaking, on a level continuously empirical, and restricted to theories of primitive or medieval type?" (Vol. I: 3).
2. "How...did the Chinese succeed in forestalling in many important matters the scientific and technical discoveries of the dramatis personae of the celebrated 'Greek miracle', in keeping pace with the Arabs (who had all the treasures of the ancient Western world at their disposal), and in maintaining, between the 3rd and the 13th centuries, a level of scientific knowledge unapproached in the West?" (Vol. I: 3).
3. "How could it have been that the weakness of China in theory and geometrical systematization did not present the emergence of technological discoveries and inventions often far in advance...of contemporary Europe, especially up to the 15th century?" (Vol. I: 3).
4. "What were the inhibiting factors in Chinese civilization which prevented a rise of modern science in Asia analogous to that which took place in Europe from the 16th century onwards, and which proved one of the basic factors in the moulding of the modern world order?" (Vol. I: 3).
5. "What...were the factors in Chinese society which were more favorable to the application of science in early times than Hellenistic or European medieval society?" (Vol. I: 3).
6. "...how was it that Chinese backwardness in scientific theory co-existed with the growth of an organic philosophy of Nature, interpreted in many differing forms by different schools, but closely resembling that which modern science has been forced to adopt after three centuries of mechanical materialism?" (Vol. I: 3).
7. "Why...did modern science, the tradition of Galileo, Harvey, Vesalius, Gesner, Newton, universally verifiable and commanding universal rational assent - the tradition destined to form the theoretical basis of the unified world community develop round the shores of the Mediterranean and Atlantic, and not in China or any other part of Asia?" (Vol. I: 19).
8. "Was the ancient and traditional Chinese thought-system merely superstition, or simply a variety of 'primitive thought'; or did it contain something in it characteristic of the civilization which produced it, and contribute some stimulus to other civilization?" (Vol. 2: 279).
9. Could natural science "ever have reached its present stage without passing through a 'theological' stage?" (Vol II: 582).

Appendix A, continued.

10. "What exactly were the relations of mathematics to science in ancient and medieval China? What was it that happened in Renaissance Europe when mathematics and science joined in a combination qualitatively new and destined to transform the world? And why did this not happen in any other part of the world?" (Vol. III: 150).

11. "The birth of the experimental-mathematical method, which appeared in almost perfect form in Galileo, and which led to all the developments of modern science and technology, presents the history of science with one of its most important and complex questions." (Vol. III: 156).

12. "In what way...had the instinctive experimentation of the technologists and craftsmen differed from the conscious experimental test of precise hypotheses which formed the essence of the Galilean method?" (Vol. III: 159).

APPENDIX B. FACTORS CONDUCTIVE TO THE EMERGENCE OF MODERN SCIENCE IN CHINA AND WESTERN EUROPE

1. The "mathematical" quality of the Chinese language coming to the attention of Leibniz and other 18th century European scholars was a factor in the development of mathematical logic (Vol. I: 32-33).
2. The precise tabulation in Chinese linguistics; precise tabulation was one of the roots of coordinate geometry (Vol. I: 34).
3. The availability of Greek, Latin, and Arabic root-words in Western Europe, added to "languages already rich in Teutonic complex consonantal combinations" (Vol. I: 36).
4. The Taoist appreciation of problems of causality (Vol. II: 51).
5. The naturalistic movement in 12-13th century Europe (Vol. III: 160).
6. Euclidean geometry, Ptolemaic planetary astronomy, and magnetical science (Vol. IV, part I: 334).
7. Indian ideas on perpetual motion in conjunction with Chinese knowledge of magnetic polarity "...deeply influenced modern scientific thought at one of its most crucial early stages" (Vol. IV, part 2: 542).
8. Clockwork and the clock-and-watch maker trade: "These craftsmen became for science what the millwright was for industry - a fruitful source of ingenuity and workmanship. The millwrights had been there all through the Middle Ages, and the clock masters from the beginning of the 14th century. Their presence was certainly one of the important roots of Renaissance science, pure and applied, for a supply of artisans was ready to generate makers of machines and instruments as soon as these things were demanded and devised" (Vol. IV, part 2: 545).
9. Monotheism of a personal god, important in generating modern scientific thought (but an inhibiting factor insofar as an enduring modern science was concerned); (Vol. V, part 2: xxiii-xxiv).
10. The history-consciousness of Christendom (Needham, 1969, 290-291).
11. The conception of linear time in the West and in China (Needham, 1969, 292-294).
12. Christian revolutionary visions, from the Donatists to the Hussites (Needham, 1969, 293).
13. Proto-scientific significance of Taoist relativity (Vol. II: 82).

APPENDIX B, continued.

14. Authority-denying mysticism in the West and in China (Vol. II: 98).
15. Chinese bureaucratism and organicism (Vol. II: 339); bureaucratism, it should be noted, is also discussed as an inhibiting factor.
16. Greek mercantilism and atomism (Vol. II: 339).
17. Natural, universal, law; precise formulation of positive law in Western Europe (Vol. II: 579).
18. Taoist mysticism (Vol. II: 12, 33).
19. The respectability of associations between gentlemen and technicians in Western Europe (Vol. III: 155).
20. Taoist distaste for metaphysics (Vol. II: 40).
21. Taoist affirmation of unity in Nature (Vol. II: 44, 46-47).
22. Taoist empiricism (Vol. II: 69).
23. Efforts of Mohists and Logicians in scientific logic (Vol. II: 165).
24. Empirical element in proto-science, scepticism, and critical spirit in China and the West (Vol. II: 346).
25. Buddhism, e.g., notions of infinity of space and time, and plural worlds (Vol. II: 419-420); inhibiting aspects of Buddhism are also discussed by Needham.
26. Unsupported cosmological speculations in China (Vol. II: 487).
27. Roots of the ideas "infinitesimals," "exhaustion," and "integration" in the Mohist definitions (Vol. III: 142-143).
28. Eminent artisans of China, who built mill-work and water-raising machinery (Vol. IV, part 2: 545).
29. Proto-scientific function of collecting natural rarities, strange gems, and animals in China (Vol. IV, part 3: 529).
30. Taoism and Neo-Confucianism (Vol. V, part 2: xxiii).
31. Animal experimentation in China (Vol. V, part 2: 295).
32. Rationalist scepticism in China (Needham, 1969, 231).
33. Confucian approach to knowledge (Vol. II: 8).

APPENDIX C. FACTORS INHIBITING THE EMERGENCE OF MODERN SCIENCE IN CHINA AND WESTERN EUROPE

1. Taoist mistrust of reason and logic (Needham, 1969, 311).
2. Poverty of sounds in the Chinese language, which inhibited the formation of a scientific terminology (Vol. I: 36).
3. The geocultural isolation of China (Vol. I: 157).
4. Confucian focus on human affairs (Vol. II: 8).
5. Confucian rationalism (Vol. II: 12).
6. Inadequacy of Yin-Yang, chhi, and the Five Elements or Phases as theories (Vol. II: 84).
7. Failure of Taoists to precisely define experimental method, and to systematize natural observations (Vol. II: 161).
8. The Taoists' strong commitment to empiricism, their fascination with Nature's boundless multiplicity, their failure to elaborate a scientific logic, their failure to recognize the need for technical terms, and their lack of Aristotle's "classificatory boldness" (Vol. II: 162).
9. Failure of the Chinese to develop a syllogistic logic (Vol. II: 200).
10. The I Ching, insofar as it led to "pigeon-holing novelty" (Vol. II: 340).
11. Buddhism (Vol. II: 396ff., 512); Needham also discusses some facilitative aspects of Buddhism; overall, however, he argues that Buddhism had a largely inhibitory impact on the development of science in China.
12. Aristotelian logic (Vol. II: 200); see the text of this paper for a discussion of Needham's equivocations on the role of Aristotelian logic in the development of modern science.
13. In general, Needham argues, the other-worldly rejection of this world is formally and psychologically incompatible with the development of science (Vol. II: 431).
14. "Historians of science are beginning to question whether the predilection of Greek science and mathematics for 'the abstract', the deductive and the pure, over the concrete, the empirical and the applied was wholly a gain" (Vol IV, part 1: 206).

APPENDIX C, continued.

15. The impossibility of resolving verbs in specific physical operations in some European languages (Vol. IV, part 1: 206).
16. Cyclical time (Needham, 1969, 292).
17. The conception of the I Ching hexagrams as deeply "embedded" in Nature (Vol. II: 443).
18. Subjective and metaphysical idealism in Buddhism (Vol. II: 507).
19. Indian notion (*māyā*) that the visible world is illusory (Vol. II: 572).
20. The checker board notation that dominated Sung algebra, an arithmetic carryover that hindered the "free-flight of symbolism" (Vol. III: 9).
21. The discovery of a general method for solving numerical equations by Han mathematicians hindered the later development of a theory of equations (Vol. III: 9).
22. Place-value in Chinese arithmetic inhibited the development of algebraic symbolism (Vol. III: 9).
23. The failure of the Chinese to invent a sign for setting up equations in modern form (Vol. III: 115).
24. Atomism, an antecedent of the roots of calculus, was missing in China (Vol. III: 142).
25. The fact that transitive and intransitive verb functions are not always explicit in Chinese (Vol. IV, part 1: 206).
26. China's weakness in the physical sciences (Vol. IV, part 1: 1).
27. The unchallenged predominance of the empirical approach over theory in China (Vol. IV, part 2: 66).
28. Failure of the experimental cooperation between the 12th century Taoists and the Reformers to survive the Chin take-over (Vol. IV, part 2: 500-502).
29. Compartmentalizing time in China, which prevented "uniformizing time into an abstract geometrical coordinate" (Needham, 1969, 231).

APPENDIX D. NEEDHAM'S GENERAL SOCIOCULTURAL HYPOTHESIS: THREE ILLUSTRATIVE FORMULATIONS, AND SELECTED SUB-HYPOTHESES

I. "Whatever the ideological inhibiting factors in the Chinese thought-world may turn out to have been, the certainty always remains that the specific social and economic features of traditional China were connected with them. They were clearly part of that particular pattern, and in these matters one always has to think in terms of a 'package-deal'. In just the same way, of course, it is impossible to separate the scientific achievements of the ancient Greeks from the fact that they developed in mercantile, maritime, city-state democracies" (Vol. V, part 2: xxiii).

II. "It may be said that while ideological, philosophical and theological differences are never to be undervalued, what mattered most of all was facilitating pressures of the transition from feudalism to mercantile and then industrial capitalism, pressures which did not effectively operate in any culture other than that of Western, Frankish, Europe" (Vol. V, part 2: xxvi).

III. "If Chinese civilization did not spontaneously develop modern natural science as Western Europe did (though much more advanced in the fifteen pre-Renaissance centuries) it was nothing to do with her attitude towards time. Other ideological factors, of course, remain for scrutiny, apart from the concrete geographical, social and economic conditions and structures, which may yet suffice to bear the main burden of the explanation" (Needham, 1969, 298).

SELECTED SUB-HYPOTHESES

1. The association of Buddhism, in several dynasties at least, with the merchant class inhibited the emergence of modern science for at least two reasons: (a) the merchants were powerless; (b) had they achieved power, Buddhism as a "Nature-denying religion" would have hampered them (Vol. II: 572).

2. The astronomer was "ultimately connected with the sovereign pontificate of the Son of Heaven, part of an official government service, and ritually accommodated within the very walls of the imperial palace". This inhibited the emergence of modern science (Vol. III: 171).

3. "...the majority of the observers who thought and calculated and wrote about astronomical problems were in State services"; see the preceding statement (Vol. III: 190).

4. "The Chinese should have been interested in mechanics for ships, in hydrostatics for their vast canal system (like the Dutch), in ballistics for guns, and in pumps for mines. If they were not, could not the answer be sought in the fact that little or no private profit was to be gained from any of these things in Chinese society, dominated by its imperial "bureaucracy"? (Vol. III: 167).

5. "There is no special mystery about the relatively 'steady state' of Chinese society...Social analysis will assuredly point to the nature of the agriculture, the early necessity of massive hydraulic engineering works, the centralization of government, the principle of the non-hereditary civil service, etc., etc. But that it was radically different from the patterns of the West is quite unquestionable" (Needham, 1969, 120).

NOTES

1. On fan kuan, see Vol. II: 456; on wu chi, see Vol. II: 466. With reference to the Five Elements notion, it should be noted that while Needham consistently uses this term to translate wu hsing, Five Phases is probably closer to the Chinese meaning: see Sivin, 1973: xviiff.
2. Needham's views of modern science and modern scientists are to a large extent, and inevitably, based on the history of physics, and the philosophical reconstruction of that history which until recently has been dominated by logical positivism.
3. This equivocation is inevitable given the uncertainties associated with interpreting the fragmentary Mohist texts: see Vol. II: 186; and Graham and Sivin, 1973: 108-113.
4. See Needham's discussion in Vol. II: 280.
5. More recently, I discovered an even earlier discussion of this idea by Katz (1975), not referred to by Parades and Hepburn (1976).
6. See the reactions to this paper in the June 1976 and subsequent issues of Current Anthropology.
7. Phenomenal regression refers to the tendency for people to "see" a "compromise" between the "real characteristics" of an object and the "sensory characteristics" indicated by peripheral stimuli such as the retinal image. The Phenomenal Regression Index is a measure of this tendency. For a discussion of the index and references to the relevant literature, see Needham, Vol. IV: 117-118.
8. Hooker made this statement in a workshop discussion of his 1976 paper on Evolutionary Naturalistic Realism.
9. In order to avoid the problems associated with trying to interpret split-brain research, this notion can be rephrased in terms of the need for new modes of consciousness, non-ordinary ways of thinking, tapping more of the brain's potential, etc.
10. Holton (1973: 275-280) is one of the few philosophers of science to draw attention to experimenticism, "...best recognized by the unquestioned priority assigned to experiments and experimental data in the analysis of how scientists do their own work and how their work is incorporated into the public enterprise of science." Holton's critique of experimenticism reinforces, to some extent, the ideas discussed in this section.
11. This viewpoint cannot be developed or defended further here. It must appear "incredible" in terms of the taken-for-granted foundations of contemporary science. It appears less incredible when considered in terms of recent discussions of nonlinguistic dimensions of thought and epistemology (Hooker, 1975), the implications of bootstrap physics for our ideas about modes and assumptions of human inquiry, and ideas about isomorphism in brain-universe interrelationships (Restivo, 1975, and 1976b; see also Ravindra, 1975-1976).

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