The Relevance for Science of Western and Eastern Cultures

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Abstract: The rise of modern science took place in Western Europe, and one may ask why this was the case. We analyze the roots of modern science by replacing scientific ideas within the framework of Western culture, notably the twin heritage of biblical thought and Greek philosophy. We also investigate Eastern (mostly Chinese) traditions so as to highlight Western beliefs by comparison, and to argue for their relevance to contemporary science. Classical Western conceptions that fostered the rise of science are now largely obsolete, and Eastern thought might be a source of new insights.

Keywords: Science, Culture, Modern science, Western culture, Eastern culture, West, East

1 Introduction

Science was not born in a vacuum, but in a specific society and culture at a particular time of history. Modern science arose in Western Europe during the Renaissance and developed mostly in Europe before becoming a worldwide pursuit in the 20th century.

Why did modern science originate in Western Europe and not elsewhere? Other civilizations had reached a high level of theoretical knowledge (notably in astronomy and mathematics) and could boast of impressive technical achievements. Chinese, Indian and Islamic cultures come to mind for recent times, and Greek civilization in Antiquity had elaborated important scientific

concepts and theories. But all these early efforts stopped short of the systematic development of modern science, which happened only in Europe.

We will contend that European culture, derived mainly from the Bible and Greek philosophy, presented the perfect mix of beliefs to make modern science possible. To support this thesis, we will first examine the main features of Western culture that facilitated the rise of science. Without denying the importance of social and political factors, Western culture was clearly an integral part of classical scientific ideas and theories.

We will then analyze the main features of Eastern culture (centering on China), because they make more obvious by comparison the characteristic features of European culture, and also because the culture of the East is a very rich and interesting domain in its own way. We will see that Eastern beliefs were probably inimical to the rise of modern science, although they are of great subtlety and complexity as an account of our place in the world.

Another reason to take Eastern culture seriously is that Eastern countries (Japan, Korea, Chinese territories and mainland China) have demonstrated an impressive industrial, technological and scientific development in the past century, catching up with the West. In fact economic power seems to be gradually tilting toward Asia. It is a reasonable question to ask whether Eastern traditions have played a role in this development, and whether they might have a role to play in the future.

Yet science has evolved dramatically since the end of the 19th century, turning into something quite different from classical science. Contemporary science has come up with radically new conceptions: the theory of evolution, system theory, relativity, quantum physics and other developments. A new scientific worldview has gradually emerged, and we will try to formulate the main features of this new science. It has become much more complex, dynamic, systemic, non-deterministic and holistic.

Lastly, we will argue that Eastern culture and conceptions would now provide a more congenial background and better philosophical foundations for contemporary science than traditional Western culture. Such a background might have avoided much of the intellectual anguish that accompanied the formulation of new scientific theories in Europe, and it could now be a source of novel, fruitful insights. In the same way that Western philosophy often helped European scientists formulate their theories, knowledge of Eastern culture may be beneficial for contemporary scientific theory.

• Some definitions and precautions

We should first define a few of the terms employed in this text. By "Western culture" we mean Western Europe primarily, and its cultural offshoots in the New World (notably in America). We will not deal with Eastern Europe, whose culture is both entwined with Western culture and the result of its own particular history. Islam could also be considered a variant of Western culture, because it has common roots with Christianity (i.e. biblical and Greek sources) and a long history of cultural exchanges with Europe, but it eventually followed a different path, missing out on modernity and on modern science.

By "Eastern culture" we mean China and countries strongly influenced by Chinese culture: Korea, Japan, and Vietnam (i.e. the Far East). They all exhibit a variable syncretism of Confucianism, Taoism and Buddhism, mixed with local traditions. We will speak mostly of China and Japan because of their importance, and simply because we know them best. Indian culture will also be in the background, because Buddhism originated in India and brought Indian ideas and modes of thought to China and its neighbors.

By "science" we mean systematic experimentation (or observation) associated with systematic formalization so far as possible, a peculiar mixture of realism and abstraction that took place mostly in modern Europe. By "modern science" or "classical science" we mean the scientific movement that arose during the Renaissance in the 16th century and developed till the beginning of the 19th. Figures such as Kepler, Galileo, and Newton would be typical representatives of this movement. Yet from the middle of the 19th and to the present day, science has increasingly taken on a drastically new outlook, which we will call "contemporary science". Scientists such as Darwin, Poincaré, Einstein and Bohr come to mind among many others.

In this text we will speak mostly of the West and of the East as if they were homogeneous entities, but this is of course highly debatable. Both traditions show great variations in time and space. Western culture changed fundamentally with the end of Antiquity and the rise of Christianity, and modern European countries developed distinct languages and cultures. Chinese history, society and values are also very different from those of Japan, Korea and Vietnam. While we are aware of these differences, we will nonetheless mostly overlook them here for the sake of the argument.

Similarly, there is no clear dividing line between classical science and contemporary science, but rather a slow (and contentious) drift into new territories in the course of grappling with previously unsolved problems. More generally, no culture is really homogeneous, coherent, stable and equally shared by everybody. A culture is more like a bundle of features which varies with space and time, out of which different people pick up different features to fit their needs. Yet we will speak about any given culture as a kind of ideal type (Memmi 2017).

2 Features of Western culture

Western civilization exhibits a specific bundle of cultural features, which are mostly derived from Greek philosophy and biblical thought (Russell 1945; Plato 2006; Bible 2004). Christianity tried from the start to work out a (laborious but fruitful) synthesis between these two traditions.

2.1 A personal God

One of the basic tenets of Western culture is that the universe has been created by a unique, personal, anthropomorphic God. The belief comes of course from the Bible (it's the first verse of the Old Testament!). This God keeps looking after his creation (this is not the absentee *deus otiosus* of other cultures) and intervenes in the world as and when he sees fit. The world can thus be understood and explained primarily as God's world.

This God is depicted as largely human-like, a deity with human emotions and a rational intelligence. Greek and Roman gods already presented a human aspect, but the biblical God adds the idea of creation and a moral dimension. God is a lawgiver, and his creation follows a coherent design and must obey moral prescriptions. In fact, the Bible does not differentiate between moral and natural laws, as the distinction between descriptive and prescriptive laws was not at all clear till the Renaissance.

Such a God is potentially intelligible and accessible, and the Old Testament is full of familiar dialogues between God and his prophets. Later on, theologians came up little by little with more abstract and distant conceptions of the Godhead, but the familiar image of God as a human-like figure is still very much part of our popular culture.

2.2 A transcendent reality

Reality is not what it seems to be, and the ultimate reality is to be found beyond the ordinary world of appearances. In short, for Westerners ultimate reality is transcendent, not immanent in our everyday world.

This view is a mixture of biblical beliefs and Platonism (already evident in St John's gospel). Because the world is God's creation, reality can be found in God's mind first and foremost. Our world is but a manifestation of God's will. And Plato forcefully argues (notably in the myth of the cave) that reality and truth are more abstract than the everyday world of sensory appearances. Only the world of ideas is real. Following Pythagorean doctrine, Plato adds that mathematics is the one and only language adequate to fully express this ultimate reality.

This is a rather strange conception on the face of it, but the preference for abstraction has had powerful consequences for the development of all subsequent Western philosophy and science. This tendency also influenced social and political conceptions for better and for worse.

2.3 Substance and ontology

Another important notion in Greek philosophy is that the world is composed of durable substances, subsisting behind changing appearances. The number of basic substances varied with different philosophers, but it was often believed that everything is composed of four elements: earth, water, air and fire. Substance is characteristic of physical matter, and there was disagreement whether ideas or forms are also substances. There has been huge variation between different conceptions of substance, yet it is a basic notion of Western culture.

The atomic theory of Democritus and his later followers gave a more detailed and eventually more fruitful account of the diversity and changes in the world, to be explained by the constant combining and recombining of atoms (we would now call this the domain of chemistry). But the indivisible atoms posited by this theory to explain the structure of the material world are still elementary, stable physical entities, i.e. separate substances.

The notion of substance is associated with the importance of ontology, the branch of Western philosophy studying what sort of entities exist and the modes of being of various entities. The emphasis on being, the fundamental assumption of the primordial existence of basic entities is a

notable feature of Western thought. This assumption has also proven to be very useful for modern science, even though the notion of substance has become largely untenable by now.

2.4 Directed time

We have inherited from Hebrew thought a peculiar conception of time as clearly directed, with a beginning and an end. The world as we know it was created by God in the beginning, develops according to God's plans, and will eventually come to an end. This conception of time was not common in Antiquity, and not common in other cultures either. For examples Indian culture sees time as cyclical, and exhibits a basic disregard for dates and history.

As time is oriented, the idea of progress has become central to most social and political thinking in the West. We can expect better times in the future, and we should strive to make it happen. This belief was more or less credible depending on the period (there were darker ages when pessimism prevailed during times of decline, war or plague) but it has been present throughout modern history. In other words, biblical messianism (the belief in a happy, final future) is a strong component of Western culture.

Paradoxically there was also (till the 19th century) a rather static conception of human society. From Plato's Republic onward, Western philosophers imagined various models of perfect society, seemingly unaware of the inevitable change and decay inherent in any human institution. Messianism would lead us to the perfect world, and time would then stop forever. A simplistic conception to be sure, but one with a strong and satisfying emotional appeal.

Similarly, classical science is not really interested in time itself and has long ignored irreversible change. Science looks for timeless invariants behind changing appearances. The Platonic ideal of an abstract, eternal and unalterable reality has been one of the main motivations of Western science, in contradiction with the biblical conception of time.

2.5 Consequences of Western worldview

These beliefs taken together depict a fundamentally stable, rational world, obeying formal laws and accessible to a human intelligence willing to look beyond appearances. This is a culture of design, looking for a clear structure in the world and inclined to build social artifacts (e.g.

cities or social systems) following explicit designs. Rationality is a paramount value of Western culture. To misquote Hegel slightly, "the rational is real and the real is rational" (what he meant was actually more complicated, but it's a useful slogan).

The primacy of design is striking in Western painting and architecture, especially since the Renaissance, in the grandiose structure of Western music (Bach would be the perfect example), in urban planning, formal gardens and political utopias. It gives European society a solid, orderly, clear and structured appearance, which seems impoverished and rigid to an Eastern eye, lacking in texture, variety and grace (compare French classical gardens with traditional Japanese gardens as extreme examples of each tradition).

Because man was created in God's image, mankind enjoys a special position in the world, given dominion over the rest of creation. But mankind is also alienated from the natural world and must obey specific moral laws which are both a glory and a curse. Expelled from the garden of Eden, mankind stands alone in the world, in an uneasy tête-à-tête with God. Reconnecting with this imperious, omnipotent God may be man's only chance to find a place again in the universe.

Another consequence of the religious underpinning of moral laws is the appalling dogmatism and intolerance that run throughout Western culture and history since the advent of Christianity. This is a culture where religious councils convened regularly to decide what was the correct dogma, which was then enforced by force. God's truth is not to be trifled with! Religious wars have been a recurrent feature of European history, and this intolerant attitude was then carried over to secular political ideologies of the 20th century (nationalism, communism and nazism) with even more disastrous results.

The peculiar combination of dogmatism with messianism has been a particularly potent force in Western civilization, with mixed consequences, to say the least. It was sometimes a force for the good, motivating political and social progress. It also was just as often (possibly at the same time) the justification for disastrous and bloody political adventures, and this attitude is still present in much of today's progressive thinking.

Yet the same belief to be upholding God's truth and to have God on one's side also gave individuals the strength to affirm their convictions in the face of church and state. Associated with the distant but powerful memory of Greek and Roman free citizens of Antiquity, free to speak their mind and to make their own decisions, religious conviction has eventually and

paradoxically been a powerful force for free inquiry and freedom of choice in Western society. Western individualism also derives from the two main sources of Western culture.

Last but not least, we will try to show below the role of the peculiar Western worldview in fostering the rise and development of modern science. The syncretism of biblical beliefs and Platonic thought was the perfect environment for the birth of Western science.

3 Features of Eastern culture

In comparison, Eastern cultures (centered on China) are based on a very different syncretism: a combination of Confucian (Confucius 2005; Etiemble 1986), Taoist (Laozi 1961, 1967; Zhuangzi 2003; Waley 1934; Kaltenmark 1965; Hansen 2014) and Buddhist beliefs (Conze 1959; Watts 1957; Davis 2014). Although Buddhism originally came from northern India, it soon blended with Taoist notions. This syncretism resulted in a specific social (Weber 1915) and metaphysical outlook (Perkins 2016).

3.1 An organic universe

In Eastern culture, there is no personal God and no creation. The universe is seen as a quasi-biological being, without beginning nor end, self-actuated and forever changing. This is very much a dynamic entity, with the emphasis on vitality and change rather than on any explicit design or purpose. Process is more important than structure, and spontaneity and flexibility are paramount values.

Accordingly, any divinity tends to be impersonal. In Chinese culture the highest divinity is called Heaven (*tian* 天) but without any clear features. It was probably originally anthropomorphic, but in the classical period (as early as the 4th century BC) it had become a rather vague and abstract figure. Beyond Heaven looms the Tao or Way (*dao* 道) which is even more indistinct, formless and impersonal, as the guiding principle (or source, or process) that underlies the spontaneous operation of the world. The Way is typically dynamic and an evolving rather than a static structure.

In Japan there are numerous gods or spirits (*kami* 神) but they are mostly formless, associated with natural objects (e.g. rocks, springs or trees) more often than with mythological human-like

characters. Beside ideas borrowed from Buddhism and Chinese culture, the Japanese world is full of indistinct spirits rather than clear divine figures.

In brief, the universe as it is takes precedence over any deities, which are at most concurrent with the world and not anterior to it. There is basically no transcendence in this worldview.

3.2 Immanent reality

Ultimate reality is then not to be found in another realm, but in our ordinary, common-sense world. This world is the real one, and no other (although we might be deluded about its import or significance). In other words, reality is immanent in our world, and it is to be found ultimately in our everyday experience of life. Any philosophical enquiry should start from ordinary experience, not from abstract notions (this can be compared with 20th century Western phenomenology).

This viewpoint is consistent with the vague and impersonal character of Eastern conceptions of divinity. If reality is immanent in the world, any divinity is to be experienced in this world as conjoined with it, not standing apart from it. The Taoist Way is to be found everywhere and anywhere in our world ("even in piss and dung"), and in Buddhist terms, the same can be said of Buddha-nature (i.e. the ultimate reality).

Still, because the Way is ineffable, it may be also interpreted as a kind of transcendence that cannot be expressed in human words, leading to various forms of mysticism (notably in Taoism and Zen Buddhism). The Way (*dao* 道) can thus be found *in* this world, but it is nevertheless not *of* this world (possibly to be seen as the flow or form of our everyday world).

3.3 Basic undifferentiation

Fundamental reality is also undifferentiated. All the ordinary distinctions to be found in human language (between objects, qualities and values) are basically unsound: they are either illusory, or temporary or relative to context (or all of these). There is a lot of variation on this issue between different authors and schools of thought. Some Taoist authors such as Zhuangzi tend toward skepticism and relativism, while Laozi and Buddhist thinkers are even more radical in their critique of any intellectual discourse concerning reality.

Buddhist philosophy in particular develops a systematic and relentless attack on the very notion of substance (anticipating by centuries recent developments in Western thought). Entities are neither distinct nor separate nor stable, and the individual self (the ego) is an illusion. The motivations for this view are primarily soteriological (it should help believers find salvation by showing them the vanity of all attachments) but it became an important part of Eastern thought.

What these different schools have in common is a general view of ultimate reality as a kind of undifferentiated background, out of which ordinary distinctions may arise and be used on a temporary basis according to context and needs. As reality is also dynamic and constantly changing, any clear-cut linguistic description is eventually a fool's game, and the sage should always be ready to let go of preconceived distinctions.

This neutral background is often described (rather misleadingly) as nothingness or emptiness (*wu* 無, *mu* in Japanese), out of which differentiated being (*you* 有) will arise. This background can also be identified with the Taoist Way. Later on (during the Sung dynasty), it was further reinterpreted by Neo-Confucians as (the source of) a kind of basic energy (*qi* 氣).

There is a recurring ambiguity, however, as to whether differentiated things are real, or only in the mind of the observer. In Western terms, there appears to be a vacillation between realism and idealism, but Eastern thinkers explicitly decline to take positions in such terms (because the mind is not seen as a separate substance, different from matter). Most classical oppositions of Western philosophy (mind-matter, mind-body, matter-form, etc.) are in fact ultimately inadequate to account for Eastern conceptions.

3.4 A holistic world

Things and events are not only devoid of a stable, separate identity, they are also regularly dependent on other events in the world. This is a holistic position: the whole is more than the sum of its parts, and mere analysis into parts would miss the crucial relational nature of phenomena. Holism is not unheard of in the modern West (from Spinoza to Hegel) but it has always been a minority position, whereas it is the default mode in Eastern thought.

Such holism is associated with an emphasis on influence at a distance, rather than the mechanical causality by direct contact that is typical of classical Western science. The Chinese started work on magnetism long before the Renaissance (they invented the compass) and they

have always seen the universe as a web of correspondences, where correlated things, events or categories naturally influence each other. Chinese medicine for example is based on a systematic catalog of correspondences within the body and between body and world. Again, similar ideas were to be found in medieval Europe, but they later gave way to the analytical, mechanical outlook of classical science.

3.5 Undirected time

One last feature is worth mentioning mainly by opposition to the Western worldview. Time in the East is not clearly directed as it is in biblical thought. China has a very strong sense of history, with a continuous tradition of precisely dated annals, but no obvious conception of time going in a particular direction. In fact the long history of China with its recurrent dynastic upheavals and renewals suggests a cyclical view of human history (whereas the shorter history of Japan hints at a more linear conception of time).

Such a view was reinforced by the strongly cyclical conception of time in Buddhism, inherited from Indian culture. India was amazingly indifferent to dates: they are insignificant and irrelevant in a cyclical universe. This conception of time was not without influence on social and political ideas, leading to some fatalism but also to a rather tolerant view of social evolutions.

3. 6 Consequences of Eastern worldview

This Eastern worldview has had notable consequences for cultural developments and social life. There is a basic distrust of formal descriptions and explicit laws of any kind; general principles to be adapted to circumstances are preferred instead. Flexibility and adaptability are more highly valued than the rigid observance of precise regulations. Social rituals are important to reinforce social cohesion (this is an important tenet of Confucianism), but they are flexible social customs, not dogmatic commandments.

This mixture of flexibility and social cohesion, associated with personal moral discipline and great respect for learning (typical Confucian values), was probably favorable to modernization and industrial development in the Far East. After initial difficulties (especially in China) Eastern countries are now advanced economies (except for Vietnam so far).

The dynamic character of the Eastern universe, the emphasis on process rather than substance is also conducive to widespread flexibility, since nothing is fixed or permanent. It makes sense to "go with the flow", to adapt nimbly to a changing world rather than sticking blindly to one's guns.

The distrust of formal rules goes together with a stress on spontaneity and intuition. As the world evolves by itself without external guidance, so should men act spontaneously, following their instinct as much as possible. This is not as simplistic as it may sound, because correct spontaneous action is often assured by long and rigorous training (in calligraphy, painting or swordsmanship for example). Spontaneity is the ideal, but within a strict social framework!

The emphasis on spontaneous action is associated with the oft-mentioned theme of non-action (*wuwei* 無為). In fact, purposeless, effortless action (as exhibited by a highly-trained craftsman for example) would be a better translation than "non-action", but this is certainly an important notion in Chinese culture.

This basic flexibility is associated with a moral tolerance that is a far cry from the rigid dogmatism of biblical culture. Conflicts for power in Eastern history have been just as violent and cruel as anywhere else, but Easterners usually do not fight over religious dogmas: they just don't think that God's truth is unique and worth enforcing. They find it perfectly acceptable to worship different deities at the same time (after all it's only prudent to hedge one's bets).

Of course, things are not that simple. Japanese nationalism and Maoism in China have proven remarkably intolerant and murderous, but these are recent developments that owe much to Western pressure, influence and ideas. They were the result of a breakdown of the traditional social order, which was replaced by brutal modern political conceptions. There has also been in Chinese history and Buddhist beliefs an undercurrent of popular messianism, which surfaced at regular intervals, but this would take us too far from our main argument.

Lastly, mankind does not have a special place in the Eastern universe. The social world is part of the natural world, and human society belongs to the biological realm. No special moral rules apply to mankind, and social customs belong to the natural order of things. Neither is mankind alienated from nature: on the contrary Easterners are very much at home in this universe and delight in their appreciation of natural landscapes. The love of nature has always been a major theme in Eastern literature, poetry and painting.

It is only recently with the march of modernization that feelings of loneliness and alienation have become prominent in films or literature (the Japanese novelist Murakami Harumi would be

a good example). Modern urban life and the dislocation of traditional social structures are now changing dominant attitudes and emotions.

4 Development of science

Modern science developed for three centuries since the Renaissance, before turning gradually into contemporary science. Let us try to survey the course of this development.

4.1 Roots of modern science

Modern science is primarily a European development (Principe 2011). Other cultures contributed (sometimes brilliantly) to astronomy, medicine, mathematics and various fields of knowledge, but no other civilization has seen the rise of modern science as we know it today (i.e. systematic experimentation or observation closely associated with systematic formalization). China, India and Islamic culture displayed notable technological and theoretical advances (they were in fact more advanced than Europe till the Renaissance), but stopped short of modern science.

It is a fair question to ask why science developed in Western Europe and nowhere else. This question was formulated in particular by Joseph Needham in the 1940s (see Needham 1969). A reasonable (but tentative) answer points to Western culture, whose particular features might explain the gradual build-up of science in classical Europe. The peculiar mixture of biblical beliefs and Platonic philosophy proved to be a favorable breeding ground for scientific inquiry.

The conception of a world created by a rational personal God makes the world potentially accessible to human intelligence, and the quest for a transcendent reality supplied a strong motivation for scientific research. The Platonic view that ultimate reality is more abstract than common-sense appearances proved to be extremely fruitful in formulating fairly simple but general laws and theories. The idea that the word is composed of a limited number of stable, elementary substances was also the source of many advances in chemistry and physics. This view is still very much alive in the unending quest for elementary forces and particles…

In short, by seeing the world as ruled by an intelligible design, Western culture was strongly encouraged to work out and formulate this design. The Greek passion and genius for mathematics,

together with the spirit of free inquiry inherited from Greek democracy, contributed even more to this general venture (Vernant 1962).

The analytic outlook and local causality developed during the Renaissance (together with the reintroduction of ancient Greek culture following the fall of Byzantium) turned out to be the right strategy for the beginnings of classical science. It helped make sense of a world of phenomena, which would have appeared otherwise too complicated to formulate. Vague global explanations could be gradually replaced with more precise, predictive formal laws.

Contrarily, the organic and holistic outlook of Eastern culture did not encourage the analysis of physical reality into elementary components. There was not the quasi-religious passion for abstract formalization typical of Western thought, and the Eastern conception of a dynamic, constantly changing universe without stable substances was inimical to the foundations of modern science. The insistence on phenomenology rather than abstraction was not a good starting point either for the formulation of general theories.

In fact Eastern conceptions were more complex and advanced intellectually than the simple analytic outlook of early Western science. Buddhist philosophy for example is remarkably subtle, logical and coherent, and full of valuable insights. But these holistic conceptions were premature for early science, and it is only now that they could be useful to help us make sense of the complexity of the universe.

Of course, cultural explanations are relevant, but insufficient to explain the course of history. Why did modern science arise during the Renaissance, and not, say, two centuries earlier? Social, political and economic conditions also played a role in the development of science, which took place in conjunction with the rise of merchant capitalism, the growing status of a bourgeois class, the Reformation and the gradual construction of state institutions. These diverse (but related) phenomena, and the growing political pluralism in Europe gave science enough space to develop, and later some official support.

Universities (another European invention) and the printing press also helped educate generation after generation of Western thinkers. The effect was not always totally positive, as universities were often very conservative and stubbornly opposed to new ideas, but the intellectual training they offered proved invaluable to European society in the long run. The role of social institutions in the history of science must clearly be taken into account.

4.2 The world of classical science

Because of this specific history, classical modern science (i.e. the scientific movement that unfolded since the Renaissance until the 19th century) exhibits strongly marked features. They amount to a fairly coherent conception of a physical world that is fundamentally comprehensible and accessible to human intelligence.

As seen above, the main idea is that there is a hidden order behind the world of appearances. This order consists in simple, stable elements and abstract deterministic laws, which can be used to explain and predict the facts of experience. One should always be looking for this abstract reality and not stop at surface phenomena. The relevant laws can often be expressed mathematically, and mathematics is thus the primary language of physics.

Classical laws are usually linear, i.e. functions of variables of degree 1, that satisfy the two following relations:

$$f(a + b) = f(a) + f(b)$$
$$f(n \cdot x) = n \cdot f(x)$$

These two related properties ensure that a linear system can be investigated in parts, and the partial results can then be recombined easily and intuitively (see Barrow 1991, chap. 9). Linear systems are additive and the whole is but the sum of its parts. Consequently, a small change in input will result in a proportionally small change of output, making linear phenomena easy to predict in practice. This is obviously a highly desirable state of affairs, which justifies the analytical approach of Descartes and others to philosophy and science.

The determinism of classical science means that the universe is in principle totally predictable. Given correct laws and accurate initial data, one could predict the future as well as reconstruct the past from the present situation (which begs the question whether time is reversible, but this remained an open issue). This type of determinism was clearly formulated by the mathematician Laplace as late as the beginning of the 19th century, and this is certainly a powerful hypothesis (which unfortunately turned out to be false).

Another important feature is locality of action. Causes and effects can only take place locally, by direct contact. This simple mechanical causality is intellectually pleasant, but becomes a

problem to explain phenomena like gravitation and magnetism that appear to work at a distance. Various attempts were made to reconcile action at a distance with local causality, but none proved satisfactory and this remained an important contradiction in classical science, a problem which elicited later developments (such as the notion of physical field).

In short, classical science looks for simple abstract explanations behind appearances, to be expressed mathematically as much as possible. Laws are deterministic, usually linear, and the general outlook is analytic: systems can and should be reduced to the sum of their parts. Causality is local, although this could not account for action at a distance. We will now see that most of these features have become untenable in the face of recent scientific developments.

4.3 Some developments in contemporary science

It is evident that science has changed drastically since the beginning of the 20th century, but it is perhaps not so commonly appreciated how radical those changes have been. Taken together, they amount to a totally different conception of the universe and of what science can do. In fact, they have been so radical that they have not yet really penetrated the common culture. Here are a few typical contemporary developments:

• Darwinian evolution

Darwinism explains the evolution of biological species as the interaction of (inheritable) variations chosen or discarded by natural selection (due to sexual selection, predation and general reproductive fitness within the environment). Evolution is then basically unpredictable, because variations occur randomly in individuals, and selection depends on the whole environment of a species in ways that are very difficult to foresee (Darwin 1859).

Darwinian evolution is not deterministic and explanations can only be given *a posteriori*. This is quite different from the classical conception of simple deterministic laws that could be used to predict the future from a present state of affairs. The systemic character of Darwinian explanations, which depend on a whole ecosystem for their comprehension, is also notable. An ecosystem is a global entity subject to constant incremental change, not a mere collection of simple, predictable phenomena.

• Concept of physical field

A field is a mathematical construct with a value (e.g. a scalar, vector or tensor) for each point in space (and time). In the beginning, a field was just a convenient notation for physical values varying throughout space, such as the value of gravity. But since the middle of the 19th century, physicists started to apply the notion of field to new domains (notably electromagnetism), treating fields more and more as independent global physical entities.

Fields are a long way from the mechanistic model of classical European science, where all interactions were seen as local, typically collisions between solid objects (e.g. billiard balls). Newtonian gravitation and the study of magnetism introduced a more global conception of action at a distance due to forces spreading through space. What remained unclear was the exact mechanism of the interaction, the medium and speed of its propagation (Newton thought that the effect of gravitation was instantaneous, while in the present view gravity travels at the speed of light). Yet the change in outlook is remarkable, and it paved the way for the theory of relativity, where fields (e.g. the gravitational field) become the dominant physical reality (Einstein & Infeld 1938).

• Dynamical systems

At the end of the 19th century, mathematicians (Poincaré notably) started to explore the behavior of specific systems of differential equations evolving through time, behavior that could only be described qualitatively. These systems are more common than was previously thought: domains such as the weather, economic or biological systems are typical examples. Dynamical systems cannot be solved mathematically and they do not allow precise predictions.

Dynamical systems can be very simple, but they are usually complex, non-linear and often chaotic (i.e. apparently random). Even though it may be actuated by deterministic mechanisms only, a dynamical system as a whole is practically unpredictable, because of extreme sensitivity to initial conditions and boundary effects (e.g. Prigogine & Stengers 2009). The slightest change in input data or parameter values can lead to drastic changes in long-term behavior, so that only qualitative descriptions are possible in terms of broad categories of behavior (stability conditions for example).

Again, one may note the move away from simple deterministic phenomena and laws, in favor of global descriptions of inherently complex systems that in practice cannot be reduced to their

parts. As simple, linear classical systems now appear to be the exception rather than the rule in the world, this represents a major conceptual change.

• Quantum physics

At the level of subatomic phenomena, physical laws are quite different from our ordinary, common-sense world. Physical values are discrete, events are fundamentally probabilistic and (instantaneous) action at a distance is possible. Physical measures cannot be separated from the experimental setup, breaching the distinction between observer and reality. These strange features have elicited passionate discussions in science and philosophy, and they add up to a theory very different from classical physics (Heisenberg 1958; Klein 2004).

Particle-wave duality is one of the tenets of quantum physics. In some experiments (e.g. interference phenomena) a ray of light must be interpreted as a wave. In other experiments (e.g. photoelectric effect) the same ray of light must be interpreted as a stream of particles. In fact the physical entity in question is neither particle nor wave, or possibly both: our classical language is just not appropriate any more. Moreover the description must be probabilistic (one cannot predict individual events) and precise outcomes are inseparable from the measure itself (in the standard Copenhagen interpretation).

With particle-wave duality and probabilistic descriptions, the very notion of stable substance disappears at the subatomic level. We are dealing here with a world of phenomena that have been perfectly formalized, yet it is unclear what kind of physical entities (if any) might lie behind these events. Substances are therefore replaced by events. In high-energy physics notably, subatomic particles appear to fluctuate in and out of existence, changing into energy and other particles, often within very short time spans.

The strangest phenomenon is probably "quantum entanglement". Particles can be linked in such a way that their (probabilistic) behavior is correlated at a distance. After much debate and repeated experiments, there seems to be no other solution than to consider either instantaneous action at a distance (without any intermediate cause), or a basically non-local, holistic universe. This phenomenon is perhaps not so frequent, but it is undeniable and inescapable, and fundamentally changes our former conception of the physical world as local and separable.

So in quantum theory, physical reality must now be seen as potentially non-separable, and the whole cannot be reduced to the sum of its parts. In other words, relations between particles and events are also to be considered basic entities in this fundamentally holistic universe.

4.4 A new scientific worldview

These various developments in contemporary science (dating back to the end of the 19th century and taking place mostly in the 20th) do not amount to a coherent unified theory. They belong to different disciplines and fields, and even within physics, it is well known that quantum physics is not totally compatible with relativity. And our choice of which disciplines to highlight is debatable (we could have mentioned thermodynamics and statistical mechanics as well). But there are similarities between such diverse developments and a kind of family resemblance which is intriguing, pointing to a new scientific and philosophical worldview. One may now try to elucidate the common features.

We are generally dealing here with complex systems, which have to be described and understood with systemic approaches and explanations. As a result, these systems are often unpredictable in detail, but one can nevertheless come up with useful higher-level regularities. Precise predictions are no longer possible and explanations will then be *a posteriori*. Phenomena are inherently random or appear to be, and we must give up determinism either theoretically or practically.

The most striking feature is the holistic character of this new worldview. Changes are often strongly non-linear, and the whole cannot be explained as the sum of its parts. Systems must be described *as systems* and cannot be reduced by analysis into parts. The notion of stable, separate substances is no longer valid in such a universe, as phenomena have to be considered within a whole system.

All this is obviously fundamentally different from classical conceptions. Modern science was dealing mostly with simple linear systems, which could be analyzed into parts without leaving any unexplained residue. Phenomena followed deterministic laws that made the universe totally predictable in principle, and action could only be local. Although this view still applies to specific subdomains of this world, it is fundamentally obsolete by now.

It is interesting to note that at the same time that scientific conceptions were slowly starting to evolve in radical new directions, comparable changes could be seen in philosophy and the humanities. A historical approach to social phenomena became prevalent in the 19th, and a systemic, dynamic, and holistic way of thinking was gaining influence. The philosophy of Hegel is a good example of this new Zeitgeist, but this is but one instance in a more general movement.

4.5 A lost opportunity?

The reader will certainly have noticed by now the similarities between contemporary science and Eastern thought. The organic view and holistic outlook prevalent in Eastern culture led to a systemic conception of phenomena that Europe has rediscovered only recently. An emphasis on complexity comes naturally with Eastern thought. The basically dynamic, ever-changing character of the universe is also quite modern (or rather contemporary). Recent disciplines such as dynamical systems or ecology would fit naturally within this worldview, whereas they have had to fight for recognition in the analytic climate of modern science.

The notion of action at a distance, to be found notably in magnetism or gravitation, has been a recurrent problem for Western science ever since the Renaissance, because it was in contradiction with a dominant paradigm of local action by mechanical contact. Descartes devised his theory of vortices (whirlwinds of minute particles) as a mechanical explanation of gravity, but it turned out to be a dead end. Yet influence at a distance was perfectly natural in the holistic Chinese culture, which explains its early interest and successes in domains such as musical acoustics and magnetism.

The distrust of common-sense distinctions and rigid laws, the conception of an undifferentiated background that gives rise to specific phenomena according to context, would have been a good starting point for the development and interpretation of quantum physics. Giving up the notion of stable substances was much harder for Western scientists that it would have been for an Eastern mind (especially for a Buddhist thinker).

Yet to the best of my knowledge, the influence of traditional Eastern thought on recent scientific developments has been very small. Neither Western scientists, usually ignorant of other cultures, nor Eastern scientists, too preoccupied with catching up with the West, have tried to put Eastern insights to good use in their scientific research. Various developments like Darwinian

theory or quantum physics are due to an internal evolution within a discipline grappling with unexplained facts and inadequate concepts. The theoretical renewal was usually slow, contentious and painful, but took place by itself.

Of course the debate and controversy that accompanied the rise of contemporary scientific theories ensured that concepts and interpretations were thoroughly thrashed out and often improved upon. Still, one feels that a lot of energy was wasted in fighting obsolete conceptions and ideas. Problems that seemed very puzzling within Western tradition (e.g. non-separability at the quantum level) would appear much less troubling in Eastern culture.

In short, we think that some knowledge of the rich Eastern intellectual tradition might prove beneficial for the advancement of contemporary science and its awkward dialogue with the common culture. This should concern Western scientists, but also their Eastern colleagues who tend to overlook their own traditions in their effort to emulate modern Western civilization.

5 Conclusion

Our conclusions will be fairly modest and tentative. We have thrown some light on the roots of modern science within Western culture, and its subsequent evolution to contemporary science. We have also suggested how Eastern culture might be a source of valuable insights in the future. And the comparative delineation of Western and Eastern cultures may be deemed of interest for its own sake. Considering Eastern conceptions seriously is a good way to better elucidate and understand the West and our own basic Western beliefs, which would otherwise remain implicit.

What is lacking from this text is an analysis of the precise social and historical conditions that also made the emergence of modern science possible. The social and economic status of European scientists (associated with the church or university at first, then often court attendants or gentlemen of leisure), growing political pluralism in Europe, technical advances and the rise of capitalism, were certainly important factors in the development of modern science. Later on scientific research was gradually institutionalized within academies, scientific societies and the modern research university.

Still, we have seen here the importance of culture to better understand social phenomena. Science in particular does not exist by itself, but develops in constant dialogue with the surrounding culture and society. Replacing modern science within the framework of Western

culture is enlightening about its concepts, developments and problems, and exposing the cultural roots of science should make it easier to advance beyond them.

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