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Twelve Thousand Years of Non-Linear Cultural Evolution: The Science of Chaos in Archaeology

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Abstract

The evolution of human societies and in general of human history, do not follow a liner trend but rests mainly on mutual interactions amongst different components. Identifying the meanings of complexity in human processes which involve material, energy, and environmental factors, the cultural evolution is viewed via a complex system approach of a collective result of non-linear interactions making a series of successive transitional phases along a trajectory. The interacted multifactorial issues derive from three concentric circles or dynamical systems, a) the internal (issues derived from within a given society), b) the external (issues derived from interaction with neighbor societies) and c) the environmental (issues related to the context and other geological phenomena). The cultural evolution of the last 12,000 years is mainly considered. This is the Holocene which defines the onset of interglacial period until present era, and we focus on some exemplary cases from Mesolithic to Roman period from Mediterranean and the world. The theory of chaos is intermingled with various identified attributes that define and affect the cultural evolution of a human organized system. The presented cases are sufficient to stress the naturalistic methodology, which serves as the basis of a synoptic and synthetic philosophy that involves art and science corresponding to classical techne and logos.

Keywords: culture, societies, complexity, environment, non-linearity, archaeology, chaos, equilibrium

Introduction

Various theories have been developed for the interpretation of the *how* and *why* in the evolution of social-cultural complexity, based on social, terrestrial and astronomical causes (1,2,3).

Here as system we take all manifestation of a group of humans that have a common conscience of similar rooting, ethics, religion et.c that develop and create a culture. It is accepted that the development and trajectories of such cultures in the world depend on various factors in a synergistic way (4,5,6). The dynamical complex mechanics are operative in any culture's formation, and the complex systems indeed present problems both in mathematical modelling and philosophical foundations. The study of complex cultural systems represents a new approach to non-linear science that investigates how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its immediate and/or distant environment.

The equations from which models of complex systems are developed generally derive from statistical physics, information theory and non-linear dynamics, and represent organized but unpredictable behaviors of such systems that are considered fundamentally complex.

Since all cultures have many interconnected components, the science of networks and network theory are important aspects for their study. It is not our scopus to formulate strict modeling and simulation of the non-linear cultural

evolution during the last 12,000 years, but instead to identify attributes and explain the complex cultural evolution with some exemplary archaeological and historical cases taken from the SE Mediterranean region though it applies worldwide (7).

Disaster dynamics in archaeology has shown to be so powerful that they changed the course of human history. Mighty empires collapsed and vanished or shocked irreversibly. Natural environmental factors triggered the fall of well organized social systems. Drought or flooding, epidemic diseases like plague and others, tremendous volcanic eruptions and meteoritic impacts, tsunamis and earthquakes influenced the circum-Mediterranean civilizations, the NW European, Asian and American civilizations. The search and interpretation of such unknown disasters leading to unexplained results is based solely on the interdisciplinary approaches.

Here we propose that every theory should rest upon diverse dynamical factors derived from the three following prominent con-centric interdependent systems—circles (Figure 1):

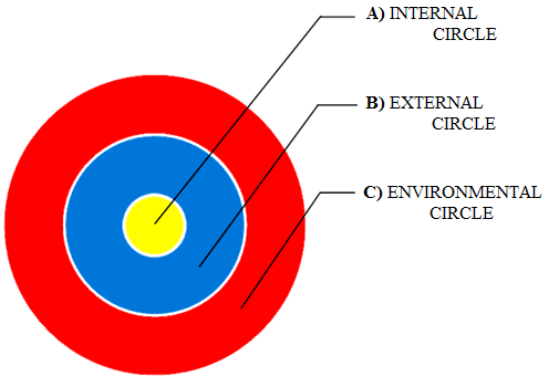

Figure 1. Three interacting circles that drive any cultural evolution.

A) *Internal Circle*: represents a population (= a group of people that live together, a core of settlers/immigrants, an organized society or habitation), one that involves social unrest/revolt, limited and controlled food producing, religion, a hierarchical system of governance, explorative character, an economic system.

B) *External Circle*: near or distant population groups/residents, with which the given population interacts directly or indirectly. An interesting critical assessment of human species-specific operating systems that corresponds to these two circles is made by Sass (8).

C) *Environmental Circle*: comprises of elements such as geophysical and climatic phenomena (earthquakes, volcanic eruptions, floods, extreme and continuous drought and rainfall), geomorphological and geographical setting. Specifically, exposure of humans to environmental threats is unevenly distributed. Some locations may pose more risk than others, e.g., high latitudes, floodplains, river banks, marshy areas, small islands and coastal areas. On other hand, human exploitations or modifications of the environment such as deforestation, increase of paved areas covered by buildings and roads, and river canalization, have created impacts often affecting areas a long way from the source of the environmental change.

The system's variables comprise of the input of energy, the flow of energy and the transformation of matter, the concept of reversibility, the organization of space and information.

The interactions between the A, B, C systems are due to the intense phenomena coming from the three circles and the unpredictability of the events (social/environmental) (Figure 2).

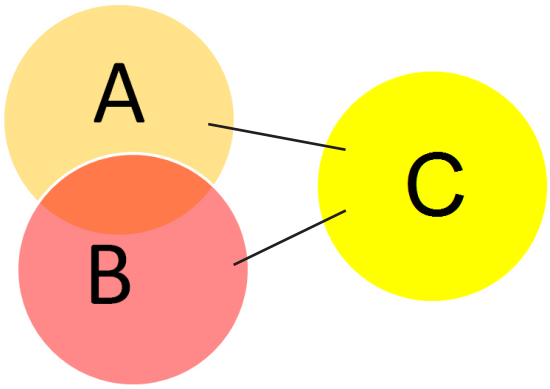

Figure 2. The three interdependent system impacts A, B, C that shape cultures—A and B in between and C with A and B.

The whole historical process is the presentation, development, conflict, destruction and restoration, collision and equilibrium of primary and secondary elements which synthesize the historical polyphonic structure. In the inner part of this general structure there exist partial homologue structures that express partial historical events.

Major cultural developments are focal nuclei that attract tension and attention, certainly not randomly, but as an anticipated outcome of any dynamic system that inheres the so called chaos.[i] Such basically, but temporally, stable (steady) states (attractors)[ii], have had been formed during certain phases of the evolutionary processes of human cultures, e.g., food production stage, technical knowledge, metallurgy, writing, social structure, permanent settling, trade contacts. Simply, in the course of time, occasionally these attractors feed in coherent cyclic actions of various types (periodical or chaotic), while the decision making and/or cultural outbursts occur at a critical point well beyond the thermodynamic domain of equilibrium. This way a new state is produced and the human evolution progressed from prehistory towards the historical era (thermodynamics is the branch of natural science concerned with heat and its relation to energy and work). In fact, thermodynamics applies to systems that are approaching equilibrium – either adiabatic, i.e., isolated, or isothermal – whereas natural systems are usually subject to flows of energy/matter to or from other systems.

Along such profound presentation of realistic structural space-time model and in the context of the three circles there are many aspects of complexity rising from e.g., hierarchy and emergence, capabilities, systems, necessities, interests, communication and control etc (3, p.283, Figure 6.10). In a complex system, such as here, the group of people living together and sharing similar language, principles and any kind of structure, there are the so called evolution equations which describe the dynamics of the elements and comprise the three above circles. As a rule a particular form of cooperation in nature is the symbiosis of two species.

At any rate, understanding how systems work requires observing them intact. Much like life, any effort at understanding life cannot be approached in the most meaningful way outside the living organism. Accurate depiction of the temporal organization of vital function is completely dependent upon intact central, peripheral, and cellular time-keeping mechanisms (9). In addition, conscience uplifts and reinforces the changes due to individuals and at the end form a collective expression. The latter resides within the unified structure of the universe and is described by unlimited expressions of energy order. It is both the prepositional consciousness and kairicity (= optimum occurrence, timing) (10) that comprise the deeper partial structures in the internal circle A above. The historical continuity is not hindered by the non-continuity induced by the human abet action, on the contrary it is restructured through imposition of human preposition.

Nevertheless, it is certain that interactions between these three circles have caused profound changes which determine the cultural route of a given society. These changes are outbursts occurred in the time—space of a seemingly steady state thermodynamic route. Such steady states become unstable beyond a certain point away from equilibrium; the critical distance. The timing for the emergence of instability is the cladding point. Beyond this point a set of new phenomena i.e., new spatio-temporal processes, are produced named dissipative structures (3).

These phenomena in general increase entropy[iii], in contrast to the thermodynamic steady branch near equilibrium with minimal production of entropy (1,11).

Scepticism on the problematic issue of non-linear trend of history especially since 1000 AD has been presented elsewhere (2), having as central thesis the view that everything that surrounds us and form the real time, are the results of certain historical events. The approach is acquitted from simplistic views about linear evolution and free by any determinism, while analysis was based on biology, linguistics and economy.

Herein, an attempt is made to demonstrate that human prehistory did not follow straight line, but instead in every cladding, alternative steady states were possible, which when activated, coexisted and interacted one with another. The changes from one status to another is principally based on drastic and mutual interactions between different components, and essentially depended upon the (type of) human civilization/social structure (nomadic or organized), the consumption of energy, and the intensity of core multi-level interactions. Using this approach the time scale of analysis is focused upon the onset of the last interglacial, i.e., 12,000 years ago.

Herein, the term civilization is defined in technical terms and is attributed to a society that has cities with large populations, a hierarchical social organization with an established leader atop the hierarchy, an economy based on farming and agriculture, monumental architecture, a lexial system, and assembles a collective consciousness. Civilization encompasses culture, which, in turn, often refers to ideological development of a group of people.

Transitional phases

The transitional progress and development phases in the prehistory and history of mankind mark significant events that changed the scope and conduct of everyday life. The various stages of social development, from hunter-gatherer groups to the organized society of the city, temporally determine the focal points of influence, (social) development and interest, and act as attractors (Figure 3). But the timing or opportune moment of events and consequent processes are characterized by complexity, which emerges from the systems as shown in Figures 1 and 2.

Complexity is defined as the non-linear process that is a prerequisite, although not a sufficient, condition, for chaos and self-organisation (12,13). On the other hand, linearity—monotonous trends in the course of time—implies the superposition principle. A non-linear evolutionary cultural trend is characterized by three factors: a) attractors that determine the stable state, b) recurrent changes in environmental phenomena, and c) a chaotic combination(s) of superimposed cyclic variations with a phase difference.

The course of a culture is driven by the influence of the internal and external (viz- environmental) variations (δ). Near equilibrium these (δ) have no impact, whereas far from equilibrium they lead to instability, namely, to non-deterministic prediction. Thus, these δ "determine" the next transition, that is, a phase which takes place in the thermodynamical domain, and which leads the cultural centre to other domains and dimensions of transient stability (Figure 4).

Therefore, even if the internal conditions and the boundary conditions that characterize a given culture are known, *we cannot predict its course per se* because there are many possible situations from which the cultural centre is able to assume through the process of variation. (See Figure 4, domains α1, α2, c1…, c6….). The term assume in this case refers to the fact that the macroscopic description does not favor a particular end-point or solution. Therefore, probabilities become important to the emergence of macroscopic order, visualized in large societal nuclei, as caused by fluctuations of microscopic interactions of constituent family nuclei. The unpredictability (but interpretability) becomes more intense with the intrusion of variable impacts from the 3rd environmental variable.

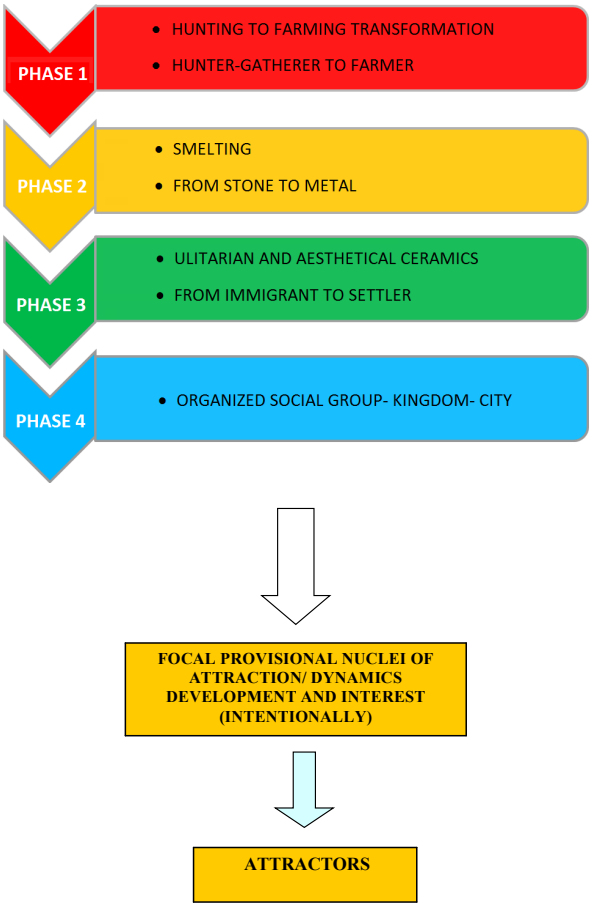

Figure 3. Transitional stages in cultural evolution which, in the given space—time, act as attractors in further production, use and interaction.

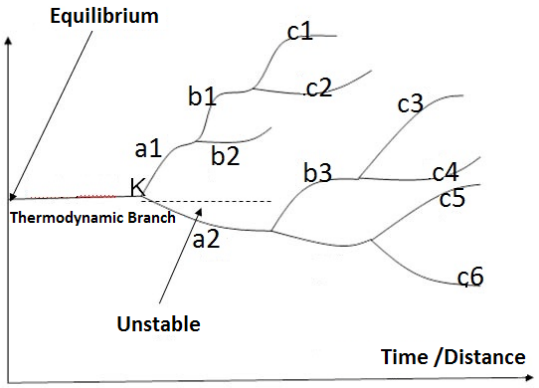

Figure 4. The thermodynamic domain for a human system far from equilibrium, stable domains, bifurcations and the unforeseeable but determining potential courses of evolution in the next phase (stage).

Human evolution is not linear; on the contrary, alternative stable states were feasible, which, once activated, coexisted and interacted. Periodic and chaotic phenomena coexist and interact with these stable structures (*attractors*)[ii] and reveal the evolutionary trend of history (14,15,16).

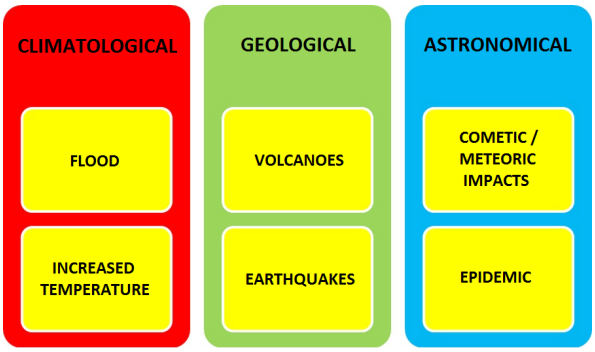

Figure 5. Circle C consists of environmental factors categorised into three causes-sources: climatic, geological, and those of astronomical nature.

The non-linear course of cultures in space-time is reinforced by the non-linear emergence of environmental phenomena. Environmental factors are categorized into three causes-sources, a) climatic, b) geological and c) astronomical, and respective resulting phenomena have been recorded in history and as archaeological evidence (Figure 5).

These factors all follow chaotic behavior as a superposition of diverse and discontinuous periodicities.

Cultural phases in archaeology

The various cultural phases can last from a few decades to hundreds and thousands of years, as past world cultures have shown. The sparse dispersion of social groups limits interactions A and B in contrast to the dense distribution of centers, mainly of homogeneous cohabitation (nomads, permanent/semi-permanent settlements, cities) (Figure 6). For different cultures in the world, in the past 12,000 years, one can notice the different duration of the cultural phases and the transitional time markers on account of the interpretation of the theory of chaos[i]. A rational interpretation for the past 12,000 years (the end of last glacial in our World) is given below using the archaeological and climatic terminology, with brief extrapolation to Palaeolithic period.

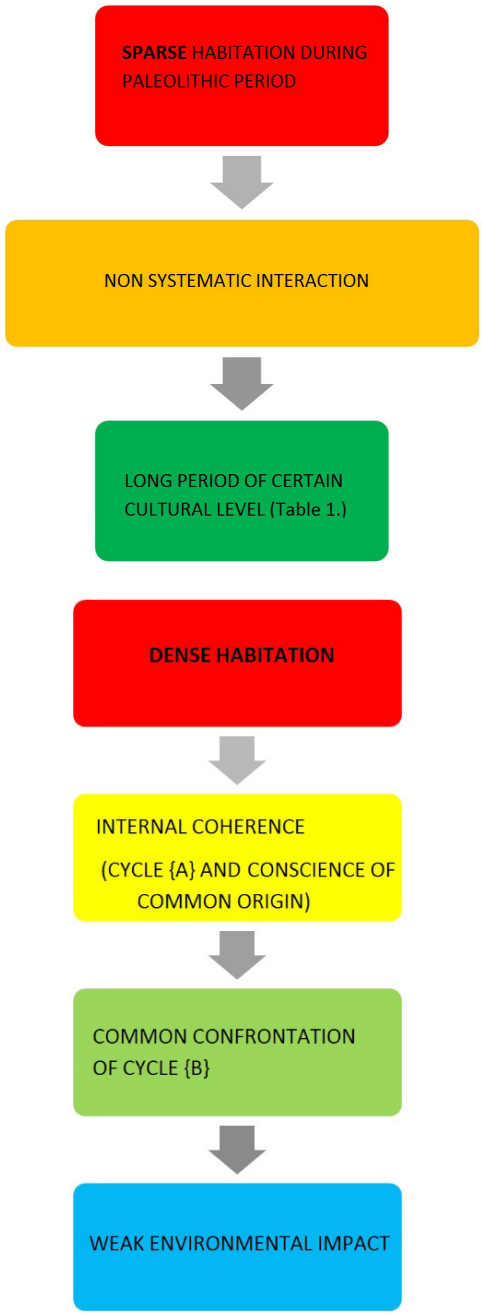

Figure 6. Sparse and dense habitation interprets interactions between human cultural systems A and B.

Indeed, the hunter-gatherer, under the effect of circle C of climatic change, the onset of the interglacial ~10,000 BC and the ice melt due to high temperature levels and low drought, was driven to the food-production stage (farming, agriculture, 7th-8th millennium BC) with more stable communities and settling outside caves, as well as, with increased loose interaction: it was the Neolithic period.

However, population grows exponentially whereas food supply increases in a linear fashion (Figure 7).

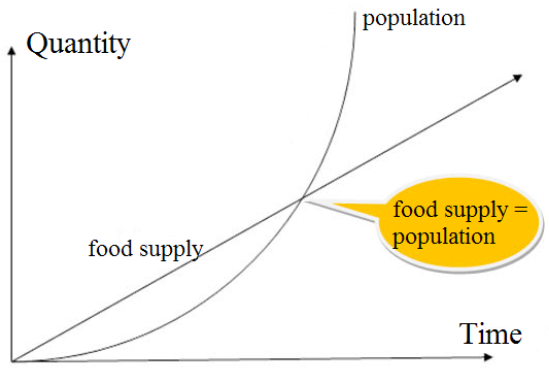

Figure 7. Population grows exponentially whereas food supply increases in a linear fashion.

Hence, at any given time on, search for food may lead to inevitable disturbances in circle A or explorations and conflicts between circles A and B (Figure 8).

Figure 8. Interaction of cultural systems A and B.

The institutions of a society (such as, farming, fishing, workshops, religion) are energy release structures created far from equilibrium and in order to remain intact they require energy release (dissipative structures), which may emerge and stay in a particular interval of threshold conditions These structures-guilds of circle A may emerge and remain for a given time at the threshold of a next stage. It is about certain focal points, the strange attractors[ii], in a hierarchical structure, which are formed evolutionarily from a certain point to these focal points (17). They represent metastable equilibria of specific transitional phases or an excess of the threshold conditions which lead to the metastable phases at a next cultural stage (Figure 9).

In the last 12,000 years, the major transitional periods of early human history (transformation of hunting to farming, transition from food gathering to food production stage, and of farmer to citizen) may not be considered as cultural phases of linear progress, instead the overpass of critical non linear limits (branching). The large climatological changes which had already started from the 10th millennium BC (the onset of last interglacial period, or the Holocene) were these that lead humans from the food gathering to the food production stage. Temperature increased and the drought of last glacial period was reduced considerably. Both climatologic events helped exit from caves which till then were the main type of habitation. The permanent settling near the lakes, rivers and valleys favored farming and pastoralism. The better climatologic conditions lead humans to leave the uncertainty of nomadic settling and food gathering stage preferring a "quieter" and safer way of life.

Specifically, the first groups (nomads, societies) of hunters in the Paleolithic epoch lived far apart and ethnographic research have indicated distances up to some hundreds of kilometers (18). The climate during the Paleolithic consisted of a set of glacial and interglacial periods in which the climate periodically fluctuated between warm and cool temperatures and landforms and coastal lines have markedly altered from sea level fluctuations. Consequently any interaction from contact was rare and certainly non systematic. Such a fact could explain the "great duration"of this cultural phase compared to the following periods and the resulted relative "steadiness" of human societies and culture, in general (Paleolithic in fact covers the largest part of prehistory, c. 2.6 mil. years to 10,000 years). At any rate, during upper Paleolithic period exceptional isolated (cultural) outbreaks may have occurred.

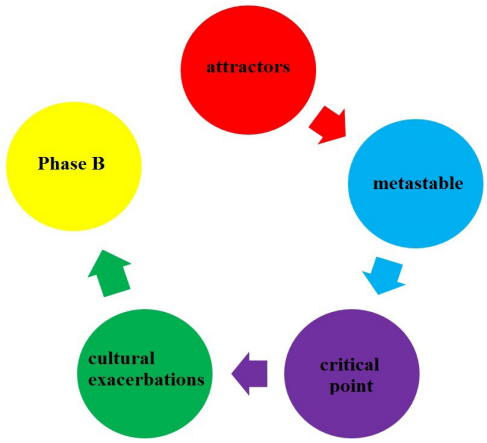

Figure 9. Attractors, metastable equilibria of specific transitional phases, passing over of a critical point, and cultural exacerbations leading to the next cultural stage B. A successive interaction on a schematic view.

Later time, in Neolithic villages, the institution of farming changed from dry farming to irrigation when the food supply was no longer secured by the established social structures. The transition from lithic to metal implements was imposed by the increased need for hard tool-making materials. Indeed, when humans started wheat cultivation

and animal domestication, the interaction between humans with fauna and flora (animals and plants) created permanent communities, humanity became more "fluid" or gathered in groups, which were interacted more frequently although loosen. This is the Neolithic period in the Mediterranean which Child named as "neolithic revolution". (neolithic agricultural revolution 8th-7th millennia BC). However, circle A in interaction with circle B in the Neolithic period contributed to permanent habitation schemes and population growth, as well as, food assurance, which in turn resulted in new life-improving, production, and security techniques in addition to the development of pottery, weaving, preliminary metalworking, to later manufacture of tools and social structure in settlements.

But, the decline, centralization, and decentralization of an urban system follow complex nonlinear dynamics (13). The spatial-temporal structure of this system is the result of the instability of successive equilibria caused by nonlinear phase transitions, more like a living organism. Therefore, loosen interactions between A and B (e.g., hostile attacks) resulting from the new development along with the impact of exogenous factors of C (e.g., drastic climatological changes, major changes in sea level, rainfall increase, alternated drought and humid periods, earthquakes and sea level rise, commentary impacts) led to new needs and equilibria. All those reasons conduced to a non linear evolutionary trend during Neolithic period and either they declined or abandoned. The order is no longer there and social upsetting predominates. Characteristic difference between order and chaos is the presence of feedback in chaos. During 7000–3000 BC the Holocene Climate Optimum occurred. This Climate Optimum warm event consisted of increases of up to 4°C near the North Pole, and while the northwest of Europe experienced warming, there was cooling in the south (23). This has culminated in Early Bronze Age metallurgy and stone tools improvement, thus launching the social group classification process, namely the Bronze Age (19). People turned to exploitation of natural resources namely, metal ores—gold, copper, silver, and various stone types e.g., obsidian, traveling long distances and crossed the seas, and were pushed to the production of best tools that would make everyday life easier, for cultivation and safety of their settlements. Order has been seemingly established in these societies with predominance of a focal point (e.g., the Early Bell-Beaker Culture, Indus valley civilization with the matured Harappan culture, the Minoan Crete, Egypian Old Kingdom, Middle East). Yet, the loosening of interactions and some relatively slowness in the assimilation of new social transformations and conditions, as well as, exogenous factors (invasions and/ or environmental effects; see, circle B or C above) lead to a relative cultural stagnation, evidenced also from the, so far, small number of sites, attributed to Middle Bronze Age. Here two separate cataclysmic events are also quoted too, one around 2350 BC and the other 2200 BC, where the former is considered as local, an Anatolian event, from the Aegean to the Caspian, and the latter event as global, as seen by the evidence from Iberia to China (20). Moreover, mythological deluges are worth referring to local mythologies speaks of flood events, (e.g., Ogyges, Deucalion, Atrahasis, Gilgames (the precursor for the Noachian flood) are thought to have happened in the first part of the third millennium BC (20,21)).

The movement of people in spite the free space at its disposable they go about a small but the same space (more like Lorentz' attractor[ii]).

Later on, the cultural stage of "stagnation", but obvious assimilation, the agricultural production became so intense leading to surplus which was gathered, stored and distributed. Then the central power imposed a commensurate network of civil laws and codes. For first time the work amongst the producers and consumers becomes discernible and specialization evident. This new period is the Late Bronze Age and the appearance of local cultures (e.g., Mycenaean civilization, Late Harappan in Indus valley). Agricultural production becomes more evident (large storage rooms in palaces), central power controlled production and goods re-distribution. The Mycenaean palaces (city-states), for example, were autonomous physical, socio-economic and cultural entities dispersed within the Hellenic landscapes, with their city-centre, the rural and peri-urban space, the acropolis and the sanctuaries, the established political alliances and the commercial network with neighboring and distant regions. Such a civilized level rectified trade exchanges, work became more discernible and this led to social stratification.

Again the drastic (fatal) interactions and environmental causes (volcanic eruption, invasions, climatological changes, etc.), led to decline of these major civilizations (22). However, the basic stable states (attractors) had already been established that is, the food production stage, techniques, knowledge, writing, social structure, permanent installation, trade exchange. Simply during time these structures occasionally fed related often periodically repeated actions of different types. Such

prehistoric cultural processes continued for the humanity passing on to the historical period.

Indeed, these variously imposed factors led to another transitional phase of "cultural blunder" when decline is apparent in art and techniques. This is the Dark Ages period (from about 1100 to 850 BC the beginning of so called Geometrical period in southern Balkans, the Hallstatt culture predominant in Central European culture developed from the previous Urnfield culture of the 12th century BC, and the followed in much of Central Europe by the La Tène culture).

Then the Geometrical and Archaic period follows Dark Ages. The 1st Millennium BC coincided with the Mediterranean maritime trade and colonization activities. Most parts of the period was characterized by an unusually cold climate in the North Atlantic region, with no more sea-level rise (23). The palaeoecological and geological evidence indicates that climate changed from relatively warm and continental to oceanic in NW Europe. The extension of fens and bogs, as well as the emergence of salt marshes, caused loss of cultivated land and led to migration from these low-lying areas, which had become marginal for occupation. Evidence for a synchronous climatic change in Europe and on other continents around that period has been produced. This period is also characterized by temporary aridity in tropical regions and a reduced transport of warmth to the temperate climate regions by atmospheric and/or oceanic circulation systems (24).

This Dark Age period culminated in the known Hellenic Classical period the most developed and ripen cultural phase of ancient times. (5th-4th c. BC). The period of stagnancy and "medieval antiquity" is over, new techniques, ideas, methods of experimentation, construction and observation were developed, aided from the exploration and colonization of surrounding lands. The introduction of writing led to the development of poetry, historiography and sciences in general. Humanity has conquered the necessary knowledge that secured food, living and surviving, and naturally turned to the development of himself and his personality expressed amongst others via the art. Even ceramics and architecture took the shape of art. People begun to express their sentiments through art. The classical period is the zenith of political and cultural evolution. The freedom of expression led to release of thought and art and to the development of a great civilization, an acme that marks the most essential time in ancient humanity and formed the foundations of later western civilization.

The weakening of the dominance of Athens, however, was caused, amongst others (internal collisions of circle A and intensive reactions of circle B), by fatal diseases (plagues, etc.), too. To this extend, a clear distinction is alerted: chaotic states cannot generally be identified with epidemics, while regular states do not always represent health. But epidemics is a considerable agent that declines a society. It was not until for example the 415 BC, that the Athenian population had recovered sufficiently to mount the disastrous Sicilian Expedition. These viruses are closely related to wetter and warmer climatic phases, to the expansion of marshes, and finally, to the global hydroclimatic cycles. During the 4th century BC, the prolonged dry spells and drought affected severely the Athenian power. A great number of water wells has been recorded from archaeological excavations and surveys used by 400 BC (25,26). Especially, the prolonged drought between 350 to 325 BC, a recurrent phenomenon since the late 8th century BC, shocked Eastern Mediterranean. Moreover, a larger number of drought periods during the last 7 millennia, have been identified in the Aegean based on archaeological tree-ring data (27,28,29). The intense interactions between A and B (city-states polemic status, invasions, irreversible expansions) as well as climatic impact (variable factor C), lead this and the immediately followed Hellenistic era to a decline at the expense of the emergence of Roman Era. Similar scale phenomena were observed in Latin American and Chinese cultures too.

Beyond these happenings in the southern Balkan and SE Mediterranean region the cultural phases of World societies do not coincide; instead there appears either a considerable or short time lag or a parallel development. The former differentiates between progressed and backward societies, and the latter implies a cultural interaction by exchange of goods, mineral resources, artifacts, but also transfer of expertise, deities and ideas.

Upon the social upheavals, reorganization, order and disorder, occurred between A and B systems (Figs. 1 and 2), these marked cultural changes consider also the 3rd factor- the environmental forces in general- speaking of the major transitional climatic changes, and their imposition to coincident cultural phases. For example, in the southeastern Mediterranean region the witnessed changes in human culture of the highest importance between ~7000 and ~500 BC. Over the same time period this region was affected by very significant shifts in climate. Stable isotope data from lake and deep-sea sediment cores and from cave speleothems show an overall trend from a wetter to a

drier climate during the mid Holocene. Superimposed on this trend were multi-centennial oscillations in climate, with notable arid phases occurring around 3300–3000 BC, 2500–1900 BC, and 1100–800 BC (all ages derive from calibrated/calendar years). These phases coincide with major archaeological transitions across the eastern Mediterranean region such as the Chalcolithic/ Late Neolithic to Early Bronze Age (EBA), EBA to MBA, and LBA to Iron Age, implying that environmental stress or opportunity may have acted as a pacemaker for cultural change and re-organization (30).

Transitional cultural phase

Sporadically, within a cultural phase, paths may be linear but can gradually reach local outbursts and saturation, and proceed to the threshold of the next phase, which is established by complex fluctuations of the three interacting domains and the internal strange attractors of circle A (Figure 10).

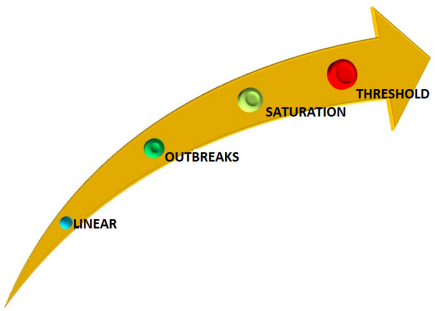

Figure 10. Trend of a cultural system towards a new state.

Therefore, the evolution of human societies (and human history in general) can be shown not to follow a linear trend, which on a steady state results to a "cultural hallmark", where Y increases as a function of time, T, where T= time scale, distance from equilibrium, Y = concentration/cultural level.

But evolution is based primarily on mutual interactions of different components f (t_i), at variable time interval (t_i= t_0 to t_1) derived from the three factors (Figure 1). Therefore, the cumulative result could be expressed as:

$$Y(t_i) = \int_{t0}^{t1} f(t_i)d(t) \qquad (2).$$

The parametrization of mathematical expressions is not an easy task and one has to define quantitatively the attributes that define cultural level per time.

The flow of the overall evolution of a system, e.g., a homogeneous population, follows irreversible processes[2]. Thus, in times of equilibrium for a homogeneous social group (inner circle) transition from one state (K1) to a next one (K3) because of the impact of the other circles, the external and the environmental, goes through an intermediary stage (K2) where transitions (K1)….→ (K2) = transitions (K2)… → (K1) and (K2)…→ (K3) = (K3)…. → (K2)…. →…, are the so-called detailed balance (Graham and Haken, 1971). Then the ratio (K1)/(K3) = ε, corresponds to the maximum entropy.[iii]

If we consider open the system[iv] from the homogeneous social group with different dynamic effects from the 2nd and 3rd circle, then for every given state a and c there are many possible states for the intermediate phase b. Among these, however, only one corresponds to the state of thermodynamic equilibrium and maximum entropy. This particular state can expand far from equilibrium in thermodynamics.

The energy change over time in a culture is reflected in the change of entropy dS = dSs + dSi + dSp, where dSs describes the transport through the boundaries of social systems, dSi the entropy generated within the social system, and dSp the entropy (of this social system) with the environment (+ or – depending on the type of exchange). The 2nd law of thermodynamics[v] certifies that dS > 0 (dS=0 applies for equilibrium). In cultural evolution the entropy production rate dS/dt is of interest, in conjunction with the rates and forces of various irreversible processes (wars, floods, earthquakes, fires, pollution, epidemics, migration, trades, invasions and raids, etc.).

The structure and function of a social group (nomad, city, nation…) are inextricably linked. But how does the structure of a culture emerge in conditions of non-equilibrium, sustained in a given mild interaction energy? Stability is the crucial point here, which is, however, interpreted by is free energy, F= E – TS, where E = energy, S= entropy. F minimizes in equilibrium in a way that even outliers in entropy and free energy ensure that cultural disturbances or fluctuations have no impact on its equilibrium. Historical periods of such stability are reported at Mycenae in Mycenaean civilization and in Athens at the Age of Pericles, and similarly in Middle East and elsewhere, where the retention period for such new states leading to a centre of culture and development ranges from a few decades to 500 years.

The existence of change phases of a social group expresses an emergent collective property that cannot be described in terms of individual trajectories. This collectivity involves coordination between the degrees of freedom of a specified social system.

Discussion

In the framework of complex systems, social/cultural dynamics is perceived in terms of transitional phase systems, release structures, exchange processes of material, energy and information with the environment, initial conditions and intrinsic or extrinsic fluctuations, branching points, strange attractors, steady and unsteady states, convergent/divergent trajectories (= paths), as a function of time, with neighboring cultures or intrinsic metastable phases.

For example, agriculture involves developing the ability to increase the prey birthrate. Thus, human population increases and can be stabilized at a certain equilibrium. For instance the long period of Early Greek Neolithic c.700 years, followed by Middle Neolithic of c.500-1000 years and Late Neolithic c.700 years. It seems that increasing complexity is the hallmark of evolution in general.

Therefore, in the interpretation of the cultural remnants, if time is specified, the cultural event that has not yet been marked out may be approached without doubt through the system of the triple concentric circles and the chaotic dynamics of individual components. The technological and social developments in given settlements that differ from others (intentionality of consciousness + individual activity + collective consciousness + matter and energy from the surrounding environment), as well as, the unpredictable external interactions and environmental effects, offer a non-linear interpretation of the time-space and events that mark the cultural phases, the course of these settlements and global cultures in general.

Human is by nature a being of "opportune moment" (10), since his energy is conscripted so that he may impose upon the world and transcend his position by exploiting the possibilities the world has to offer. The concept of time is defined as a discontinuity in a temporal continuity and requires the recognition or creation of similar discontinuity from the intentionality of human consciousness. Therefore, intentionality of consciousness enables the rebuilding of time by classifying the three static categories (before—during—after) into two classes of time: that of not yet and that of no longer, which are principally dynamic. Thus, investigation of the attainable by man is conscious and consistent with temporal and spatiotemporal categories.

The above reassert socio-culture(s) that can be defined, described and analysed in accordance with systems mechanics and through an holistic approach. These are supported e.g., by Bertanlanffy and Weisacker's works, though both are rooted back to pre-Socratic and Platonic ideas.

In particular complex systems theory finds some of its earliest roots in the work of von Bertalanffy (4) who observed that the same equations appeared in many different disciplines. He proposed a logico-mathematical discipline, "general systems theory" to understand the laws governing a "system" at a general level. In reality though, a theory has little value outside of the context of study and von Bertalanffy took his level of theorising one step too far in the abstract direction towards studying Platonic "spheres" rather than Aristotelian reality. It is not until later (31) that we find a workable definition of the notion of a "complex system" as made up of parts which interact in a non-simple manner. Complex systems science therefore, offers explanations of the patterns of systemic interactions at any given time and how these evolve between different states of the system.

In modern times, systems science has been invigorated by the application of network theory and has become prevalent in such diverse fields as physics, mathematics, biology and sociology *inter alia* (32).

Scientists in this new field started with thinkers, such as von Bertalanffy and Simon, and expanded upon them hugely using graph theory to characterize and understand the topology of the system and its evolution, something earlier thinkers had struggled with. In this style, a complex system can be described as a set of nodes and a set of connections between them which facilitate interactions (33).

Recording von Bertanlanffy, "...you cannot sum up the behavior of the whole from the isolated parts, and you have to take into account the relations between the various sub-ordinate systems which are super-ordinated to them in order to understand the behavior of the parts" (5). The "atomistic" approach was particularly unsatisfactory in biology. An organism was a complex whole or a system. Consequently von Bertalanffy decided to seek solution for the enigma of living organisms in a holistic philoso-

phy. On similar grounds has moved Wezsacker especially with his works especially the unity of nature (34).

Without diving into the complexity theory the fundamental premises of the theory of chaos to archaeology presented above, it is operative to maintain that cultural evolution consists of an established construct of systems-in—systems mechanisms that are functional from the sub-cellular to the supra-sociocultural levels, that operate both linearly (under aberrant and/or dysfunctional states) and non-linearly (under "functional" and adaptive states) in accordance with complexity dynamics (that engage chaotic and quasi-chaotic characteristics).

Space-time is significantly chaotic. The phenotype of inhabitants of a region in terms of behavior and way of thinking, is a reflection of the non-linear dynamic environment in which they live. Populational temperament is therefore driven by such chaotics, and these factors have been imprinted as a similarly chaotic network into a populations gene pool(s) and phenotypic expression(s) (6).

Conclusion

The hermeneutics of cultural evolution overviewed with archaeological terms basically is founded upon the theory of complexity.

The last 12,000 years in various world cultural systems, often at different time, the basic stable states (attractors) have already been established that is, the food production stage, techniques, knowledge, writing, social structure, permanent installation, trade exchange. Simply during time these structures occasionally fed related often periodically repeated actions of different types. Prehistoric cultural processes continued for the humanity passing on to the historical period.

In our analysis we looked at the material and energy interactions through human populations of last 12,000 years. In other words, human history and prehistory did not follow straight line, considering the civilized societies as the far end target of humanity, but instead in every cladding, alternative steady states were possible, which by the time they were activated they coexisted and interacted one with another. The changes from one status to another depended upon the three types of impact, the type of human society, the consumption of energy, the intensity of interactions and environmental agents (of terrestrial and astronomical nature), as evidenced from the recent and remote past human and environmental remains.

Certainly, cultural changes, which occur in a non-linear, but variable and hallmarked degree, cannot be attributed alone to a single factor. Their occurrence is an interconnected and multi-factorial problem whose initial conditions and limitations are unknown. There seems to be limited chaotic oscillations protecting the society acting as "organism" from a dangerous inflexibility. The presented cases are ample to stress the naturalistic methodology, which serves as the basis of a synoptic and synthetic philosophy that involves art and science corresponding to classical *techne* and *logos*. Nature is seemingly discontineous but apparently there exists a network of variable systems that activates and self-organizes on a universal analogous law—a correspondance principle between micro and macro systems. In this case the ancient artifacts and relics of socio-culture reflect the dynamic interaction of humans themselves and the environment (with its broader, geographical, sense), and any attempt to interpret the cultural evolution trajectory, and the survived remains, by interpolation and/or extrapolation, needs to account the tools derived from an applied epistemology.

We may recall Herbert Spencer's thesis that relates science and philosophy where the latter is seen as a synthesis of the fundamental principles of the special sciences, a sort of scientific summa to replace the theological systems of the Middle Ages. Spencer, for example, thought of unification in terms of development, and his whole scheme was in fact suggested to him by the evolution of biological species that gave metaphysical support to the liberal principle of variety, according to which a differentiated and developing society is preferable to a monotonous and static one.

Disclaimer

All claims herein made are the responsibility of the author.

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Competing interests

The author declares to have no competing interests.

Footnotes

i. Chaos theory is a field of study in mathematics, with applications in several disciplines including physics, engineering, economics, biology, and philosophy. It deals with the behavior of dynamical systems that are highly sensitive to initial conditions, an effect which is popularly referred to as the butterfly effect. Small differences in initial conditions (such as those due to rounding errors in numerical computation, the neighboring relationship between settlements, non-perceptible seismic tremors, initial cloudness) yield widely diverging outcomes for such dynamical systems, rendering long-term prediction impossible, in general (35). This happens even though these systems are deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved. In other words, the deterministic nature of these systems does not make them predictable. This behavior is known as deterministic chaos, or simply chaos (36).

ii. An attractor is a set towards which a variable, moving according to the dictates of a dynamical system, evolves over time. That is, points that get close enough to the attractor remain close even if slightly disturbed. The evolving variable may be represented algebraically as an n-dimensional vector. If the evolving variable is two- or three-dimensional, the attractor of the dynamic process can be represented geometrically in two or three dimensions. An attractor can be a point, a finite set of points, a curve, a manifold, or even a complicated set with a fractal (non-integer) structure known as a strange attractor. It derived from the attractor that resulted from a series of bifurcations of a system describing fluid flow. Describing the attractors of chaotic dynamical systems has been one of the achievements of chaos theory. A trajectory of the dynamical system in the attractor does not have to satisfy any special constraints except for remaining on the attractor. The trajectory may be periodic or chaotic. The Lorenz attractor is a strange attractor that arises in a system of equations describing the 2-dimensional flow of fluid of uniform depth, with an imposed vertical temperature difference.

iii. Entropy is the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work. Perhaps the most familiar manifestation of entropy is that, following the laws of thermodynamics, entropy of a closed system always increases and in heat transfer situations, heat energy is transferred from higher temperature components to lower temperature components. These processes reduce the state of order of the initial systems, and therefore entropy is an expression of disorder or randomness. In thermally isolated systems, entropy runs in one direction only (it is not a reversible process). There are two definitions for entropy; the thermodynamic and the statistical mechanics.

iv. An open system is a physical system which can exchange both matter and energy. This can be contrasted with the isolated system without any external exchange—neither matter nor energy can enter or exit, but can only move around inside, and with a closed system, which can exchange energy with its surroundings but not matter.

v. The second law of thermodynamics states that the disorder (entropy) of an isolated system (in contrast to a closed system that could be a remote society group) always increases or remains constant. As the disorder in the universe increases, the energy is transformed into less usable forms. Thus, the efficiency of any process will always be less than 100%. On the other hand, the first law of thermodynamics, also called conservation of energy, states that the total amount of energy in the universe is constant. This means that all of the energy has to end up somewhere, either in the original form or in a different from.

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