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A Physics for Civilization

Arthus S. Iberall

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Editor's Note: The following paper, retrieved from the archives at Dickinson College, was presented at a session on the economic origins of civilizations and on the death of civilizations, at the 1980 Annual Conference of the International Society for the Comparative Study of Civilizations, held at Syracuse University, in May 1980.

A highly accomplished polymath, Arthur Iberall (1918-2002) served as an executive board member of the ISCSC as well as a long-time member and a distinguished participant in the ISCSC annual meetings. He was an expert on complex systems thinking.

Many discussions over the years were punctuated by his vigorous debating style and brilliant, insightful assertions. Few claims were spared in these intellectual thrusts. For example, I recall his arguing very persuasively, with data – and against others – about the direction in which the South Pacific and South America actually were settled by humans.

According to biographical material online, he held three patents, gave four U.S. Congressional briefings, and was awarded an honorary Doctor of Science degree by Ohio State University in recognition of his interdisciplinary scientific research. He published eight books, 95 peer-reviewed articles, and 49 scientific conference extended abstracts.

Wikipedia sums up his intellectual contributions by reporting that he "was an American physicist/ hydrodynamicist and engineer who pioneered homeokinetics, the physics of complex, self-organizing systems. He was the originator of the concept of lines of non-extension on the human body which was used to create workable space suits."

Arthur Iberall

Thus, it is no surprise that an obituary online reports that "Dr. Iberall was honored at the *1998 Homeokinetics Conference* at the University of Connecticut in Storrs, Connecticut where hundreds of his colleagues joined together to show how the application of homeokinetic principles explains the functioning of complex systems, in contrast to chaotic theory that has no physical basis."

During his career, Dr. Iberall was a consultant to NASA, the Department of Transportation, the Army Research Office, as well as the Navy and the Air Force. His applied research was carried out at the National Bureau of Standards (1941-53), Rand, and other scientific organizations and major academic institutions. He is credited with having contributed significantly to the development of the first space suit, the high-speed dental drill, breathing regulators, fiberglass cutters, and major home appliances such as stove surface burners, the electric knife, and fancy-stitch sewing machines.

A fundraising drive to create a Distinguished Annual Lecture series in his honor at the Center for the Ecological Study of Perception and Action at the University of Connecticut stated:

> Arthur Iberall had a vision in which he incorporated the questions that all of us asked – How do complex systems really work? Can physics be applied to real world problems? Is there a logic to running our society? How do human systems actually work? Where are all the thermodynamic engines and oscillators in the body and how do they interact? What physical and chemical data really need to be collected to do tasks such as design drugs that incorporate a homeokinetic perspective? What are the catalytic messaging units in the neuronal language?

On the topic of comparative civilizations, he used physics to explain the emergence of settled civilizations. He described a pattern based on stability transition, a process similar to that of matter condensation. First came a "condensation" to fixed settlements, and this was followed by a transition to urban civilization, he argued.

Among the eight books he published was one co-authored with David Wilkinson and Don White entitled *Foundations for Social and Biological Evolution.* The book examines how mankind populated the Earth (including its laws of growth), how settlement in place and urbanization occurred, the commonality of cultural and civilizational evolution over the entire Earth for the past 15,000 years, and the processes which have undergirded it all.

Clearly, the paper he gave at Syracuse for the ISCSC meeting broke new ground and expanded considerably the research map upon which scholars of comparative civilizations may pursue further understanding of the discipline and its parameters.

A Physics for Civilization

I. The General Construct (1,2)

1. We are concerned with fluid-like systems, in which the atomistic participants are involved in movement relative to each other. (There is a very comparable physics which can be developed for solid state-like systems, but it will not be our present concern.)
2. In a system of such atomistic participants, the physics of motion and change for the ensemble of participants is tracked by means of those quantities which are conserved upon interactions between the participants (3).
3. In a simple system, there are three quantities which are conserved upon interaction – mass (the quantity of matter), energy, and momentum (the product of mass and velocity).
4. In a complex system, processes emerge which are long time delayed compared to the interactional time (e.g., time between collisions). They emerge because long time delayed complex processes are involved in the atomistic interiors. These long-time delayed processes modify the basic conservations in the following way:

   a. Chemical change may emerge, as atomisms are transformed. This appearance of new forms requires a statement of conservations for each individual mass species that may emerge atomistically.
   b. In the case of living systems, in which a complex chemical reproductive process involving birth, growth, life, death, and dissolution may take place, one distinguishes between the conservations of mass species and the conservation of population number. The new interactional conservation is contained in the statement that generation begets generation. That lengthens the total effective interactional time to the generation time.
   c. The physical conservation of momentum transfer between participants is modified. Instead of the relevant time scale for transfer being the interaction time (known technically in physical science as the *collision* or *relaxation* time), it is the time scale over which all internal processes within the interiors of the atomistic participants complete a cycle and reach an equilibrium. e denote this time scale as the *factory day* of the atomism. It is not only characteristic of living systems, but of all complex atomistic systems which conduct a great deal of action internally.

Such interior actions are not immune from physical law. It is just that a great deal of time-delayed fluid and chemical processes take place among another hierarchical nesting of smaller atomistic participants (e.g., cells in the living organism, or molecular clusters in the living cell).

However, over the factory day, instead of movement and change solely by external momentum, what emerges is a matrix of action modes, those characteristic actions which the atomistic participants perform:

- For living systems, they are psychological actions, partially internalized, partially externalized, as well as physiological actions.
- For mammals, they number perhaps nine; for humans perhaps 20.
- For long-lived species, most of the action modes are discharged over the geophysical day (for the individual, not the species).

Thus, there is a social physics possible for a social group of such individuals from the daily scale on up. Since the human is tied to a complex ecological web, action is more nearly complete in a societal physics for the geophysical scale of the year.

But if the conservation of population is to be invoked as a constraining conservation for the species (when the species is the *ensemble*, rather than a group), the social physics at the generation time is the first minimum scale for physical equilibrium for the species. Note at this scale, the individual's actions are hardly to be detected anymore. Instead, the historical process, stripped of individuals, emerges.

5. The science of ensemble physics relates to -- and only to -- the quantities that are conserved upon interactions. Thus, individual-to-individual interactions are described by kinetics relating to these conservations. Motion and change in an atomistic ensemble are described by summing up these kinetic interactions, within a statistical mechanics, to produce a continuum-like thermodynamic description of the ensemble's motion.

   That continuum-like description has three facets, all relating to the conservations.

   First, as a result of continuing interactions throughout the ensemble of atomistic participants, the conserved quantities are partitioned (shared) among all the participants to produce what is known as the <u>statistical distribution functions</u> of the ensemble. These are statements about how matter (density), momentum (or action) and energy (e.g., kinetic energy) are each distributed throughout the space (or in any local region).

   Second, the statistical measures of these three conservations are related. These related measures form the <u>equation of state</u> of the ensemble. That equation expresses how ensemble average measures (macroscopic variables) of the essential conservations are related.

Such an equation holds both if the entire ensemble, in all of its regional extent, are contiguously in equilibrium, or only near equilibrium. (At equilibrium, for example, they will share the same kinetic energy measure and momentum measure.)

Third, if the ensemble is only near equilibrium, then there will be <u>equations of change</u> which will express fluxes (flows) and transports or diffusions of the conserved variables between regions of the field.

6. These equation sets, <u>equation of state</u>, <u>equations of change</u>, the existence of underlying atomistic participants, and boundary conditions that are constraints put on the field, complete the construct of physics for field ensembles. The boundary conditions generally are potentials (*storage bins*) from which sources for the various conservations may be drawn.

7. These two sets of equations are applied to a field, e.g., a social field, in the following sense:
   - First, having identified the basic atomisms (e.g., molecules, or in this case people), there is a minimum space and time scale at which such near continuum descriptions hold. For example, one certainly aggregates atomistic performance over the earth's day rather than being concerned with momentary postures of the individual (the action mode matrix is largely completed in a day). And one aggregates over the local community in which daily activities are performed.
   - Second, there is a maximum space and time scale for which the field results are intended. For example, if civilizations and Man's evolutionary history of civilizations are of concern, then the time scale likely has to be as extensive as Man's 40,000-year history, and the entire continental surface of the earth becomes the spatial field.
   - Thus, the range: a day to 40,000 years, a few acres to the earth's land surface, defines the bounds of concern. Within those bounds, there will be an extensive spectrum of effects. Given external large-scale causality for such spectral domains, the equation sets can be conceptually or actually applied to those domains.

The following temporal domains furnish natural divisions in the social process:

- <u>The social process of the day</u> (dominated by earth's day-night rotational variation, it is marked within the chemical encoding of most biological organisms).

- The social process of the year (dominated by the seasonal variation, the ecological web by which all higher species depend for material and energy supply is entrained in that periodic process).
- The social process of the generation (each species has a generation time scale, associated with its chemical genetic code).
- The social process of the life span (the life span, differing from the generation time or the life expectancy, e.g., 90 years for humans, marks a period over which the likelihood of any survivors on the social scene is essentially negligible. All social continuity then has to depend upon some form of information and memory transmission). These scales are clearly physically – chemically – biologically determined, ones over which the atomistic species has no control. They are exogenous to the social field process. The same is true for the following scales, but the theory and database are more controversial or speculative.
- The social process associated with a cultural life span. We would argue that this is of the order of 500 years. It is the scale at which a small isolate culture can maintain coherence, i.e., the scale of which it can retain a founder figure myth and transmit its cultural epigenetic (ed.- relating to or arising from nongenetic influences on gene expression) heritage generation to generation without an extensive recorded abstract language.

We made an *a priori* estimate of the number of generations (about twenty) for which reliable information transmission might be expected. Then we found confirmation of that estimate in Murdock's Ethnographic Atlas, which suggests that cultural independence exists for a small group if it has been separated either a few hundred miles or a thousand years from neighboring groups.

The fact that comparative civilizationalists (e.g., Mencius's estimate, and more modern estimates, such as Blegen's dissection of the levels of Troy, or Melko's estimates) typically identify a scale of about 300 – 500 years for civilization even in complex social systems, is added evidence for the intrinsic nature of the information transmission process time scale.

What the numerical result implies is that there is a great deal of linear independence in the cultural process, in which it remains coherent and only diffuses slowly with such long-time constants even in the presence of other groups in a coupled interacting ecumene.

Ethnicity, for example, simply does not disappear in a few generations.

- Even more speculative is a time scale of the order of a few millennia. Over this scale, as the process time for a number of "independent" cultural waves to cross a large land mass (diffusional time scales are of the order of one mile per year; thus, in a few thousand years, the chance of a number of diffusions and refractions to have taken place increases), one may expect reformations of social strategies, changes in the character of the epigenetic value potential, to have taken place.

  Such a process scale would not exist among stimulus-bound animals, nor even the higher primates. One would have to associate it with the extra interneuronal capacity that developed with Pleistocene cortical evolution, and likely with the increased unstabilizing lateralization in the human brain (4).

The appearance of the extensive epigenetic value potential in the human brain makes that brain more unstable, not so tightly bound in its decision making. This is associated with the characteristics usually identified as "free will."

Nevertheless, a successful system's life, in a physical sense, must have a program for persistence of action, for survival. If it is not preprogrammed, that program has to consist of a strategy. In time the strategy (human strategy) may become stereotyped (Aristotle illustrates a first effort to count the types of political systems), but it has not yet become so.

Thus, one may seek a scale, an intellectual scale, at which strategies are reformed. Obviously, the individual and the individual culture are engaged constantly in defining such a process. But is there a supra-cultural time scale?

We suggest that such change occurs at the few millennia time scale. Why? It is a property of nonlinear decision making.

McCulloch, for example, illustrated why the briefest reaction moment of the individual organism is made up of about three response units, e.g., 0.1 second to determine position, 0.1 second to determine velocity, and 0.1 second to determine acceleration.

Or another example – it has been shown that business activity has a fluctuation time scale of the order of three years. (See, for example, Dewey Cycles.) One can conjecture that investment and business activity decisions require a minimum observation of the yearly balance, but that – as before – 3 to 4 units of independent binary decision units (e.g., yes-no) have to pass before a decision can be entrained by the nonlinear discrete brain process.

When it comes to social change, through cultures, an ecumene cannot change its outlook until a number of cultural changes have been observed. In any case, we realize that these longer scales may very well be speculative.

However, the equation sets would apply to each spectral domain, starting from the shortest scale unit and integrating (or aggregating) up to the next unit scale.

Summarizing, as applied to living systems, the following conservations are involved in making up relevant equation sets:

- energy flow (e.g., the daily caloric expenditure, roughly 2,000 kcal/day for Man
- matter (loosely speaking, the conservation in the adult of the carbohydrate, fat, protein, minerals, ions, water content of the organism)
- action modes (the *factory day* budget of actions – energy-time product – that are characteristic of the species; e.g., among mammals, such behavior modes are noted (as) ingestive, eliminative, sexual, care-giving, care-soliciting, conflict, imitative, shelter-seeking, investigatory behavior; in humans, perhaps twenty modes are noted)
- population (for systems that grow, live, and die, conservation of the species requires that invariably generation begets generation)

The following potentials (*storage bins*) are involved, as boundary conditions:

- temperature (the solar flux, interacting with earth's atmosphere, produces a temperature range that supports life and its ecological web)
- chemical potential (the earth, as substrate and depot, provides both materials, e.g., foodstuffs for building materials, and energy, e.g., foodstuffs that produce energy by chemical reaction)
- genetic potential (an internal chemical potential, carefully carried from generation to generation by germ cells in the form of a specific hereditary molecule DNA)
- geographic potential (the lithosphere, hydrosphere, atmosphere -- are available as substrate and surround to support life processes)
- epigenetic potential (another internal potential, emergent from the command-control system of living organisms, which furnish various competences for action, such as memory; in higher mammals, value systems)

The general character of physical law is largely contained in the statement that potential gradients drive fluxes. This is almost tautological because the potentials are *storage bins* for the flux quantities. The physics becomes interesting in how potentials come into being.

II. The Construct Specialized for Man

Very little has to be added to this construct to extend it to Man, except for some modifications and additions to the conservations and potentials.
First, for example, retreating to Man's Plio-Pleistocene hominid ancestors, one finds an enlargement of their epigenetic potential. They obviously begin to extend their mammalian and primate memory system to where it can be transmitted as an epigenetic heritage from generation to generation.

We surmise that that "freedom" included a growth in value systems as part of the epigenetic heritage. It is fair to say that a new internalized potential emerged within that hominid brain, a technological rate potential. (Tools are found before modern Man's cultures.)

This potential is represented by the capability of each generation to add additional tool making complexity to the epigenetic heritage. The technological capability is likely best measured by the amplification in power-handling capability of the individual.

As far as we can tell, for the period of such tool evolution, e.g., perhaps two or more million years, that technological rate of increase has been linear for Man's hominid ancestors. Each generation (e.g., measured in hundred to thousand generation units) could make an equal increment change in tool complexity.

We base that assertion on crudely estimating the gain in power-handling capability of the various evolutionary tool assemblages that have been identified with the past few million years (e.g., eoliths, hand axes, flakes, microtools).

We assert that the technological rate potential is new and independent of the epigenetic potential because it represents a new form of abstraction, beyond memory transmission, and because an epigenetic heritage can be imagined independent of a changing technology.

However, the social life that emerges for those higher primate hominids hardly differs in general character from that of other higher species, e.g., mammals, primates. One surmises that one major difference, as these pre-prehensile, facile upright species gradually transformed from predominantly frugivore gatherers to omnivore hunter-gatherers, is a band organization of camps with a considerable division of labor, rather than the more common pecking order organization of these other species.

Yet among primate organization, the gross social organization of hominids does not appear to be unusually different (5).

So now we turn to modern Man of the past 40,000 to 50,000 years. Whether the species Homo sapiens (who appeared then) and homo sapiens neanderthalensis (who disappeared at about that time) were members of the same breeding pool, or the same species, is not really known. Some significant anatomical features make them different, and there is a sharp difference in what has been identified with the characteristics of culture.

We take the position that on the criteria of handedness (4), change in speech capability (6), the distinctive change in tool-making that marks middle Paleolithic assemblages, and the appearance of abstract artifacts and symbolic art forms, as well as evidence for magico-religious social practices, such evidence points to association of these characteristics with a new species or breed, the current human species. This new species seems capable of all of performance of current Man, speech at neural rates, abstraction, a much more rapid rate of technological development, in short —human culture.

Thus, we start our boundary conditions from that new species, modern Man, emergent about 40,000 years ago with new tool assemblages and a richer technological potential (a higher rate of change). The species begins as a highly competent hunter-gatherer. Evidence exists that within the subsequent 10,000 - 20,000 years, the species is spread lightly through all continents (7) except possibly the Americas, to which the species cross likely in more than one wave, with few reliable datings earlier than 10,000 to 15,000 years before the present. Its highest latitudes are up into the northern tundra.

The question is why does a discontinuous change in social characteristics of that species take place, wherein it is subsequently found highly precipitated into place and organized into what is called civilization? The only potentials and fluxes available are the ones we have named.

We can ask two questions. One, are there any analogous changes or forms known in the biological kingdom? And two, what sort of physical process does the change suggest?

As to the former question, it is possible to analogize with regard to the plant kingdom wherein there are mobile phases of existence and finally a fixed existence, but much of that is related to the different way the woody plant is tied to its chemical potentials and the different time scale for its metabolism. Thus, many more have been attracted by the social insects who seem well organized into physical forms in place.

There is little doubt that this metaphor has inspired the creator (8) and many of the proponents of sociobiology. However, the metaphor is still far-fetched because of the fact that most of the behavior of those species are stimulus-bound and limited in central nervous system capacity.

The characteristics we seek are much more to be associated with the physical freeing of the central nervous systems of higher animals (9), which because of its increased inter-neuronal richness becomes increasingly less bound in its behavior, with increasing computational and storage capability, and in the case of the Pleistocene hominids explosive in its growth in cortical capacity.

The contrary problem is thus created. On what sort of behavioral program should such freedom, particularly an abstract high-speed linguistic capability, light upon? From a biological and a physical point of view, that strikes us as the central question.

The very clear physical answer that this question foreshadows is that the problem of human social evolution is a matter of dynamic stability, one in which a transition takes place from one type of field process operation to another.

Ever since pioneering work in elastic stability by Euler (e.g., the buckling of a column), in hydrodynamics by Reynolds (transition from laminar to turbulent flow), in mechanical orbits by Poincaré and Lyapounov, the subject of mechanistic stability has flourished, and it has been realized that the problem is associated with nonlinear dissipative processes. Recent conferences (10, 11) have assembled a large amount of material on the generality of the problem. We have offered a prior conjecture on its application to the social transition problem (12).

The problem we confront here is to try to explain the process in terms that social scientists may be willing to accept.

III. The Transition Process Toward Civilization

It is clear from what we have said that the beginning epoch of modern Man, 40,000 to 30,000 years ago, say, was represented by a style of life not much different from earlier hominid species or, except for the particular band characteristics (2), much different from many other modern primate species. This is true even though specific human cultural artifacts can be found.

What was that style of life, particularly as described in a physical sense?

Even before knowledge was available as to a possible progression of species, it had become feasible to distinguish a difference between Paleolithic, Mesolithic, and Neolithic tool assemblages, and in the Paleolithic, upper, middle, and lower periods.

We, of course, are concerned with human transitions, and so we can speak – in an ergodic sense – with some authority for human processes of thought (we are human).

But to the modest extent that we wish to invoke a particular thought process, we can surmise it to hold for Man's tool-using ancestors.

In particular, we surmise that evolution of tools is simply not a process that follows automatically upon the thought process, but that in general, there are perceived needs and the hominid brain – dealing in abstraction – creates tools as abstractions and their modifications to deal with those needs.

Note -- Animals can distinguish self and other than self. That is, they possess such world images. Recent work, on recognizing self in mirrors and as objects of manipulation, have begun to clarify the existence of graded differences among higher apes. Thus, evidence is building up for the graded difference in abstraction abilities among primates.

Nevertheless, it is still one further step of abstraction when a hominid primate began to incorporate an epigenetic heritage of tool-using into his regular existence. A tool is neither self nor outer world, but an object which can be precisely manipulated between self and outer world to affect motor and sensory competences. That triangular relationship is an abstraction.

But the continued evolution of such tools has to follow additionally perceived needs. Nevertheless, while an epigenetic heritage can exist, it may exist within a "traditional" culture without change in tool-making. Thus, clearly there was social pressure to evolve tools. At the present we can only infer the character of the pressure from the direction that the tool types took, and a possible relation to the changing climatic-geographic potentials.

We can quickly jump to the lower Paleolithic hand axe which emerged in the mid-Pleistocene. This tool type is basically associated with Homo erectus, and it was the leading tool over an immense period of time for much of the territory in which that species has been found.

Perhaps this was 500,000 to 100,000 years before the present, not as far north as modern Man but up to the northern-most latitudes of the Black and Caspian Seas in Eurasia – but not east of India – and Africa (13) (14). Tool evolution existed over that immense period, but it was not exceptionally rapid.

This brings us to the Middle Paleolithic traditions which emerged in the late Pleistocene. This epoch is basically associated with Neanderthal Man, or Homo sapiens neanderthalensis. (By being so designated, it is increasingly considered to be an early subspecies, likely largely extinct, which preceded the current subspecies Homo sapiens sapiens.)

That subspecies of hominid, e.g., associated with Mousterian and Levalloisian tool traditions, was dominant over the period 100,000 to 50,000 years before the present, and it has been found even further north in Eurasia (15). A change in tool evolution is usually found, marked by a predominance of flint tools based on the production of flakes. Instead of producing one tool from a large core, a diversity of implements could be produced by continued flaking of small pieces from such a core. That tool technique was widely diffused throughout the hand axe province. Although the time scale of change is much more rapid, the changing industries are not precipitous. However, the database available and the scatter in type of tool is still not extensive enough that detailing at the level of a few millennia at a time can be done.

The important characteristic of that type of tool change (advance in the tool-making rate potential) was that it accompanied (and perhaps made possible) a significant extension of the range of human settlement to colder climes, and it accompanied an extension of the hunting-gathering capability of the hominid species.

Can we not jump immediately, then, to modern Man, a new subspecies who somehow may have lived contemporaneous with Neanderthal for some overlapping period, but then proceeded by some unknown legerdemain to have knocked out Neanderthal's sharing or competing for the same niche, by virtue, perhaps, of superior hunting and killing tools? That is a common impression left in popular archeological literature.

However, some recent stories, relevant to civilizational startup, is bringing more perplexing detail to the transition; in other words, a sharper picture of the transition to civilization requires greater detailing in all occupied earth regions for a lower Paleolithic 250,000 to 100,000 years before the present, and a middle Paleolithic 100,000 to 30,000 years before the present period, including detailing of ecological conditions.

A case in point is the Nile valley history (16). History and evolution there were dominated by climate, just as in the northern Eurasian development. For example, we may start by noting that the area had a drought from about 500,000 to about 120,000 years before the present.

Eolithic (ed. - relating to or denoting a period at the beginning of the Stone Age, preceding the Paleolithic and characterized by the earliest crude stone tools) tools are found in the Nile valley.

They have a lower Pleistocene date of about 700,000 years before the present, associated with a rainy period. Dating to about 500,000 years before the present, hand axe traditions are found. One can conceive (as pure speculation) that the hominid path of diffusion, of population, of tool making, might have spread through the Nile valley from southern and eastern Africa to the Near East in an earlier period.

It appears that with the end of the drought and the beginning of a new pluvial age, the Abbassian (lasting from 120,000 to 90,000 years before the present), the late Acheulean (hand axe) hominids spread from the limited oases more broadly into the former desert wastes in search of large grazing animals.

We will here make the point that each time such weather changes have taken place, e.g., with the later withdrawal of the glaciers in Europe about 10,000 to 12,000 years before the present, both plants and grazing animals disperse as more broadly wetter regions appear, and tool-using hominids are forced by necessity to adapt their food searching style.

What is interesting about this instance, earlier than the one we previously discussed, is that it indicates the pressure on an earlier tool-using hominid to find related solutions and make some sort of lifestyle transition.

The hominids that were involved were those making a transition between Homo erectus and Homo sapiens neanderthalensis. One begins to find some of the earliest evidence of house-like structures. The suggestion is that these Acheuleans ventured seasonally into the open grasslands and retreated to permanent watering holes during the dry season.

The Abbassian pluvial was followed by drying desert conditions in the entire Sahara. The Neanderthals took refuge in the great oases of the Nile valley. At about this time, that species of Homo began to exhibit the Levalloisian tool-flaking tradition in Africa as well as Europe. One type of tool that may have been of revolutionary importance in hunting efficiency was the stone projectile point. This could be hafted to wooden shafts to make a hunting spear far superior to the fire-hardened wooden spear used earlier. Just as in northern climates, these flakes could be used as scrapers to prepare furs for clothing.

One senses that each such technological advance, made out of necessity for a particular climatic era, then had a capability of flowering in a subsequent age if the climatic changes were suited.

Thus, the Mousterian pluvial, a period from 50,000 to 30,000 years before the present, was ushered into the Sahara, much lusher than the earlier pluvial. The Neanderthals colonized every available niche in North Africa (just as they were spread across Eurasia). Rooted in this culture one finds the Aterian Industry, viewed as being contemporaneous with middle Paleolithic cultures in Europe, dating back to over 40,000 years before the present, with a demise just under 30,000 years before the present.

This interpretation is new. It demonstrates a slow but fairly continuous development of middle Paleolithic to upper Paleolithic culture. While the Aterians (who are likely Homo sapiens sapiens) had a somewhat superior tool assemblage to the Mousterians, it seems that they coexisted in a cultural mosaic during much of the Mousterian pluvial.

"The side-by-side persistence of strikingly different technological and possibly cultural (?) traditions is not unique to this period in Egypt but, as we shall see, characterizes the late Paleolithic sequence in the Kom Ombo Plain in southern Upper Egypt and probably continued through predynastic times to be echoed in Dynastic traditions of the cultural duality of Upper and Lower Egypt." (16)

This seems to be an example of the kind of prehistory revisionism in progress. An earlier example in the mid-60s was the work of the Binfords on Mousterian settlement traditions. A great deal of overlapping cultural diversity existed on the savannas and oases of Middle Paleolithic northeastern Africa.

We cannot attempt to develop (or master or wait for) the discovery of all the detail that refers to this and other areas. A few references that enrich these stories is contained in References 17 through 33. But the basic need thus is to begin to trace the story of change and transition between, say, 30,000 years before the present – 2,000 years at a time, down to 4,000 years before the present, when the historical period is safely in hand.

The boundary conditions are likely the historical period of evolution of modern man 40,000 to 30,000 years before the present related to the climate of that period (e.g., glaciated in northern Eurasia, pluvial in Northern Africa), the diffusion of that species and the tool assemblages, and the ecology available for support of a human cultural life. Then the question is to what extent can regional predictions be made.

It would be one of our key theses that the basic relaxation process, by two millennia segments, would be a changing perception of how to conduct a life style.

That may be. The problem we face here is to offer some sort of physical theory for the transition that took place in that time slot, say 30,000 to 4,000 years before the present, and related to the operational boundary conditions 40,000 to 30,000 years before the present, given the conservations, their fluxes, and the potentials we have named.

It is clear that the transitions we are concerned with are phase transitions, transitions like the condensation of matter from gas to liquid to solid phases. First, how would we describe Man the earlier hunter-gatherer? Similar to most other mammalian species, Man operated in a hunting range, appropriate to his size and metabolism (there being moderate differences in such ranges for carnivores and frugivores). At slow rates, he diffused over a wide habitat.

Climatic conditions, and thereby ecological conditions, in the main, governed that diffusive habitat. All this constitutes essentially straight-forward biological-ecological results.

Physically that motion, with its near isolation, e.g., typical band separations on large land masses was of the order of 70 – 100 miles, can be considered to be nearly gas-like motion, a two-dimensional gas. Its mean free path was of the order of one roaming range, e.g., 25 miles; its relaxation time was of the order of one generation, e.g., 25 years. That is, its propagation speed was of the order of one mile per year (34). "Information" (cultural information) could hardly be propagated at higher speed.

But note that low potentials of temperature and water and food would always cause condensation. A note on this is desirable.

One might think that diversity of form and complexity is associated with high energy. This is not the case. At high energy, e.g., high kinetic energy, systems move toward a gaseous phase. All low energy bonds are broken. Remaining degrees of freedom of motion are each equally endowed (equipartitioning) with energy. It is only at low temperature (low kinetic energy), as Einstein showed for the specific heat of matter at low temperature, that the same energy has to make do for many ordered configurations. There is a cooperative phenomenon which takes place; order is imposed, authority is established. Thus, matter condensation, e.g., liquid and solid states, always exhibit more diversity and complexity of order than does the gaseous state.

All species will respond to a poverty of potentials by some sort of condensation, in extreme cases in very great changes in sociochemical form. In each case, it is the internal potentials, e.g., genetic, that will select the condensation path. Hominids, with an additional epigenetic and tool-making potential, have always adapted by means of all three potentials.

The very nature of extreme climatic changes puts the major action in the Northern temperate zone in Eurasia, from northern tundra limits (dominated by the Scandinavian ice sheet), and Northern Africa, just as at a later date – when Man enters the Americas – another play takes place in that continental mass.

In the African case, it is the alternation of wet and dry which drives Man toward oases and toward dispersals. Likely as a universal theme, the more promising condensations are driven toward river valleys, and certainly invariably to search for reliable water supplies. Of all the chemical potentials, oxygen and then water are the most pressing (followed by temperature).

But the nature of the condensation depends on the state of the technological potential.

What the new Egyptian story indicates is that the potential for significant condensation already exists in the Neanderthal-modern Man transitional period. The adaption, by necessity, of the wide variety of mid-Paleolithic tool industries is indicative of such capability.

What can come out of these two driving potentials – change in water potential, change in technological potential? Either cleverer adaption of tools and modes of living (and there is ample evidence around the earth for those processes), or condensation in place. This is via domestication:

- domestication of plant and animal, and
- later water resource, and still later
- all required resources—the status we are seeking now.

Thus, we would submit, that with these two changing potentials, it is only a matter of time and place for condensation to fixed agriculture to occur, as a liquid-like condensation.

We believe critical detailed study could establish much more precisely criteria for such transition, and when or where it might have occurred (35). In Europe, it relates to the end of the glacial age 10,000 years before the present. In Northern Africa, to the 8,000 (rather, 8,000 – 7,000) to 4,500 pluvial age. In both cases, the new condensation related to changed water supplies and the existing technology.

But the empirical data seem to foreshadow the theoretical result. The process of transition is (a) neither so difficult to occur, nor (b) so guaranteed to be lasting.

Note that all that is required is Man to adapt his action modes of behavior to the species he wishes to domesticate, and to put some selection pressure on the species to adapt toward his action modes. Such symbioses are very common in the biological world, so it was hardly a novel invention. An epigenetic memory of time and place and sequential ordering is quite useful. But these are the attributes that Man had, so that the adaption process did not have to take the more usual million-year genetic scale of species. Rather, it could be a facilitated diffusion speeded up a thousand-fold to thousand-year scaling. That is the difference between the genetic and the epigenetic process.

So, near self-sufficient agriculture could emerge in the Nile valley, in the Tigris-Euphrates valley, in the Americas, elsewhere in Africa, in the Asian steppes (and be given up), in the Indus valley, in China. Were these all independent, or diffusively propagated? That requires expert detailed study. Some were independent, others derivative. For example, the diffusive spread of agriculture over Europe at the millennial scale has been carefully documented (36).

The emergence of a settled life and a dependence on cultivation is as extensive as the period of perhaps 20,000 to 10,000 years before the present. Without a great deal of local specificity, there is no reason to expect any lesser period of transition, and one would expect only very spotty beginnings.

Therefore, it is no surprise that a significant threshold for the startup of agriculture is given by about 10,000 years before the present (35) and associated with major changes in water potential:

- In the Eurasian region, one would associate it with the withdrawal of the glaciers (end of the last ice age), dated loosely 12,000 to 10,000 years before the present, and the dispersion of melting front, grasses, grazers, predators, toward new "permanent" water supplies – river valleys, well-watered mountain flanks, lakes, and springs.
- In Africa, one would associate it with concomitant wet-dry periods with condensation and radiation forces toward more permanent water supplies.
- In the Americas, with a time delay to master the land, we can see multiple starts at a later date.

Thus, the self-sufficient agricultural village, located strategically with regard to water supplies, became a new feature of the earth's social landscape for Man, interspersed in some regions mosaic-like with hunter-gatherers.

In general, what one appears to see prior to civilization is a deterioration of environmental conditions, pressure for technological innovation, regionalization of social groups, a mosaic of cultural types (*sympatric societies* – various cultures occupying roughly the same niche, by basically using different tool traditions, and with modest separation, i.e., latent condensations).

Now, in a physical context, one would say that:

(1) two or more atomistic type fluid-like assemblages coexist in the field – solvent or solute (?)
(2) in which one kind of precipitated-out group (already condensed, or nearly condensed) will
(3) take over the superior social role and
(4) force the other groups either into opposition,
(5) or, dispersal (unlikely),
(6) or, absorb them into the condensation.

Therefore,

- This occurred, hypothetically, as the Mousterian – Cro-Magnon transition (that is, 50,000 to 40,000 years before the present);
- In the hunter-gatherer – agriculturist transition (that is, 20,000 to 10,000 years before the present);
- It may have happened in various agriculturist – nomad transitions either way;
- It may have occurred in the Acheulean – Mousterian transition (likely a Homo – Homo transition); or
- Even in the eolithic – Acheulean transition (still an X-Homo transition, as far as the certain record of hominid types is concerned); and
- It occurred in the agriculturalist – civilizational transition (e.g., 8,000 to 5,000 years before the present).

IV. Civilization, a Second Transition – Appearance of a New Conservation

Given these two possible social forms – hunter-gatherer, agricultural village settlement (and also, forest efficiencies and pastoralist nomads), why is there any need for any further transitions? There is obviously pressure for continuing evolution of agricultural-based technology, as well as dwellings, clothing, further domestication. But why any further transitions? Are there needs that dominate?

Such condensations, although they are liquid-like, that is no longer with 70 to 100 miles separations, are not all located in a perfect strategic manner. The greater permanence of food supply, with agriculture, instead of mobile hunter-gatherer, permits an appreciable growth or accretion in population and population density. Their separation is reduced to less than roaming range size, i.e., less than 25-mile separation. But now, again, mutual needs – for materials, for breeding population, for alliances against human predation, for security from climatic vicissitudes – all make some form of trading intercourse necessary. Since the settlement is fixed, and the materials of trade have to be carried, a fluid-like flow process known as convection is involved.

It is a remarkable consequence of physical interaction that, in an interacting field, there are only three types of field processes – diffusive, wave propagative, and convective. The first two are linear, the third is non-linear. It is marked by the product of the field carrier's variable, e.g., velocity, and that which is carried, e.g., energy, momentum, matter, population, action.

In mathematical physical theory, there is an interesting consequence of having the combination of nonlinear and dissipative processes: The diffusions involve energy dissipation. What that means is not disappearance of energy, which is a conservation, but its dispersion, thermodynamically, among various participants. New singular states of motion may arise, as stability transitions (10, 11).

Notice that this does not involve a new matter condensation – after all the settlements have already provided condensation – but a new social format for movement and change throughout the field. The question is how shall the human social process respond to such new social pressure?

One must dwell on the requirement for social cohesion in any population center. People must recognize each other and have a basis for social bonding. This is represented within the agricultural village and it probably limits the size to less than 500, a rough count of the number of faces that can be recognized (37).

Primate social ordering— see Eisenberg (5)— or the more specialized hominid band formation (2) suggest the "traditional" kinds of village leadership that may emerge, and the variety of possible dependences on kinship and hereditary and appointed occupations arising or developing from a division of labor (for further, see Murdock (38)).

But now with convective fluid forces, there is pressure to permit the foreigner in for trade. Diffusion coefficients still prevail to govern conductances (a tautological statement), but they are now facilitated diffusions. For those familiar with hydrodynamic and engineering fluid mechanical concepts, these diffusions are no longer molecular diffusions (that is, person-to-person Brownian motion, per Einstein) but eddy diffusions. They are carried by the field fluxes, not by the individual atomisms.

We will now make the required connection to the central theme.

What is the essential nature of civilization? As we heard the themes in the 1979 ISCSC session on origins of civilization, it is a source of argument whether religion, or agriculture, or urban settlement, or trade, or literacy, or recorded tradition, etc., is the essential causal ingredient for civilization.

Let us go to the dictionary for what is the common ingredient involved in civilization. It appears to be the notion of *civitas* – the existence of a formal set of objective rules that clearly set forth to the onlooker, whether insider or outsider, what the relations are that govern hierarchical, heterarchical, or stratified class members that are permitted physical access to the society; e.g., ruler-citizen, master-slave, citizen-citizen, or citizen-outsider. It is rules of civil organization.

Believe it or not, that set of formal constraints, as "political" – flow of authority, for example, see Lasswell (39) – constraints, determines the impedances or conductances (diffusions) to flow. Diffusions are no longer solely physically determined, but they are facilitated or impeded by Man-made law.

It is quite interesting that, with written language going back to perhaps 5,000 to 5,500 years before the present, very largely recording person-to-person transactions (or extolling the deeds of ruler elites), that by about 4,200 to 3,700 years before the present, we find the first recorded codes governing largely class relations in the urban city-state. These clearly emerge as an equipollent (equal in power or significance -- ed.) or heterarchical (system of organization in which the elements are unranked or may be ranked in various ways -- ed.) element in the rise of empires (ensembles) of city-states.

It would be very impressive to push such city-state codes back another millennium, or even more impressive – in sharpness of transition – if such codes were found "recorded" (instead of simply implied) for the period of about 8,000 years before the present (or, at the outside, 10,000 years before the present), but we have to allow the possibility of a number of two millennia relaxations for Man to make such drastic transitions.

At the present, we cannot offer any greater precision in social scaling. An agricultural (effective) startup of 10,000 years before the present could not be accompanied by further hydrodynamic stability transitions in fewer than a few such relaxations.

How is such rationalization effected? (Rationalization: the creation of bureaucratic institutionalized forms by which human actions are regulated, e.g., laws.) It obviously involves abstractions, a functional performance which can be spewed out of the human mind with great ease. But how to endow it so that it has…value!!

Clearly, Man, as Man, with cultural symbols from his beginning (even with indications of their beginnings in Neanderthalers), could accept, in fact had to accept, value systems. Why "had to"? Because of the new freedom of abstraction in the brain, which would permit him both to time delay and form arbitrary "linguistic" associations.

Magico-religion became one such value system – e.g., shaman and totem and taboo, and ritual. But clearly agricultural systems and later urban systems required much more complex totems. It is hardly accidental that ziggurats in the Tigris – Euphrates mark some of the earliest structures in that urban explosion, or the probable evidence of religious formalism in Catal Huyuk.

So, certainly a particular explicit form (structurally institutionalized religion) emerges quite early in civilizational interaction. Clearly now civilizational interaction begins when there is extensive convection of trade among population concentration (urban) centers. They would be marked by populations greater than 500; e.g., composite groups in which appreciably more than a threshold of perhaps 2,500 persons were involved. The latter number was estimated from a cut off of complex cultures of about this size in Murdock (38).

But that convective interaction involves stranger and insider. It can no longer be governed by established tradition (an oral heritage accepted by all internal parties, as in the family, or in the local isolated village). Thus, an objective symbolism must be invented. Using what? Using the intensive store of epigenetic value, but now externalized into value-in-trade, a symbolic form invented out of mind and endowed with value for all transactions. All other real conservations can be traded for using this idealistic conservation.

The basic rule is that in each transaction, "equal" value is traded (by whatever defines equality of value at the moment). Thus, the economic conservation is invented, comes into being out of mind. With it arises a pricing system. And with it arises also the utter terror of inflation, a runaway value system. As Pareto explained (40), it is all right for society to pull the rug under its value-in-trade system as long as the next generation of players is not discouraged from play.

This hopefully introduces, by physical reasoning, the economic variable into a social physics as one additional and final conservation.

V: A Note on the Death of Civilization

But an optimistic note that each adolescent generation brings anew to the social experience, that this is the life, that the now of this lifetime is the only one that counts, is doomed to failure. Why? Because the system is unstable, thermodynamically. The "why" of that instability is a basic piece of physical reasoning.

The young diffuse into society, diffuse and bind into its nested hierarchical institutions – family, neighborhood, local political community (now largely either urban or rural), national political community, plus acquire an epigenetic heritage, and gradually take the roles of the adults they displace and replace.

That turnover guarantees no new successes. The problems of the past are propagated, new ones are added. The conservations that have to be satisfied remain the same, what each generation does not learn is the total operational wisdom that the past generation may have acquired. That seems to take a lifetime of perhaps 20 to 40 to 60 years to learn something about.

In traditional societies, in which movement is slow (movement from outside), the old can act as ambulatory memories on how things are best done. The integration of notions of how to deal with complex social systems in which the convective currents (e.g., daily, weekly, monthly, yearly, per generation) are large and constantly changing with vicissitudes is not quickly learned. It is a limitation of the human mind.

Most elite leaders are thrown into their basically abstract reasoning role in society with less than twenty years of experience past their adolescent growth. Their reactions are based on the biological motor-sensory responses of the moment. A political horizon of six months to one year is and has been the most common characteristic of Man since civilization began.

That turnover period is fine and fits the agricultural village or the hunger-gatherer society to a T. In such societies, the only conservations that have to be satisfied are materials, energy, and action modes. Some vague attention has to be paid by ambulatory memories as to the reproductive balance; the biological action mode of sexing itself is no issue. Each generation of young comes superbly prepared to quickly learn the mode, if necessary by trial and error. So, the social action, if any, is to regulate and control the issue of childbirth. Clearly, under these circumstances, the need for longer range planning or information, of an abstract nature, can be left to a few – leaders, elders, shamans, priests.

But face the issue in civilizations, with the continued influx of strangers and trade, and the requirement for symbolic balance in trade, requires responsiveness to ever-changing external conditions. Now one requires each youthful generation to develop a fantastic amount of action capability to deal with a complex series of interactions. As usual, it is not the populace who are concerned with the mastery of such operations but an "elite" structure, if you will, a new "priesthood." As usual, from the nature of command and control systems, such operation is confined to an elite of a few percent of the population.

But they are not biological queen bees, endowed by some royal jelly with special powers. They are ordinary human beings, the same youth as the more plebian followers. As young priests of the market place—whether in feudal societies, or commercial, or capitalistic, or communistic, or socialistic, or dictatorships, or anarchies – they cannot and do not learn how to operate a complex society. That literally requires understanding and controlling conservational balances for periods of the order of one to three generations, the social equilibrium period.

In civilizations, that also involves high expectation of major wars per generation in the ecumene. Civilizations, from their beginnings, involve alternations of trade and war.

The issue, further, is that not only must the elite leader understand how to strike all the necessary balances for such periods, but he must convince the people, his followers, to carry out the requirements so posed. Over one year he can do it; for three years (e.g., the political process), he can do it. But to impose the kind of rational regulation and control required for longer periods, he cannot succeed. The political leader, and other elites, can supply a schema for rationalization (the hallmark of civilization), but he cannot succeed in supplying a schema for rationality.

And so periodically, the overall mismanagement of the social system catches up with itself and the system tumbles.

We have no real belief that we can make more than a handwaving estimate of that time scale at this time, but it also seems to come out – by any reasonable theory – to be of the order of 500 years. It takes perhaps twenty odd generations of elites before the mismatch produces incoherence.

But the societal members and local institutions— e.g., family, local agricultural community, are still designed for the year operation. So even when civilizations tumble, or come apart, or reform, the local units largely survive intact and begin the task of putting together a new form. And so, on it goes and has to go on for this biological species.

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