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Science Matters: A Unified Perspective

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What is science? The answer is that "everything in Nature is part of science." On the one hand, what we called "natural science" is actually the science of (mostly) simple systems; they are human-independent knowledge. On the other hand, humanities/social sciences—human-dependent knowledge—belong to the science of complex systems. Demarcation of Nature according to human and nonhuman systems, and the recognition that complex systems are distinct from simple systems allow us to understand the world differently and profitably. For completeness, the nature of simple and complex systems is briefly presented. The origin of the two cultures (made famous by C. P. Snow), humanities and "science," is traced and some confusing issues clarified. While a gap between humanists and "scientists" does exist due to historical reasons, there is no intrinsic gap between humanities/social science and "natural science." If these disciplines look different from each other, it is because they are at various level of development, scientifically speaking. To *properly* bridge the gap and to advance the search for human-dependent knowledge, a new discipline—*Science Matters* (SciMat or scimat)—is introduced. SciMat treats all human-related matters as part of science, wherein, humans are studied scientifically from the perspective of complex systems with the help of experiences gained in physics, neuroscience and other disciplines. Consequently, all the topics covered in humanities and social sciences are included in SciMat. The motivation and concept of SciMat, and a successful example (*histophysics*, the physics of human history) are presented and discussed. Four major implications of SciMat are described. In particular, a new answer to the Needham Question is offered for the first time. This chapter ends with discussion and conclusion.

1.1 Introduction

All earnest and honest human quests for knowledge are efforts to understand Nature, which includes both human and nonhuman systems, the objects of study in science. Thus, broadly speaking, all these quests are in the science domain. The methods and tools used may be different; for example, the literary people use mainly their bodily sensors and their brain as the information processor, while natural scientists may use, in addition, measuring instruments and computers. Yet, all these activities could be viewed in a unified perspective: they are scientific developments at varying stages of maturity and have a lot to learn from each other.

That "everything in Nature is part of science" (see Section 1.2) was well recognized by Aristotle and da Vinci and many others. Yet, it is only recently, with the advent of modern science and experiences gathered in the study of statistical physics [Lam, 1998; Paul & Baschnagel, 1999], complex systems [Lam, 1997; 1998] and other disciplines, that we know how the human-related disciplines can be studied scientifically.

Science Matters (SciMat or scimat) is the new discipline that treats all human-related matters as part of science. SciMat is about all human-dependent knowledge, wherein, humans (the material system of *Homo sapiens*) are studied scientifically from the perspective of complex systems. Here, the term "complex systems" means simply "very complicated systems," in the sense adopted by common people; they may not be fractals or chaotic. After all, when fractal and chaotic systems are usually complex, not all complex systems are fractals or chaotic; and there exists no unique and satisfactory definition of complex systems, technically or otherwise [Lam, 1998; 2000]. SciMat includes all the topics covered in humanities and social sciences, with human history as a particular example [Lam, 2008a].

This chapter is organized as follows. The very nature of science is revealed in Section 1.2, followed by an introduction and analysis of the "two cultures" in Section 1.3. Demarcation of everything in Nature according to human and nonhuman systems is introduced in Section 1.4. Section 1.5 discusses simple and complex systems, including a brief introduction of the latter, one of which is the human system. The motivation, concept and an example (histophysics) of SciMat is given in Section 1.6. Four major implications of SciMat, including a new answer to the Needham Question, are presented in Section 1.7. Finally, Section 1.8 concludes this chapter with discussion.

1.2 What Is Science?

About 2,600 years ago, Thales (ca. 624 BC-ca. 546 BC) proposed the first "theory of everything": Everything is made of water.[1] (See Fig. 1.1.) Subsequently, Aristotle (384-322 BC) studied various aspects of the universe—astronomy, physics, biology, botany, zoology, logic, ethics, politics, and so on—from the same platform [Llyod, 1970]. In other words, he was interested in almost all the subjects of study existing in universities today. This was not accidental.

Fig. 1.1. Two water-loving philosophers: (a) Thales (ca. 624 BC-ca. 546 BC) from the West, and (b) Guan-tze (?-645 BC) from the East.

[1] The Chinese philosopher, Guan-tze (?-645 BC), also favored water [Liu, 2006]. He said, among many water-related utterances, "Human is water. When the 'essences' of male and female combine, water flows and takes shape."

The fragmentation of knowledge into different disciplines is a relatively recent phenomenon, starting only a few hundred years ago. It results more from management convenience than from the intrinsic nature of knowledge itself. *Knowledge knows no separating boundaries*. After all, the highest degree conferred by a university is still called Doctor of Philosophy (not Doctor of Physics, for example), wherein, philosophy means "wisdom"—all kinds of wisdom. As will be explained below, there is a material basis underlying the unified intrinsic nature of knowledge.

Knowledge about our universe or the world could be divided into two groups: those unrelated to humans, and those related to humans. For instance, Newton's three laws of mechanics are *human-independent*. That is, if there were extraterrestrial intelligence (ET), sooner or later, these three laws could also be discovered by them, even though the laws might not be named after Newton. Examples of *human-dependent* knowledge are literature and dance. An ET might not dance like us, because it could have three, not two, legs.

Human-independent knowledge is commonly called "natural science"; human-dependent knowledge, humanities and social science. However, this classification is inaccurate and inappropriate. On the one hand, humans are *Homo sapiens*, a material system consisting of atoms—the same atoms that make up the systems studied in "natural science." Consequently, all human-dependent knowledge is part of natural science, since the objects studied in natural science are *all* material systems.

On the other hand, science is about the study of Nature and a means to understand it in a unified way. Nature consists of everything in the universe—all material systems, humans and nonhumans. The two terms science and natural science are thus identical to each other.[2] It then follows that there could be only one conclusion [Lam, 2006a]:

[2] With this understanding, every possible enquiry undertaken would be about Nature. The term "science" in its German sense of *Wissenchaft*—any systematic body of enquiry—and its use in the English language will coincide with each other.

$$\text{science} = \text{natural science} = \text{physical science} + \text{social science} + \text{humanities} \qquad (1.1)$$

where "physical science" includes not just physics, but chemistry, biology, and so on.[3] In other words: *Everything in Nature is part of science*. This conclusion was known to the early Greeks. If some of our contemporaries do not know about this, it is because the word science is either misunderstood or misused.

1.3 The Origin and Nature of the Two Cultures

Forty-nine years ago, on May 7, 1959, Charles Percy Snow gave the lecture "The Two Cultures and the Scientific Revolution" at Cambridge University [Snow & Collini, 1998].[4] The lecture essentially contains three themes: the distinction and non-communication between the scientific culture and the literary culture in the West, the importance of the science revolution (defined by Snow to mean the application of the

[3] In this chapter, "natural science" with quotation marks means the science of mostly inanimate systems, identical to that in conventional usage of these two words; the same goes for "natural scientist."

[4] There are at least two factual errors in this famous article, apparently never pointed out by anyone before. (1) Snow is wrong when he writes, "No, I mean the discovery at Columbia by Yang and Lee" (p. 15 in [Snow & Collini, 1998]). In fact, in the famous paper that earned Lee and Yang the Nobel Prize in 1957, the authors' names appears as Lee and Yang [Lee & Yang, 1957]. (The ordering of the two names in this and other joint papers by the two authors is not a small matter; it plays an important role in the two men's subsequent total breakup of collaboration and friendship [Yang, 1983; Lee, 1986; Jiang, 2002; Zi *et al*., 2004].) While Lee indeed worked at Columbia University, Yang's address at that time was the Institute for Advanced Study at Princeton, New Jersey (see the address bylines in [Lee & Yang, 1957]). The truth is that Yang has never been associated with Columbia University. (2) A few sentences later, still referring to the work of Yang and Lee, Snow makes another mistake in his sentence, "If there were any serious communication between the two cultures, this experiment would have been talked about at every High Table in Cambridge." In reality, the work of Lee and Yang is purely *theoretical*, which is to point out that there was no experimental evidence supporting or refuting parity conservation in weak interactions at that time. They went on to propose several experiments to settle this issue without predicting the outcome of these experiments. Parity nonconservation was discovered in an *experiment* by Chien-Shiung Wu (1912-1997) [Wu *et al*., 1957], a colleague of Lee at Columbia University.

"atomic particles," presumably nuclear physics and quantum mechanics), and the urgency for the rich countries to help the poor countries. Very interesting, big themes—but nothing original, as admitted by Snow himself (see "The Two Cultures: A Second Look (1963)" in [Snow & Collini, 1998]).

The lecture generated tremendous interest and much discussion around the world, which helped to earn Snow 20 honorary degrees (mostly from universities outside of England) and carve his name in history. While the other two themes are definitely worth talking about, it is the "two cultures" theme that causes the most controversy and debates. This is not at all surprising. Many in the literary circle felt slighted by Snow in his lecture and had to defend themselves or their profession (see Stefan Collini's "Introduction" in [Snow & Collini, 1998]). And, by definition, literary people are those who can write. Now, the important question, not addressed by Snow himself in his lecture, is this: What is the origin of the two cultures?

1.3.1 *Emergence of the Two Cultures*

About ten thousand years ago on earth, the early *Homo sapiens*, our ancestors, started to wonder about the things around them—things in their immediate surroundings and things in the sky. Curiosity serves not just human needs but for those who figure out how things work from their observations, it is a survival skill *via* the evolutionary mechanism according to Charles Darwin (1809-1882).

Among these activities, literature is the description of humans' reflection on and understanding of Nature. Here, Nature includes all (human and nonhuman) material systems, such as falling leaves in autumn, the changing weather and seasons, effect of moonlights on lovers, the way humans treat each other in different spatial and temporal settings, and, quite often, thoughts in one's brain as a function of happenings inside or outside the person's body. When the authors write down all these, they are using their bodily sensors (sighting, touching, smelling, hearing, and so on) as the main detectors and their brain as the major information processor. Apart from that, for latecomers, they could also input information by reading what other writers wrote.

As time went by, the observation and understanding of certain kinds of phenomena progressed faster. The process started with Galileo about 400 years ago. The success results from three crucial and cleaver steps.

1. We pick simple systems (such as a ball rolling down an inclined plane) to study.
2. We do big and daring approximations in constructing theories (for example, approximating the ball by a point particle).
3. We use detectors and information processors other than those from our own bodies.

Consequently, for example, how things fall under the influence of gravity can be predicted and measured with high accuracy. Let us consider the case that the falling object is a human body. The human body falling from a tall building is the same complicated human body described in a piece of literature, but in physics we pretend that it is a point particle (that is, an idealized particle with zero size) in our calculations. This is an approximation; it works because the size of the earth, the source of the gravitational force, is much greater than the size of the human body. Furthermore, we can record the positions of the falling body by digital cameras and compare them with our calculations, with the help of calculators or computers.[5]

This branch of study is now called "natural science," which involves mostly nonliving systems even though living systems (such as humans in free fall and other simpler biological bodies) are not excluded. However, the so-called "natural sciences" are actually "science of simple systems," while all human-dependent studies (humanities/social sciences) are about complex systems since, in fact, a single human being is the most complex system in the universe.

As we just pointed out, "natural science" succeeds because it chooses to deal only with a special subset of phenomena. And literature is stuck with the complicated aspects—such as pride and prejudice—of the complex system called humans.

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[5] For smaller falling objects, low-tech devices are used to record the positions at regular time intervals. This is routinely done in freshmen physics labs.

As study deepened, specialization became essential and we were left with two distinct groups of practitioners, the writers in the literature profession and what Snow called "scientists" for those working in "natural science." Since writers use their own bodies as tools, only those with supreme bodily sensitivity and suitable hard wiring of neurons in their brains can become good writers, while scientists need other types of quality (such as supreme self-confidence) to succeed. There is no overlap between these two groups of professionals,[6] and we end up with "two cultures"—with a gap in between.[7]

1.3.2 *The Gap Today*

The method to close the gap between humanists and "natural scientists" as proposed apparently by Snow is to encourage the literary people to learn some freshmen physics, and the "scientists" to read some good literature.[8] This method is widely adopted in the universities and other places but, in fact, *it is problematic and ineffective*.

To understand this, we have to examine how the gap is formed *presently* in practice (while what described in Section 1.3.1 is how the gap was formed historically), and the very nature of the gap itself.

1. <u>How the gap is formed today</u>

As correctly pointed out by Snow [Snow & Collini, 1998], the existence of today's gap is due to the design of our education system. Students in high schools and universities are directed too early towards either humanities or "science." In response, the way to bridge the gap is to cancel this early division of students in high schools, and (after the gap is formed) force them to take general-education courses in the universities.

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[6] This was painfully experienced by Snow himself. In 1932, Snow had to recant publicly his "discovery" of how to produce Vitamin A artificially after his calculation was found faulty. Snow, a trained chemist, decided to leave scientific research completely after this incident and became a novelist (p. xx in [Snow & Collini, 1998]). He indeed made the correct move, judging by later developments in his career.

[7] These days, the two separate groups in the two cultures are commonly understood to be humanists on the one hand and "natural scientists" on the other hand.

[8] As good literature is concerned, unlike the case in science, there is no unique choice suitable for everybody. Reading Shakespeare or Tang poems/Song proses will equally do.

These remedies are actually carried out in some countries and in most universities. However, we are no longer in the early Greek days. Economically there is strong competitive pressure to arm our students early with special professional skills. It is impossible to get all countries, especially the developing countries, to agree on a slow-down schedule in their education systems. And so, to narrow the existing gap, the response is to increase the dose of general-education courses in the universities and the enhancement of popular science activities (reading popular science books in particular) in the society. (See [Lam, 2008b].) But will this work in its present form? And is this effective and necessary?

2. Nature of the gap today

The gap today exists in the form of different knowledge contents picked up by the two camps of people, humanists and "scientists," during their schooling periods and beyond. And this is the rationale behind the proposal to encourage them to read something from the other camp. But (1) this is hard to achieve; (2) it is ineffective even achieved.

To illustrate point (1), let us take the different groups within physics as an example. The fact that physicists can talk to each other is true only to a certain extent. There is not much to talk about between a particle theorist and a condensed matter physicist if the subject is the standard model of particles. But all scientists, be they physicists, biologists or chemists, do share some common knowledge such as the second law of thermodynamics, because this law is a required learning in the college education of these scientists.[9]

Professional activities require high concentration of attention and usually are time consuming, and, especially in the case of science, involve very keen competition. Time is short, for the professionals. Many first-rate scientists do not read books, particularly science books,

[9] The second law of thermodynamics is the example used by Snow to test the scientific knowledge of the literary people in a gathering (p. 15 in [Snow & Collini, 1998]). This is in fact quite unfair, because the second law is less universal and useful than people think. It applies only to closed systems and only to their thermodynamic equilibrium states. It applies neither to humans—an open system and the interest of literary people—nor to the expanding "cosmos" as Snow wrongly claimed (p. 74 in [Snow & Collini, 1998]). The reason is that our universe is ever expanding and is never in an equilibrium state [Lam, 2004a]. See [Zhao, 2003] for a detailed discussion.

because what contained in books is usually not fresh enough. Instead, they read research papers that they think might be helpful to their (present or future) work. That is what the scientist had in mind when he, asked by Snow what books he read, replied, “Books? I prefer to use my books as tools.” (See p. 3 in [Snow & Collini, 1998].) Tools, here, mean something that will help him to do his research. There is in fact a fair chance that literary books will be read by scientists, for relaxing purpose, for example, when they are in an airplane after attending a conference. But these books are not Shakespeare’s. The same goes for the people working in literature or humanities. Why should they read any science book if they cannot find anything there that would help them to do their job? Time is short for them, too.

As for point (2), let us assume for the moment that the humanist now knows something about basic physics and the “scientist” has read some Shakespeare or other great literature, and they meet in a cocktail party. If they ask each other what is new in the other’s profession, they will not be able to go too far in their discussion because a sensible opinion in literature or “science” these days requires more knowledge than what is in they possession. Instead, for example, they can converse on Ang Lee’s “Brokeback Mountain” (2005) or his other movie, “Crouching Tiger, Hidden Dragon” (2000). These movies’ storylines are as deep as Shakespeare’s, and perhaps more entertaining.

3. The proper way to bridge the gap

The gap can never be completely closed, nor should it be. What makes the world interesting is diversity; diversity requires some of us to be writers or artists and others physicists, and so on. What we can and should do is to *bridge* the gap. In our final analysis, the non-communication between the two camps is not due to the non-overlap of the people involved, but due to the *absence of any common language or principle in their trades*. Isn’t it wonderful to teach every student something, if exist, when they are still in high schools or universities that they could use for the rest of their life no matter what profession they end up with, in humanities or “natural science”? That would guarantee that everybody can communicate with anybody else, in a cocktail party or on the beach, say. Yet, this “something” did not exist in the 1950s when

Snow delivered his lecture;[10] that is why Snow resorted to the *ineffective* remedy in bridging the gap—a remedy that is still being blindly adopted by others presently. Today, fortunately, this "something" does exist. Since the late 1970s, some general principles applicable to almost all disciplines (and thus could serve as the common language mentioned above) have been discovered. Before these general principles can be introduced and appreciated properly, let us look more carefully at what the right-hand side of Eq. (1.1) actually means.

1.4 Demarcation According to Human and Nonhuman Systems

The "physical science" listed in Eq. (1.1), historically and as explained in Section 1.3, is mostly about the study of inanimate and simple systems. However, with the advancement of chaos theory[11] and the ubiquity of personal computers, and perhaps also due to the stagnation of research in particle physics (superstring or M theory notwithstanding) [Smolin, 2007], quite a number of physical scientists have turn their attention the other direction, towards systems of larger and larger scales and "discover" complex system (such as those from Cells and up in Fig. 1.2) [Lam, 1998].

Generally speaking, social science consists of anthropology, business management, economics, education, environmental science, geography, government policy, law, psychology, social welfare, sociology, and women's studies. [12]

Philosophy, culture, religion, language, literature, art, music, movie and performing arts make up the humanities, at least most of them. History, by its very nature, could be part of social science, but it is listed in the humanities at some universities such as Stanford University. The aim of literature, music and art in the humanities is to stimulate the human brain—through arrangement of words or colors, sound or speech, or shape of things—to achieve pleasure and beauty, or their opposites,

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[10] The powerful evolution theory of Charles Darwin does cut across all biological systems, but stops at inanimate systems.
[11] See Section 1.5.2 for an introduction to chaos.
[12] http://www.sosig.ac.uk.

via the neurons and their connecting patterns [Pinker, 1997].[13] The brains, some sort of computer, of the creator and the receiver at the two ends of this process are heavily involved. Linguistic is the study of the tools involved in written words and speeches, supporting the three disciplines mentioned above.

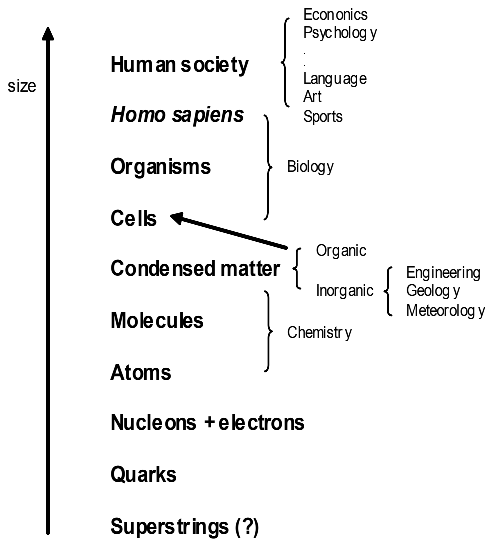

Fig. 1.2. Different systems (left column) studied in various disciplines (right column), listed from bottom to top as the system's size increases.

The *scientific* development of these disciplines in humanities is at a primitive level—the empirical level, using methods that are largely analytic, critical or speculative.[14] And that is why they are separated from social science, which is at an intermediate level (while physical science is at the highest level).

[13] And quite often, especially in the case of literature, to promote or stimulate a person's understanding of the world.
[14] http://en.wikipedia.org/wiki/Humanities (July 16, 2008).

At this point, it becomes clear that the three items listed on the right-hand side of Eq. (1.1) are classified distinctly because of their scientific level in development, and *not* because of the nature of the objects under study in each category. Actually, the three items are arranged, from left to right, in increasing level of scientific development.

This classification scheme may be convenient, but is definitely neither logical nor natural. To study something seriously and logically, Nature in this case, one would like to group the objects under study according to their intrinsic nature and not how much we happen to understand them presently. For instance, at least in the beginning, if we want to study orange we will focus our attention on all kinds of oranges and put them in the same category, instead of starting from the category of oranges and clams, say—even though we may compare the two and benefit from the findings of orange and clam studies during the research process. Another example: if we are interested in electrons, we will not group them with rocks and study electrons and rocks together. Common sense, isn't it?

Consequently, to study Nature a natural way is to categorize all objects in Nature into two broad classes, namely, human systems and nonhuman systems.[15] Equation (1.1) then becomes

$$\begin{aligned} \text{science} &= \text{natural science} \\ &= \text{nonhuman-related science} + \text{human-related science} \end{aligned} \quad (1.2)$$

Here, "nonhuman-related science" means the study of inanimate and nonhuman-biological systems—what people usually call "natural science." "Human-related science" consists of humanities, social science and medical science, whereas medical science includes neuroscience and genetics in particular. Apart from the obvious fact that medical science is about humans, the inclusion of medical science in human-related science is dictated by the *belief* and recent findings that many significant human

[15] This is due to the fact that it is humans who do the study and control the research budget. If ants were in control, they would classify Nature into the two groups of ants and nonants.

characteristics and behavior (such as morality [Shermer, 2004]) do have a biological basis, as revealed in neuroscience and genetics studies.

By grouping humanities and social science together under one umbrella, human-related science, one can understand anew and more logically the connection between the constituent disciplines (Table 1.1). For the sake of convenience and with full respect for life—an interesting phenomenon in Nature with yet an unknown origin, let us call a human being a "body." There are several basic facts about such a body [Lam, 2002]:

1. Each body is macroscopic, about 40 centimeters to 200 centimeters long; it is a classical particle—that is, quantum mechanics is irrelevant to these bodies.
2. Each body in their daily life moves very slowly compared to light; no need for Einstein's special relativity theory here.
3. The mass of each body is so small (compared to that of a planet, say) that Einstein's general theory of relativity can be forgotten, too.

Table 1.1. Classification of the human system in a focused study according to the number of bodies involved, with examples and major relevant disciplines.

	One-body	Few-body	Many-body
Example	a Greek male, a Tang Dynasty female, Einstein, Barbra Streisand, Hark Tsui, you, me	Romeo and Juliet, husband and wife, husband and wife living with mother-in-law, a person with two lovers, small-size family, the Beatles	large physics class, tribe, city, country, Roman Empire, society, stock market, IBM
Discipline	art, music, performing arts, language, literature, psychology, history (biography), neuroscience, genetics, medicinal science, law	psychology, literature, performing arts, history, (family) law	anthropology, (mass) psychology, philosophy, literature, culture, religion, history, business management, economics, education, environmental science, law, social welfare, sociology, women's study, law

4. Each body consists of layers and layers of structures (molecules, cells, organs, and so on) and many *internal states* (memory, thought, mood, and so on).
5. All bodies are derived from the same ancestor (African Eve, say) only some ten thousand years ago and, according to Charles Darwin's evolution theory, human body and human nature take a long time to evolve and thus are practically unchanged over the last 6,000 years or so—the period in which human history is recorded.
6. Each body is an *open* system, inputting oxygen and food and outputting something else; the second law of thermodynamics does not apply here since the law is for closed systems (and equilibrium states) only [Lam, 2004a].
7. Each body is under the influence of *external fields*, the most important of which is the community or society to which the body happens to belong.[16]

Keeping these facts and Table 1.1 in mind is important and advantageous when a human-related study is being undertaken. It allows you to pick the right tools and the right approximations (that is, simplifying the problem by ignoring some irrelevant factors) to do the research. And it allows you to borrow or be inspired by some successful experience from other areas of study such as physics (wherein, same classification like that in Table 1.1 is used).

For example, in physics, a two-body problem interacting gravitationally with each other[17] is solvable, while such a three-body problem is chaotic and unsolvable [Stewart, 2002]. Now you probably understand why it is so difficult living with your mother-in-law since it is a three-body problem. Just kidding! You cannot simple-mindedly take a

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[16] Other fields could be physical in nature, such as electromagnetic fields if cell phone is used; sunlight when the body is outdoor (guaranteed in summer in San Jose, California but not necessarily so in Beijing well before *Olympic 2008*); and unavoidably penetrating (harmless) neutrinos and non-penetrating cosmic rays (harmful in large dosage).

[17] The gravitational interaction between two bodies is given by Newton's law of gravity, which states that the force on each body is inversely proportional to the *square* of the separation between the two bodies; similarly, the electric force between two charged bodies due to Coulomb's law.

result from physics and apply it without thinking (or with wrong thinking) to human affairs, because the interacting force between you and your mother-in-law does not obey the inverse-square law as in gravity.[18] More seriously, by ignoring all internal states of a body and treating it like a point particle, and using simple rules of interaction between the particles, computer modeling is able to explain and predict many human-group behaviors, ranging from pedestrian movement and traffic flow to voting processes, economic markets and war [Ball, 2004].

As the classification of systems in Nature is concerned, apart from dividing them into human and nonhuman systems as proposed in this Section, there exists in fact another way, that is, dividing them into simple and complex systems according to the system's complexity. However, as we will show in the next Section, the latter approach though very valuable in clarifying a lot of problems, is not that suitable for the purpose of demarcating systems in Nature.

1.5 Simple and Complex Systems

Let us start by explaining what it means to be complex, followed by a brief introduction to complex systems. The reason that complex systems are relevant to our problem of understanding humans will then present itself.

1.5.1 *What It Means to be Complex*

There is a feeling that our world is very complex. According to Webster's dictionary:

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[18] The uncritical application of physical results beyond physics is common, too common, among non-scientists, even among some non-physical scientists. The carefree misuse of chaos in human affairs published in numerous popular science/nonscience books is another example. A further example: Since Einstein's relativity theory tells us that mass and energy can be exchanged, $E = mc^2$; and since my body does have mass, therefore it gives me energy to dance. The fallacy is obvious: a piece of rock also has mass but it does not dance. All these pitfalls lie in the use of analogies without bounds, a symptom of parallelism [Scerri, 1989].

> Complex: composed of two or more parts…hard to separate, analyze, or solve.
>
> *Complex* suggests the unavoidable result of a necessary combining and does not imply a fault or failure; *complicated* applies to what offers great difficulty in understanding, solving, or explaining.

Scientifically, the mechanisms driving the complexity of our world are more than what the dictionary suggests; it is not purely due to the existence of two or many parts [Lam, 2004a]. And, in deed, complex systems are hard to analyze, but progress has been made in the last two decades or so [Lam, 1998].

It would be nice if we can quantitatively define *complexity* and use it to compare different situations. Unfortunately, complexity is like love, you know it when you encounter it but it is hard to pin it down. In fact, people came up with more than 30 definitions of complexity, all different from each other. For our purpose, a working definition is enough: *Complexity is determined by the length of the shortest description of a system*; the longer the description, the more complex the system. For example, let us look at three sequences consisting of 1s and 0s.

(a) 11111111111111111111111111111111
(b) 11001010001100000110010101101001 10
(c) 00101110010101110000001101010001 11

Sequence (a) can be described by "all 1s." Sequence (b) is generated randomly, and so is described by "1s and 0s generated randomly." There is no pattern in sequence (c),[19] and the description has to be a recitation of the whole sequence; sequence (c) is thus the most complex among the three.

[19] Admittedly, this point is hard for the reader to see; to the naked eye, sequences (b) and (c) both look random. However, a technical test can differentiate the two: In the difference map (that is, the plot of x_n *vs*. x_{n+1} where $\{x_n\}$ is the given sequence of numbers) a random sequence (with large number of elements) will spread out uniformly in the plot, while a non-random sequence will not. Let us say that such a test has been performed.

Such a definition is, of course, problematic. First, if we are not informed that sequence (b) is generated randomly, it could be hard to know this by examining it, and we will assign it the same complexity as that for (c). Second, the definition of the "shortest description" is also subjective. It could be we are not smart enough to identify the rhythm or pattern in (c), or we may be able to identify it a month later. Well, let us keep these limitations in mind and move on.

1.5.2 *Complex Systems*

Partly and largely due to the difficulty in defining complexity, there exists no rigorous definition of complex systems. Generally speaking, a complex system usually consists of many interacting components; each component could have a few or many internal states and is adaptive in its behavior. The weakness of such a definition is easy to see. For example, a system may appear complex only because we do not understand it yet. Once understood, it becomes a simple system. Moreover, whether a system is complex or not may depend on what aspect of it we want to study. If we want to know the inner structure and formation mechanism of a piece of rock, the rock could be a complex system. But if we only want to know how the rock will move when given a kick, using Newtonian dynamics will do the job and the rock is simple. The lack of a technical definition and the ambiguity in the concept of simple/complex makes it unsuitable to be used as a demarcation tool of anything.

For our purpose in this chapter a working definition could be adopted: almost all subjects covered in the universities, except those in traditional physics, chemistry and engineering departments, fall into the domain of complex systems [Lam, 1998]. In other words, at the minimum, *biological systems including humans, and all topics covered in humanities and social science belong to the domain of complex systems*. Most of the rest belong to simple systems.[20]

The importance of complex systems makes it worthwhile to know something more about them. Here is some basic knowledge about complex systems.

[20] Note that "simple" does not imply "easy"; these are two very different concepts.

All material systems in Nature are made up of "elementary" particles. Going from small to large in size, we have many layers of materials: quarks (or perhaps superstrings), nucleons (protons and neutrons), atoms (nucleons plus electrons), molecules, condensed matter (liquids and solids), cells, human organs, and human beings (Fig. 1.2). It is commonly known that at each layer of organization, there are many *emergent* properties—that is, properties not easily guessed from the lower layer of constituents.

Life is such an emergent property: the fact that a human body is made up of cells and organs does not automatically lend itself to the expectation of life. Another example: the fluidity of water, a property not transparent from knowing that water is made up of H_2O molecules. To describe and understand the emergent property at each layer, one does not need to start from the very bottom level. For example, to describe the flow of water, one does not need to start from the quarks, not even from the molecular level. In fact, based on a few basic principles of symmetry, physicists are able to derive a phenomenological equation describing water flows—the Navier-Stokes equation—which is still being used today. Similarly, to understand complex systems related to human phenomena, one can start from one of several levels such as the *empirical, phenomenological* or *realistic* level [Lam, 2002]. And one has to study complex systems case by case.

Fortunately and surprisingly, since the late 1970s and through the extensive study of simple and complex systems, three general principles of organization in Nature have been discovered. These three unifying principles can be applied to many—though not all—living and nonliving systems,[21] coming, in particular, from humanities and social science. And we are referring to fractals, chaos and active walks [Lam, 1998].[22]

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[21] Some people call these principles "universal," a misnomer.

[22] Self-organized criticality (SOC) proposed by Per Bak (1948-2002) *et al.* [1987] was advanced as another such general principle for complex systems [Bak, 1996]. Unfortunately, SOC was at odd with many experimental findings in real systems, the ultimate judge in these kinds of things (see, for example, [Cross & Hohenberg, 1993]).

1. Fractals

Fractals were introduced by Benoît Mandelbrot in 1975 [Mandelbrot, 1977]. A fractal is a self-similar (mathematical or real) object, possessing quite often a fractional dimension. Self-similar means that if you take a small part of an object and blow it up in proportion, it will look similar or identical to the original object. A famous example is the Sierpinski gasket [Lam, 2004b]. Fractals are everywhere, ranging from the morphology of tree leaves, rock formations, human blood vessels, to the stock market indices and the structure of galaxies. Fractals are even relevant in the corporate culture [Warnecken, 1993] and the arts [Barrow, 1995].

2. Chaos

Chaos has been investigated by Henri Poincaré at about the turn of the century and subsequently by a number of mathematicians. The modern period occurred in the late 1970s after Mitchell Feigenbaum discovered the “universality” properties of some simple maps, which was preceded by the important but obscure work of Edward Lorentz (1917-2008) [1993] related to weather predictions. Chaos is the phenomenon observed in some nonlinear systems, wherein, the system’s behavior depends sensitively on their initial conditions.[23] Examples of chaos include leaking faucets, convective liquids, human heartbeats, and planetary motion in the solar system. The concept is also found applicable in psychology, life sciences and literature [Robertson & Combs, 1995; Hayles, 1991]. A review of chaos for general readers is available [Yorke & Grebogi, 1996].

3. Active walks

Active Walk (AW) is a major principle that Mother Nature uses in self-organization; it is *a generic origin of complexity* in the real world (see also [Zhou *et al*., 2008]). Active walk is a paradigm introduced by Lui

[23] Chaos, a daily word, is used by scientists as a technical word with specific meanings. Before one can call a time sequence of numbers chaotic several tests have to be performed, such as showing the Lyapunov exponent to be positive [Lam, 1998]. The mere look of being random or chaotic is not enough—a pitfall committed by many laypeople.

Lam [2005; 2006a] in 1992 to handle complex systems. In an AW, a particle (the walker) changes a deformable potential—the landscape—as it walks; its next step is influenced by the changed landscape.[24] Active walk has been applied successfully to a number of complex systems coming from the natural and social sciences. Examples include pattern formation in physical, chemical and biological systems such as surface-reaction induced filaments and retinal neurons, formation of fractal surfaces, anomalous ionic transport in glasses, granular matter, population dynamics, bacteria movements and pattern forming, foraging of ants, spontaneous formation of human trails, oil recovery, river formation, city growth, economic systems, parameter-tuning networks [Han *et al*., 2008] and human history[25] [Lam, 2002; 2006a; 2008a].

These three general principles are what we referred to at end of Section 1.3. All three principles are now an integral part of complex-system science, which is becoming important in the understanding of business, governments and the media, among other things. But, of course, in the study of complex systems there remain a lot of virgin lands waiting to be explored.

1.6 Science Matters

The motivation and concept of Science Matters are given here, followed by an example (histophysics). Implications of SciMat will be presented in the next two Sections.

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[24] For example, ants are living active walkers. When an ant moves, it releases chemicals of a certain type and hence changes the spatial distribution of the chemical concentration. Its next step is moving towards positions of higher chemical concentration. In this case, the chemical distribution is the deformable landscape.

[25] In the AW application in history, think of the walker as an active digger on a soft land. The digger could dig a round trough and keep him moving in circles; he could dig himself a hole deeper and deeper and got himself trapped; or he could dig himself out of a hole and survived. These three situations, respectively, could be used to model what happened to some historical figures; or, when applied sequentially, three stages in the life of an individual. It all depends on the landscaping rule and the stepping rule involved, either or both of which could be time dependent; there are infinite possibilities. That is why AW is such a powerful modeling tool or metaphor in history and other studies.

1.6.1 *Motivation*

The discussion presented in Sections 1.2 to 1.5 shows that there is *no* gap between humanities/social science and "natural science"; they are all part of science. After all there exists no natural dividing line among the items listed in Fig. 1.2; it is a continuum. The gap referred to by Snow *is* between humanists and "natural scientists," which was formed historically and is maintained by the education system; this gap is not intrinsic in nature. It is then possible to narrow or bridge *this* gap.

It was almost half-a-century ago that Snow gave his lecture on the two cultures; the world today is quite different. We now realize that the *real* reason to bridge this gap is not simply to let the two sides to have something to converse on in a cocktail party but [Lam, 2006b]:

1. To have citizens who are better-informed on both humanities/social science and "natural science" and thus can vote more sensibly on issues that could be scientific and/or ethical in nature (such as funding for stem-cell research).

Furthermore, to bridge the gap between humanists and "natural scientists" *properly* and *effectively* as well as, more importantly, to advance *knowledge* about the world and *humanity* (as explained below), we—humanists, social scientists and "natural scientists"—need to work together:

2. To raise the scientific level of humanities.

While both aims are noble and important, the second one is dearer to us, epistemologically speaking.

1.6.2 *Concept*

New disciplines of study are born from time to time, like in the case of human babies, but less frequently; or, like new stars emerging in the sky, being suddenly noticed after a long period in the making.

Science Matters as a new discipline [Lam, 2008c] is created for the two aims listed above. SciMat is the scientific study of all human-related systems. Equation (1.2) is now rewritten as:

$$\begin{aligned} \text{science} &= \text{natural science} \\ &= \text{nonhuman-related science} + \text{science matters} \end{aligned} \tag{1.3}$$

By naming "human-related science" in Eq. (1.2) as SciMat, we want to emphasize the fact that all human-related matters *are* part of science.

The *concept and method* of SciMat are: Following the good tradition of Aristotle and using the successful experience gained in physics (especially statistical physics), neuroscience and other disciplines, all human-related systems are treated as part of science and studied from the perspective of complex systems. The fact that there do exist general principles (see Section 1.5.2) that cut across all disciplines tells us that this approach is entirely possible.

Figure 1.3 illustrates what we discussed so far. Out of all the objects in Nature, SciMat focuses on the humans (the right box in the upper panel), the most complex system in the universe. Should be fun!

1.6.3 *An Example: Histophysics*

History concerns itself with what happened to the *Homo sapiens* in the past [Stanford, 1998].[26] The focus could be on an individual (such as Cleopatra, Alexander the Great or Ava Gardner), a family or an empire; that is, the system under study could be, respectively, one-body, few-body or many-body (Table 1.1). Traditional historians would collect historical records, analyze and put some order in the data or information at hand, then come up with some insights on why something happened and not merely how it happened, and perhaps offer some historical lessons; they stop there usually. No matter how convincing they are, these insights are frequently just educated guesses. As far as I know, no historians in the last few thousands of years had come up with any

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[26] This is the best book on historiography in my opinion.

historical laws; most of them even doubt the existence of any historical laws.

Histophysics [Lam, 2002; 2008a], the physics of human history, is a new discipline that views human history as the past dynamics of a complex system, from the perspective of SciMat; that is, there is a material basis underlying everything happened in human history. History is very complicated or complex, but could be discerned if one is lucky and the right kind of research tools are used. Techniques borrowed from physics and complex systems—such as statistical analysis, computer modeling, computer simulation and the Zipf plot—have been successfully used to tackle problems in history. In particular, *quantitative* laws are found in the distribution of war casualties and of lifetimes of Chinese dynasties (from Qin to Qing, spanning 2,133 years). The latter are in fact laws in macrohistory, favored by the French *Annales* school [Burke, 1990]. (See [Lam, 2008a] for details.)

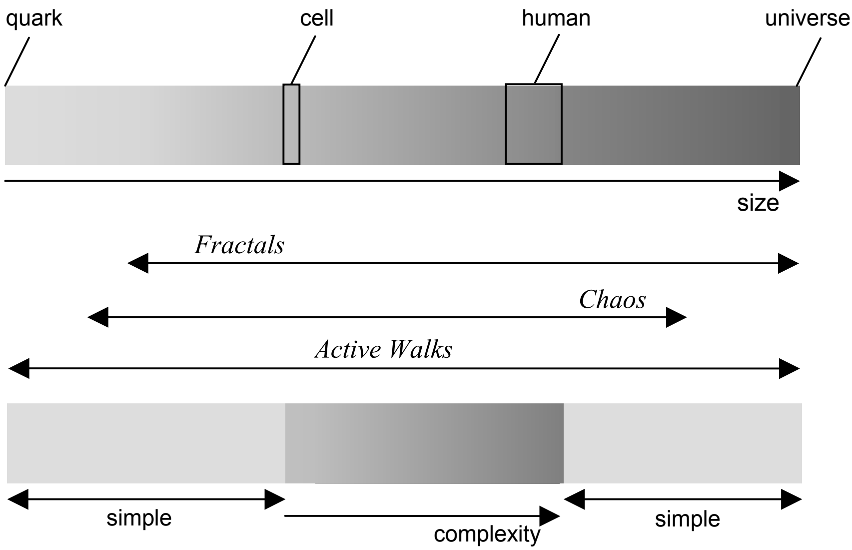

Fig. 1.3. *Upper panel*: systems arranged in increasing size from left to right (not to scale). Humans are the object of study in Science Matters. *Middle three lines*: Range of applicability of fractals, chaos and active walks (from top to bottom). *Lower panel*: Complexity increases from cell to humans, the domain of complex systems; simple systems sit on the left and right regions, respectively, outside of this region.

The success of histophysics confirms the fruitfulness of the SciMat approach in studying human matters; it reinforces our confidence in the direction outlined in SciMat.

1.7 Implications of Science Matters

Calling the study of human-related matters by Science Matters is not merely a change in name. There are important implications. Four major implications of SciMat are presented here. More are given in the next and last Section.

1.7.1 *Clearing up Confusion in Terminology*

Let us designate by x the item included in humanities/social science, where x could be art, literature, music, culture, society, and so on. And, for the convenience of discussion, we even allow x to represent "science" in its conventional usage, which actually means "natural science," the science of simple systems. As we all know, there already exist studies of the scientific aspect of x, called the "*science of x*," say; for example, the "science of art." What is wrong with that?

Nothing, except that it is *confusing*. According to SciMat, art is already part of science. As we explained above, the present state of Art as we know it does not look like a science simply because art, a very complex thing by itself, is at the early stage of its scientific development. Our brain is still the best computer in handling very complex things; that is why artists are still using their brain and not a supercomputer in creating art. Some day in the future, perhaps, when a super-supercomputer better than our brain is available, we will see artists using it to make a living—like the way that physicists are using their personal computer to solve a nonlinear equation these days.

Will it be depressing when this happens to art? Don't worry; the super-supercomputer still needs someone to input something and analyze the results, like the physicist has to decide what nonlinear equation to study, and how to interpret and use the computer results. Anyway, like in the case of physics, one would have more time to go fishing or go to an art museum and be happy.[27]

Why art is developing so slowly as its scientific level is concerned? There are two reasons: (1) Art is a very complex thing and hence it is very difficult to raise its scientific level—the reason just mentioned. (2) And this is very important as art (and in fact arts which include performing arts) goes: humans have buying power; there are enough number of them willing to buy from the artists and thus helping to keep their discipline at a low scientific level. In other words, low-scientific-level art products sell so well already, there is no need to raise its scientific level. It is the market force at work here.

It is interesting to compare this to the case in physics. Physicists are able to control an electron and make it "dance"—a performing (electron) art. The electrons do *not* have buying power; no electron would come and buy a ticket to watch the show.[28] Consequently, the physicists have to raise the scientific level in their trade by doing two things: (1) They build a "superhighway" within a computer chip, which involves Nobel-prize-level breakthroughs. (2) They force the electrons to run like slaves in the superhighway inside the chip. Then they sell this computer chip, electrons included, to their fellow humans. And humans *do* have buying power; you see.

To avoid confusion, the correct way to say "science of art" is "art as a science matter." The case of "*science and x*" is worse; it is *misleading*. For instance, let x be Culture here. "Science and Culture" is misleading because it implies that science and culture are two different things, which could even be opposing each other while, in fact, culture is part of science; culture is a many-body problem in SciMat (see Table 1.1). The use of the term "science and culture" is unfortunate because it endorses Snow's ineffective remedy of bridging the gap (see Section 1.3.2) and thus *prolongs* the gap between the humanists and "scientists." To

[27] It seems that people get happy by watching something more complex than what they are doing daily in their lab/office. You never see a physicist leaving her/his lab and go watching the swing of a pendulum. Galileo's days are long gone.

[28] The physicist would be an ultra-billionaire if only 0.001% of the electron population within a 1-mm long copper wire showed up for the show by buying tickets at 0.001 dollars each.

properly bridge the gap, we should help both camps (and everybody else) to understand "culture as a science matter."

1.7.2 *The Science Matters Standard*

Since everything is part of science—the fundamental basis of SciMat, there should be one and only one standard in validating the "correctness" of any theory in humanities and social science, that is, the one adopted in "science," established through thousands of years of painful trial and error and the sacrifice of numerous human lives. According to the American Physical Society (*APS News*, June 1999):

> The success and credibility of science anchored in the willingness of scientists to: (1) Expose their ideas and results to independent testing and replication by other scientists. This requires the complete and open exchange of data, procedures and materials. (2) Abandon or modify accepted conclusions when confronted with more complete and reliable experimental evidence. Adherence to these principles provides a mechanism for self-correction that is the foundation of the credibility of science.

With these words in mind, let us propose the following *SciMat Standard*:

1. We will be honest with the reader and ourselves and present our findings in clear writings, and will not try to hide our relevant thinking.
2. We will not quote anyone's writing to support our own argument.
3. We will not be ashamed to admit our own mistakes in our findings and correct them as soon as possible.
4. A conjecture[29] or *hypothesis* becomes a (temporary) *theory* only after it is confirmed by experiments or by practices in the real world.
5. We will abandon (or revise) the theory if it does not agree with confirmed and irrefutable evidences.

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[29] A mathematical conjecture is a small theorem that is proved. We do not mean this kind of conjecture; the word conjecture used here simply means an educated guess.

Explanations for these five rules are in order. Rule 1 is the basic ethic of any honest researcher or knowledge seeker, but is not always practiced in non-physical disciplines. Yes, we understand that complex systems such as those studied in humanities/social science are very complicated, and one does not always have a clear idea of what one's thought really is. If that is the case, please tell it to your reader which part is clear to you, which part is not, and mark your work as "work in progress." Better still, present your ideas like these in a seminar or cocktail party but not in a conference. If every paper was written clearly and findings/results were presented as "objectively" as possible, and if the paper *always* ended with a section of Discussion/Conclusion in which the author presented what lessons she/he had learned, perhaps the Sokal hoax [Sokal & Bricmont, 1998] would never have to happen and the Science Wars [Labinger & Collins, 2001] could be avoided.

Quoting others to support one's argument is a common practice in non-physical disciplines. But this is completely useless. For example, while Einstein was proven right in his many writings such as the two theories of relativity, he could not always be right and he did not [Kennefick, 2005]. We all know about this; that is why Rule 2.

One should not be ashamed of making mistakes when doing complex-system studies since the job itself is so difficult. What one should do is simply admit their mistakes once recognized and correct them as soon as possible [Shermer, 2001]. In this regard, good economists are real scientists who know their limits and act accordingly; they keep on adjusting their predictions of the stock index or the gross domestic product (GDP) and should be respected for doing that. That explains our Rule 3.

If anyone put out an educated guess (what we mean by hypothesis), this guess has to be confirmed before it can be called a theory. Common sense, right?! Rule 4 is copied from the practice in physics and other "natural sciences." We just want to unify our terminology in communicating to each other, since in SciMat we very likely are coming from different disciplines with different training and background.

Let me emphasize this: We do not mean that physical science is superior to humanities/social science. It is not. In fact, the opposite could be true.[30] Humanists and social scientists are tackling very complex systems, while most physical scientists are dealing with simple systems. Those dealing with complex problems could be more courageous and should be respected. In fact, to be a *good* artist is more difficult than being a good physicist. In physics, there are rules to be obeyed and experience to follow and the choices in solving any physical problem are more restricted[31] than what is available to a painter who wants to create something new. The painter has infinite possibilities and really needs imagination and talent. That is why there are more good physicists than good painters in the world.

With Rule 4 in place, no social theory in the form of political ideology of *any* kind could be validated, since it is unethical to try experiments on living human beings, especially in large numbers.[32] Political leaders are advised to try their "experiments" with computer simulations and be prepared to adjust their policies frequent enough.

Rule 5 is obvious. Finally, it follows from the spirit of this SciMat standard that we will adopt a better standard if that becomes available.

1.7.3 *There Is Always the Reality Check*

There is something called the "reality check" as science matters are concerned. We accept Einstein's result, $E = mc^2$, not because it comes from Einstein but because it comes from the special theory of relativity which agrees with most existing experimental findings. Furthermore, the relativity theory gives a sequence of predictions that are later confirmed, even just last month; it helps our confidence in it. The fact that the atomic bomb, built according to $E = mc^2$, works is another plus. This is

[30] My daughter is an artist and my hero.

[31] Examples of the restrictions are: all the established laws have to be obeyed and confirmed experimental results respected. New theory cannot ignore or negate them; new theory could improve on them and/or find out where the validity boundary of the old theory is.

[32] Of course, sadly, this has not prevented some historical figures from trying, with disastrous results. An example is what happened in Cambodia: From 1975 to 1979, two million Cambodians were killed under the Pol Pot regime because the leaders mistook a social hypothesis as a theory and applied it to their people; that is, they broke Rule 4 of the SciMat Standard. This and other examples point to the urgent need of greatly improving the scientific training of political leaders, President George W. Bush included.

an example of reality check, even though reality check does not call for an atomic bomb every time, luckily for humans.

Now comes this old woman from Africa who tells us $E = mc$; the reason is that she does not like superscripts. And comes this philosopher from Europe who advocates $E = mc^{\sqrt{2}}$. His reason is that he wants to show his independence from Pythagoras (born between 580 and 572 BC, died between 500 and 490 BC) who abhorred irrational numbers [Lloyd, 1970] and besides, the philosopher honestly thinks the superscript $\sqrt{2}$ is more aesthetically appealing than 2. This phenomenon is called the *multicultural view of science* [Liu, B., 2008]. Who do you think a university will hire into her faculty?

We agree that each one of these three individuals should be fully respected by others for their honest attempts to understand Nature, and be allowed to air their views (freedom of speech) or even publish their findings in a suitable journal/magazine/newspaper of some kind. These days, no opinion can be completely suppressed. At the minimum, there is always the Blog on the Web that they can air their results, and it is free.

In practice, whether someone like you or me would spend our valuable time and listen to an individual's opinion (or read her/his article) on something, science included, does not depend entirely on the quality of that opinion, which we do not know ahead of time anyway. It depends on the *reputation* of that individual; in other words, it is a history dependent process. For instance, we are more inclined to read Einstein's article than that coming from the African woman or the European philosopher, because Einstein has an established reputation. It does not mean, however, everything uttered by Einstein is correct; but even wrong, his uttering could be inspiring. And that is why we make that choice; it is a matter of betting one's time. And we could miss something very valuable and important, because that philosopher's writing could turn out to be very exciting and useful. We accept the risk, and do a catch up by Googling it after the philosopher's finding is reported in the newspaper, say. It is all a matter of allocating finite resources; it has nothing to do with disrespect for Africa or Europe, or *local knowledge* for that matter. The same goes for research funding. Misjudgments are made from time to time; the remedy is to open up more avenues of funding, like those coming from private wealthy individuals or private foundations, just in case.[33]

In fact, people *can* always ignore the reality check and hold on to whatever view of science they want and be happy—and we respect their right to be happy—as long as they do *not* try to put their "theory" to work. To build a cell phone you need quantum mechanics, not any kind of mechanics. But not everyone needs a cell phone, right? And the right of not wanting or producing cell phones should be respected. It is called *cultural diversity*. (See also [Liu, D., 2008].)

1.7.4 *The Needham Question*

In 1954, in his book *Science and Civilisation in China* Joseph Needham (1900-1995) [1954] at Cambridge, UK, asked a question that goes something like this: Why did modern science develop only in the West after the 16th century (and not in China who, in the past, applied natural knowledge to practical technology and invention more efficiently than the West did)? [Liu, D., 2008]. There are many explanations offered [Liu, 2000]. Some are obvious; others, not. Here is a new explanation which, I think, is right on the mark.

Remember Aristotle? Aristotle studied and pioneered a number of disciplines, in increasing order of complexity: physics, astronomy, biology and zoology, logic, ethics, government, politics, and so on. Today, his work on physics and astronomy are known to be completely wrong; his biology/zoology is partially wrong; but his logic and ethics studies are still found useful. The same smart Aristotle; how did this happen? The answer is that physics and astronomy are simple systems, biology/zoology is about complex systems, and the rest related to humans are extremely complex systems. It just shows that human-related matters as complex systems are very difficult to study, and we have not made much progress since Aristotle's time in these complex areas. Not Aristotle's fault; we still respect and admire him despite his failures.

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[33] An example is the funding of extraterrestrial-intelligence (ET) searching in USA. The government funded it for a year and stopped; a rich man came along and continued the funding of SETI, the ET searching institute in Mountain View, CA. Everybody is happy; ET not found up to this moment.

The ancient Chinese—Confucius (551 BC-479 BC) included, for whatever reason (which could be incidental), decided to start their enquiry of Nature with complex systems—humans. They came up with some great insights but no clear conclusions [Wolpert, 1993]. Worse, for unknown reason and unlike Aristotle, they did not or chose not to write down their findings in unambiguous language (that is, they disobeyed Rule 1 in the SciMat Standard; see Section 1.7.2). That is like publishing a paper in a physics journal with writings that the reader can interpret in multiple ways; no way to make progress. In contrast, the Greeks did concern themselves with both simple and complex systems right from the beginning; for example, Archimedes (ca. 287 BC-ca. 212 BC) studied buoyancy of simple bodies and his own body, and was rewarded with the Archimedes Principle. Eventually, the Greek's successful results of simple systems got passed on in the West and ended up in the hands of Galileo, who started modern science. The ambiguous findings in complex systems from ancient Chinese passed on and kept *confusing* and *entertaining* the Chinese for more than two thousand years, even today. This is my answer to the Needham Question.

Here is the Lam Question: Why did modern science arise in Italy and not in other European countries?

1.8 Discussion and Conclusion

Here are ten points of interest.

1. There are always grey areas as demarcation of any kind is concerned. Some mathematicians find out about this and come up with a new mathematics called *fuzzy logic* [Klir & Yuan, 1996]. Similarly, the division between humans and nonhumans, and that between simple and complex are not sharp divisions. For example, how many cells have to develop in an embryo before you will call her a human being? In the grey areas, it is common that new and interesting phenomena and question might pop out. Pay attention to the grey areas.

2. According to SciMat, Chinese medicine [Ma, 2007] *is* science at the empirical level. We hope this will settle the debate on this topic once and for all (see [Liu, B., 2008]). The traditional "theory" of Chinese medicine offered in the old books or by its practitioners may seem

strange to outsiders, but they could be some kind of phenomenological theory (or such a "theory" in the making, continuing for over two thousand years)—the next step beyond the empirical level in any scientific development—that works, partially or completely. The fact that the "theory" so far does not match anything in Western medicine implies one of three things: (1) the "theory" is on the wrong track and should be modified or abandoned in the future; (2) the "theory" is on the right track except that it will take time to connect it to that in Western medicine; (3) Western medicine is wrong or irrelevant. Case 3 is unlikely. Case 2 actually happened in the history of superconductivity: the Landau-Ginzburg phenomenological theory (1950) turned out to be correct and could be derived from the BCS microscopic theory (1957) after the latter was discovered [Tinkham, 2004]. Whether that is also the case with Chinese medicine remains to be seen. But we all know this: the debate on Chinese medicine involves something more than prestige. In China, Chinese medicine is heavily funded (quite a number of hospitals and research institutes in Chinese medicine are in place), but anything identified as pseudoscience would be banished.

3. No artists, writers or other humanists should feel threatened by SciMat. They could go on doing what they do best. Humanities are such a vast field that we need a lot of people working on it at the empirical level. Advancing the scientific level of humanities needs to be done mostly by trained "scientists" with the help of or in collaboration with the humanists. We do hope that artists and writers will help.

4. There is no need to abandon the general-education courses in universities. But in all courses, general-education courses in particular, the instructor could start by introducing the concept of SciMat, explaining to the students why Eq. (1.1) should be replaced by Eq. (1.3), and so on. That would help tremendously in narrowing the cultural gap for our students, possibly our future writers and "scientists." Naturally, for the benefit of everybody, we would like to see a SciMat course like *The Real World* [Lam, 2008b] be included in all universities as a *required* general-education course.

5. There could be a brand new theory about macroscopic humans waiting to be discovered, like quantum mechanics lurking there in the case of microscopic systems about 100 years ago. The *only* way to find

out is to set out to look for it, *assuming* temporarily that the new theory indeed exists and is just hidden somewhere, like children searching for Easter eggs on the lawn of the White House each year. What is needed is the smoking gun, similar to Planck's black-body radiation experiment or the double-slit experiment in the case of quantum mechanics.

6. Airplanes and humans, both complex systems, could be very different.

7. When the rule(s) of the SciMat Standard was broken, it often happened that it was humanity and not merely personal honor that suffered.

8. There is already a crowd out there doing econophysics and sociophysics [Chakrabarti *et al.*, 2006; Ball, 2006]; doing humanities as complex systems could be more challenging and rewarding, more fun guaranteed.

9. Da Vinci (1452-1519) could be the last person in history who succeeded in mastering quite a number of topics from both "science"/technology and the arts. His failure to build many of his own designs in engineering, not to mention bringing them to the market, is due to insufficient funding and the absence of a large enough team, and also the non-existence of a suitable industry in society at his time. With the explosion of knowledge in modern times, no one could be as broad and deep as da Vinci was any more. And there is no need to be. What we have to do is encourage people to be experts in two disciplines. With enough number of these bi-disciplinary scholars, all disciplines in the world will be able to link up with each other, directly or indirectly (Fig. 1.4). Here, we are talking about the flourishing of interdisciplinary education and scholarship, and the proper use of science communication [Lam, 2008b], not just for histophysics and SciMat but for all interdisciplinary studies.[34]

10. It was for these reasons that an international conference on SciMat was held in Ericeira, Portugal, May 28-30, 2007 (Fig. 1.5) [Sanitt, 2007]. We are looking forward to more conferences like this one, to

[34] In China, there is the journal *China Interdisciplinary Science* (Science Press, Beijing) which treats interdisciplinary studies seriously. It started in 2006 and has published two volumes so far.

provide an international platform for people to exchange ideas face to face. And, learning from the French: to drink, to eat and to sleep [Glover, 2000]. Naturally, the purpose of doing all these is to reach the goal of "Let the Earth be peaceful forever!"

To conclude, Science Matters matter because science matters. But ultimately, Science Matters matter because humans matter!

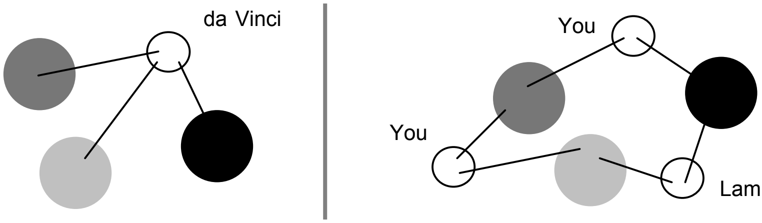

Fig. 1.4. One needs not do everything like da Vinci did (left), but does interdisciplinary work (right). The filled circles represent different disciplines; open circles, individuals.

Fig. 1.5. Poster of the First International Conference on Science Matters, Ericeira, Portugal, May 28-30, 2007.

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