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Human Sociogeophysics – Phase I: Explaining the Macroscopic Patterns of Man on Earth

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Abstract: The demography of man on earth is treated by a physical model for that forward transport for the subspecies in time. By examining the distribution of man and his Neanderthaler precursor, it is inferred, as a likely hypothesis, that the initial "Phase I" expansion of man on earth (40,000–15,000 ybp) was at a constant density of about 0.04 persons per sq.km with little or no remixing. We suggest that the nature of the physical process was a diffusion, a "random walk" process with a diffusive velocity of one roaming range (30 km) per generation, i.e., 1.5 km per year. The physics and physiology of the breeding process permits us to estimate the total earth population, the birth rate b, the death rate d, and the net difference (that is the Malthusian constant K, $dP/dt = KP$, where $K = b-d$, P = population, and dP/dt is the rate of change in population).

From a thermodynamic point of view, man in society is an open fluid-like system. Intrinsic to that openness are both man's ability, and his need, for relatively free movement on the surface of the earth. That movement engenders the local constraints on human land use. There has been no historical attempt to provide the space-time scaling for human movements in any systematic way. This is a first such attempt from a socio-physical point of view. We will expect such motion to be, loosely speaking, a diffusion of ethnicity (the coherence associated with a breeding pool), as moving ethnic band enter new areas and mingle with extant breeding pools.

Density and Distribution of Neanderthalers 90,000 – 40,000 ybp

To introduce the setting, we begin with modern man's precursors. Constable (1973) provides a glimpse of the Neanderthalers (e.g., 60,000 ybp) showing clearly the known concentration of key sites in the temperate latitudes (then tundra and savanna), mainly in Europe. Covering about 70,000 to about 35,000 ybp (Riss/Würm Interglacial to the end of the Mousterian, Middle Würm II/III), Klein (1973) identifies about another 25 Neanderthal (Mousterian) sites in the Ukraine. These mappings suggest an average separation of such sites of perhaps 160 km. One very crude estimate of the population density of such a collection of sites is an occupancy of 0.04 to 4 persons per sqkm (Wobst in Milisauskas 1978).

One of us has suggested, in an earlier study (Iberall 1973a), that a functional estimate of hunter-gatherer group sizes of the order of 25 to a few hundred seemed compatible with ethnographic studies (Murdock 1967). If the group size is considered similar for Neanderthal and for Cro-Magnon man (a very bold assumption), then – as Milisauskas (1978) discusses – group sizes of 25 people up to perhaps 500 people are conceivable for Paleolithic bands. The earlier study (Iberall 1973a) also suggested that the human (as omnivore) daily roaming range might be of the order of 40 km radius; in that case the implied 80 km diameter may serve as a measure of band separation, with nearly complete separation at the 160 km distance, while close cultural coupling might exist at distances as close as 8–16 km. Murdock (1967) suggests that several hundred kilometers (or 1,000 years) are conditions for essentially complete cultural independence [1].

All such estimates are loosely compatible with a population density in the range 0.01 to 0.5 Neanderthalers per sqkm (our estimate) which overlaps Wobst's estimate of 0.04 to 4 Neanderthalers per sqkm (Wobst in Milisauskas 1978). The argument advanced by Wobst is that a minimum band (25 people) exploits a territory of about 1,200 sqkm. But we have no real evidence that middle Paleolithic (Neanderthal) groups were that tightly clustered. Thus we incline more to the nominal empirical separation of perhaps 160 km, and Wobst's lower estimate of density. A 10–20 fold increase in number of sites would move the density estimate toward the higher range of Wobst; barring such increase, we prefer the lower estimate of density.

Judging from Constable (1973) and Klein (1973) Neanderthalers could be found in land areas of the order of 25 million square kilometers (the available temperate northern zones: for some notion of the total spatial range of Neanderthal see Clark 1967). If so, the Neanderthal population might be represented by a total of 1000 range sites with a total population of perhaps 25,000–500,000 members (Wobst's densities would yield 150,000–15,000,000). Our 'best' estimate would be of the order of 200,000 members, about the same as Deevey (1960).

Human Phase I: Density and Diffusion of Early Modern Man 40,000 – 15,000 ybp

Modern man, the advanced hunter, homo sapiens, emerged about 40,000 ybp. If we examine Klein (1973), we find that the number (and, approximately, the density) of upper Paleolithic (modern man) middle Würm sites (40,000–24,000 ybp) in and around the Ukraine has not increased tremendously over the previous epoch; only in the late Würm (24,000–13,000 ybp) do they show a large increase. Since he indicates an order of 100 sites in a region of the order of 1,600,000 sqkm, the average separation of settlements has been reduced to about 130 km, instead of 160 km. In the epoch 40,000–25,000 ybp, the population density of man might not have been appreciably different from the earlier Neanderthal population.

In the absence of better data, we shall imagine this region (40°–55°N, 20°–50°E) to be the locus of origin of homo sapiens, Man. Quite early in his subspecies history (40,000–35,000 ybp), his habitat range began to spread rather quickly, at a diffusion rate of the order of 1.5 km per year throughout the Old World. At that rate of diffusion, in that period, it would be just possible to reach the southern tip of Africa, southeastern Asia, eastern Siberia, and the nearer shores of Australia.

We conceive diffusion as a random walk. A prehistoric human random walk through the land-connected earth habitat in search of niches would have to cross a (topographically and climatically) most inhomogeneous territory. Such a diffusive expansion, therefore, would be by no means uniform, but rather a swarming, hiving diffusion in which geographic inhomogeneity would produce some reflections, some refractions, some condensations, during a process that could only lightly populate the earth. (Subsequent diffusions might be expected to tend toward more uniformity, and perhaps somewhat greater homogeneity.) The initial explosion might be expected to be that of a common breeding pool, one "race", i.e. one homogeneous ethnic composition. But the inhomogeneous niches in the geographic-climate milieu, the size of that milieu, its shape with respect to the original population (which radiated divergently from a central location), and the long distances of diffusion (and the consequent long time delays for rediffusion) assured the evolution of many and varied breeding pools. Races were born, perhaps within 5 or 10 thousand years (40,000–35,000 or 30,000 ybp) [2].

We can make an estimate, say, of the population as of 35,000 ypb. If we take the now available land areas as about 80 million sqkm (the Eurasiatic band extended into northern climes, Africa), but the separation and density as before (3,000 sites), we now could expert a three-fold increase in population, i.e., perhaps 600,000 population, assuming the same size hunter-gatherer band (say averaging 200 persons, with about 8 camps of 25). Deevey's estimate (1960) is about 3 million.

If now we imagine a jump in the density of sites, that is if we imagine land use to become somewhat more crowded, a little more interactive in the period 35,000–20,000 ybp, even the separation reduction from 160 km to 130 km would increase the population by 50 %, i.e., implying a population of the order of one million (Deevey's estimate is about four million).

We can turn for a sharper starting point to Prideaux (1973). This presents a picture of modern man's spread as of 18,000 ybp. One finds perhaps 250 sites depicted (i.e., known, say, as of 1972). We would regard this to be a fair sample of what we estimate might be a total of 4,500 sites (50 % increase over 3,000 sites). Again we would tend to believe that our population estimate of one million, perhaps even two million is a fair estimate.

In any case we are willing to accept that picture (Prideaux) as a fair sample of modern man, dispersed, racialized, through Eurasia, Africa, even into Australia, but not yet likely in the Americas, as of say 18,000 ybp.

The 'last', initial diffusion into a heretofore unoccupied land mass, the Americas, it is conjectured (e.g. Martin 1967) took place in a relatively narrow time slot (about 15,000 ybp) across the Bering Strait land bridge. We would conjecture that it may have taken place in a number of waves, but that a major diffusion took place at that time suggested by Martin. In any case, continuing the diffusive process, it may very well have taken 5,000–10,000 years to diffuse all across the Americas (e.g., 15,000–10,000 ybp, 18,000–8,000 ybp). Martin further conjectures that newly entering man, the hunter-gatherer, killed all the large mammals in the Americas (except the bison) in perhaps a thousand years.

Fig 1 Nominal time frames for the first round of diffusion of man on earth

Prideaux' map shows the subsequent concentration of modern man sites in the Americas. Their North American density is not markedly different from the Eurasian-African density. Thus another 15–25 million sqkm of territory is made available.

A depiction of the world situation, as of 20,000 ybp, in rather general form, may be found in Barraclough (1979). It shows (a) the ice limits: 20,000, 12,000, 11,000, 10,000 and 8,000 ybp; (b) the land bridges 20,000 ybp; (c) the land areas favourable to man in dry and in moist periods (p. 37). It also depicts the Martin model of man's diffusion into the Americas from about 12,000 ybp. This bears out the basic 'independence' of this diffusion from changing climatic conditions (although the capability for the diffusion is shown to depend on specific climatic events – the existence of the Bering Strait land bridge, 20,000 ybp, and the Canadian ice corridor 12,000 ybp). It suggests that man arrived (diffused) to the tip of South America by about 10,500 ybp. On the basis of our model, we would quarrel modestly with the arithmetic of the Martin model in the following sense; if man reached the southernmost tip of the Americas in say 10,500 ybp, we would prefer to consider it more plausible that the diffusion into the continent (Bering Straits) might have begun 17,500–15,000 ybp.

It is useful to superimpose Prideaux' depiction of Cro-Magnon bone and artifact sites on Barraclough's world map to have some sense of the occupancy and range of man. It is also useful to carry Barraclough's picture (pp. 34–35) of the movements of earlier ancestors, from about 50,000 ybp, as they spread northward from Africa into the Eurasia land area, through about 10,000 ybp. The 100,000 ybp line of homo occupancy extends as far north as about 50°N on the western Atlantic coastline of Europe. It swings down to about 40°N through the Caspian Sea. It dips down to about 30° N through India and climbs back north to 40°N to the South China coast.

By 40,000 ybp, the line of occupancy has pushed to the Scandinavian ice sheet latitude 52–60°N. A northern corridor (the edge of the Scandinavian ice sheet) extended as far as 65–70°N, from about 40–45°E. The eastern edge of the corridor plunges precipitously south from about 45°E to about 75°E in India, i.e., from 70°N back down to 30°N in India. Little northern extension is then found across Asia, except near the South China coast where the

Tab 1 Age Scale of the Tool Traditions of Man

Age	Center Age (ybp)	Range (ybp)
Perigardian	28,000	33,000 – 24,000
Aurignacian	23,000	26,500 – 21,000
Solutrean	17,500	20,000 – 16,000
Magdalenian	13,000	15,500 – 11,500
Azilian	7,500	10,000 – 5,000
('Historic')	2,500	4,000 – 0
('Futuristic')	– 3,000	0 – (–6,000)

range extends farther north to about 45°N. Thus, it is largely Europe, northern Europe, and the Eurasian steppes up through the tundra that the homo species in transition to homo sapiens extended its occupancy.

The extension of modern man, 40,000–10,000 ybp, was largely across Siberia. The line of occupancy extended northward, swinging from 50°N – 70°E in the Russian steppes, to 70°N – 160°E in Siberia. (The only areas not occupied were the Dzungarian, Tarim Basins.) It was that opening to the north that reached the Bering Strait bridge and crossed over to the Americas, conceivably in the 17,500–15,500 ybp slot.

In this description thus far one may sense a large degree of geographic-climate determinism, a physical determination of a thermodynamic nature [3)].

We do not deal with the evolutionary problem (i.e., the diffusivity of species' genotype), which operates on the longer hominid time scale. We do not, in other words, confront the problem of bifurcation of a particular species and branching off, for instance, of a new species and an old one (perhaps modified). Rather we are confronted by a microevolutionary process – the diffusivity of microgenetic changes, likely of the point mutation nature – which leads by geographic-climatic selection pressure to changes in the breeding pool. That process apparently is 'half' of a pair of processes, one of small genetic changes interspersed with remixing, which we will view as proceeding as a diffusion of 'ethnicity' (rejoining of such separated breeding pools with their small differences). Microevolution deals not with macrosplitting and bifurcation but with microsplitting and remixing. Microevolution we view as a complex 'chemistry' of a single species, a complex of 'chemical reactions', the chemical potentials represented by the genetic code for the single species.

The movement we have 'justified' (by contending that it is *plausible*) is a generalized diffusion at a relatively constant rate into all feasible breeding niches – "feasible" meaning temperate, up through the periglacial steppes, such as through Latitude 55°N. (Klein (1973); for those early times this is equivalent as a habitat, to say, Latitude 65° at present [4)].) We thus treat modern man as resembling many other species in being temperature and rainfall limited. One would say that modern man's range was more extensive than Neanderthal's range, because of a better cold adaptation, even though that "adaptation" worked through the technology of tools, as exemplified by clothes and shelter, rather than through physiological mechanisms. Thus because of man's epigenetic capability (made possible by his extended genetic properties), he filled all of the earth's space available to him in his initial inhomogeneous diffusion.

More precisely, a great number of local inhomogeneous social games have gone on, but there has not been a great deal of widescale mixing. Up to this point there has been little remixing. Thus the land area expansion of this superb hunter-gatherer has been at near constant population density for the 25,000 year period that constitutes Phase I of man.

The most convincing evidence of the existence of a primary 'unmixed' (meaning little mixed, except perhaps locally and a shorter time scale) outward diffusion with only point mutations in the species is the appearance of the widely separated distinct 'races'. 'Races' constitute clear evidence for separation into differentiated breeding pools [5)].

That the races were in existence by 15,000–18,000 ybp seems in little doubt. That the process of differentiation into races began 'early', and was largely completed by 30,000–35,000 ybp might require somewhat greater argument [6)]. That there was little remixing 20,000–30,000 (or 15,000–30,000) ybp might even require still greater 'proof' and discussion. We hypothesize that this was the case. Our hypothesis is drawn from our account of diffusion by a logical process. The character of the hypothesis, and the evidence required for its testing, seem quite clear.

The Phase I process we have described is well recognized as part of prehistory. What we have added are some assertions about what "man" the maker of prehistory was and is.

Why not invoke 'culture' to explain the diffusion pattern? Certainly man through the entire period of Phase I possessed 'culture', and the epigenetic ability to transmit that culture. But for the mobile hunter-gatherer, there were some limitations on the manifestation of 'culture'. In some respect, 'culture' was written on the winds, in being transmitted as a largely oral heritage, which we estimate has a time scale trace of 'only' perhaps 500 years (at most). We reject the extreme argument (Jayne 1976) which suggests that man had no personal consciousness until the actual period of historical records. We consider this far-fetched by reasons not of evidence but of our assumptions: in our neurophysiologically oriented view, a "world image" of self and outer world descends very deeply into all living systems, or rather all systems above the viral level of chemical organization among biochemically processing organisms. No doubt our belief that human communication, speech, *at neural rates* (10 Hz), only began with modern man, not even Neanderthal (see Iberall 1973) will seem to some an equally far-fetched hypothesis; certainly it will require a great deal of accretion of positive proof before it can be widely accepted.

Even assuming human consciousness and oral communication, however, a social process constrained by limited life expectancy (barely past reproduction age), a very small breeding rate, and 'only' oral tradition, is hardly conducive to much memory trace being left by any individual, except in some magic-mythic sense, for very much more than one or two generations. The memory trace – person to person – is rather short. Human society is up to this point not highly thixotropic (possessing memory of past states). In a sheet of liquid droplets on a pane of glass, driven by intermittent winds and rainfall, each drop may carry and diffuse a small amount of dissolved constituents – its 'memory' as a trace of things it has picked up on the way. The initial human society seems to us fairly represented by this metaphor, in that such a system of interacting droplets would tend to be describable by the physics of an amnesiac near-ideal gas rather than of a fully thixotropic fluid-plastic solid state of matter.

As a consequence of their social-physical status, there is no way we can know these initial groups' members as individuals. Their trace is their archeological record. Their marks as men are their artifacts, the assemblages that mark their culture [7]). These artificial assemblages increase in complexity over time. Each hominid development, since their evolution in the Pleistocene Age (or more extendedly in the Plio-Pleistocene) shows increasingly richer scales of cohesive interaction. The 'culture', as represented now by life-style traces, of modern man is thus more prominently left and available in shorter term than for other hominids. This must be kept in mind if we are to understand the extension of this trace-depositing process into what will 'soon' emerge as the historical epoch.

Introducing Human Phase II: Condensation, Precipitation and Settlement of Man 15,000 – 8,000 ybp

We next portray the emergence of modern man in modern society from that point in time, about 15,000 ybp, in which, scattered on the face of the earth in essentially the modern biological form, from an initial somewhat inhomogeneous diffusion to a moderately homogeneous low density in all of the relevant land areas, the initial primitive hunter-gatherer ecumene made its first world appearance on the stage of the nearly connected land masses of the earth. A second phase, of densification, of mixing in response to changing conditions, 'now' begins.

'Now' means '15,000 ybp' (or '10,000 ybp' in some areas – we hardly can distinguish 15,000–10,000 ybp). 'Now' we face a new climatic condition, the end of the ice age, the warming of the earth, the withdrawal northward of the glaciers of the northern, more continental hemisphere where the species man is nucleated and dispersed. Now the next phase of man's existence – the diffusion of ethnicity by remixing – begins. It is this process that will define the subsequent (to recent) pattern of land use (Phase II) [8]).

There existed something to be mixed. The first phase expansion had produced some striking 'cultural' differences. As Binford – see Milisauskas 1978 – points out, no "patterned 'stylistic' variability has been demonstrated in the archeological record prior to the upper Paleolithic (starting from 40,000–35,000 ybp)"; thus he "assumed that there was no ethnic (by us a biological term) composition of groups before the upper Paleolithic". One has to assume both cultural variability, and some small amount of genetic diversity for the beginning of the second phase mixing period.

Did climate change first, or did man increase his density and precipitate first? Considering the extended scale of inhomogeneity and the existing derivatives (rates of change) in both space and time, this question is not answerable (certainly at present) in simple terms. The general argument is that a phase change, a change of "state", was in process because of general instability throughout the human cultural "atmospheric" space. It requires a very sophisticated cloud physics to name the precise centers and locations at which droplets and "rain" begin (or in the converse process, where bubbles and "nucleate boiling" begin). Yet even if we lack that sophisticated physics, we can say that under certain conditions the field is unstable, like a bubble chamber, and its "atmosphere" is ready for local condensations.

Was climate change what caused human condensation? It is not impossible. The rate of climatic change increased near the beginning of Phase II. Phase I climate was of course not entirely stable. Klein, for example, discusses considerable temperature-derivative action in the range 40,000 ybp to present, when one observes temperature at a near 2,000 year scale. We are aware that a 'flat' glacial epoch, say through Würm II and III up to 14,000 ybp, simply is not to be found. Temperature swings, shown in England, Netherlands, Siberia, range through arctic, subarctic, to the boreal; mean July temperatures range from 3–10°C. Europe exhibits the Göttweig interstadial in the 40,000–30,000 year slot.

Nevertheless, the steepest sustained increasing temperature gradient begins for various regions in the epochs 18,000–9,000 ybp, 14,000–8,000 ybp, or 12,000–6,000 ybp in an avalanche of rises and falls with perhaps a 2,000 year period (a few local European temperature peaks are identified as the Bölling and Alleröd peaks). Similarly in the Americas, the positions of the ice margins in the Late Wisconsin age are identified by Dreimanis (1976) as a rather rapid retreat from about 15,000–10,000 ybp (from a near maximum southerly position of 40°N to 47°N, as noted in the range 75–95°W).

It is moderately fair to say that the change from the glacial age to the temperate climate of the Holocene (e.g., say mean July temperature near an 18–29°C range) could be found by about 8,000 ybp. This range change, e.g., from perhaps 15,000 ybp nominal to perhaps 8,000 ybp nominal, represented a change in northerly areas from cold to moderate, and a change throughout the more southerly areas (Europe, Asia, Africa, Americas) in the wet and dry characteristics of these regions. Thus the problem confronting man as of 15,000 ybp was a considerable, 'recent' experience (as of that time) of changing climatic and/or changing hydrological conditions. Wet-dry, warm-cold became the main contrast facing man from that day to this [9]).

Did such change precipitate man in place? Not directly. We suggest rather that such climatic-hydrological change began the remixing process, and that it was remixing (given also the potency of ethnicity, newly perceived now at a changing more rapid time scale) likely helped foster or accelerate the precipitation or condensation of man in place. Climatic instability initiated a new, directed diffusion, a diffusion in search of more permanent water supplies and more permanent food supplies.

The period of condensation does not have perfect ecumene closure. As of 15,000 ybp, the Americas were not explored. Thus one cannot simply say that it was an end to population growth at near constant density that marked the 15,000 ybp point. In fact it is more appropriate to consider that the next 6,000–7,000 year period represented a continuing expansion of man, as a near constant diffusion behind an expanding front through the Americas, made possible when (a) man reached the Siberian terminus, and (b) the land bridge was open. (One notes that a water gap may very well have been overcome to Australia in a much earlier period.) Though the exit from Asia for continued diffusion to the Americas was relatively small, it did exist. We thus incline to assert a *local* population condensation under changing climatic conditions (warmer in Europe, deteriorated dessication in Northern Africa post 30,000 ybp) in areas furthest from the opportunity to diffuse into new habitat.

If such a scrambling for place did indeed occur, it would hardly have left an orderly trace. One might however ask, from a thermodynamic point of view, what might the transition settle out to be. That question has been addressed (Iberall, Soodak 1978); the answer suggests that a real condensation phase-change had taken place in the first instances by about 8,000 ybp. (The condensation into urban trading assemblies: the first two were in Anatolia and Armenia.) These transition numbers and the underlying related earth process (cold-warm, wet-dry) are so closely correlated that we may reasonably infer that the rising temperature ramp with its attendant hydrological changes drove the relevant species (grasses, ruminators, carnivore predators) into new distributions which in turn resulted in sharp condensations of the human population.

In this transitional Phase II, we must identify the process of condensation that marked the transitional density (not quite settlement) between say 15,000 (to 18,000) ybp to 8,000–10,000 ybp in land occupancy. We are well aware that the terminus period, 8,000–10,000 ybp, marks both the Mesolithic transition and the beginning of the Neolithic revolution that figured so prominently in Childe's brilliant description of the most recent phase of man. But the period we allude to precedes modern take-off. Change within it is not so prominent; its explanation has to be more subtle, perhaps, as we have contended, more physical.

Thus we would tend to look at the condensation process of human society from the point of view of a changing hydrological-climatic picture after 15,000 ybp, in which man, the 'superb' hunter-gatherer, changes his density from population centers of a few hundred people with average 130 km separations to something more crowded. We would tend to believe that the initial diffusion could be programmed on a computer to give a good model fit to existing distributions, given the climatic-geographical-ecological characteristic of the land; and so could the second rediffusion (mixing) and clumping via ethnicity.

Does Culture Matter?

So far this account does not differ significantly from a physicalistic description of the standard (diffusive) foray to be expected of any newly differentiated species expanding into a suitable habitat (in this case the newly connected 'temperate' land areas of the world). Thus to more sharply define (or differentiate) the human species from all other species, we have to underline its definite feature, its capability for a historical 'evolution' of its epigenetic property of tool-making.

Human tool-making was an expression of a newly acquired genetic property, an evolution of handling – computing – internal information by creating the abstraction of 'tool'. Internal information handling itself is an old concomitant of increased cortical capacity, which finally culminates in a single genetic change, the ability to conduct internal – and external – language at neural rates of 10 Hz, presumably (and testably) as a result of the evolution of hemispheric coordination centers. Clearly, the hemispheric differentiations by which speech, percept and cognition are dealt with constitute testworthy 'proof' of the evolutionary novelty of the language capability of modern man (40,000 ybp). That particular new change (that is of the total genetic change associated with hemispheric differentiation, speech, and what has been referred to as a general rapid abstractional ability – see Iberall 1973b) accelerated the epigenetic evolutionary process of tool-making, over the hominid rate of tool evolution.

We can now add one additional purely human character to the mix of ideas. It was surmised in an earlier report (Iberall, Cardon 1973) that technological innovation was essentially linear (with a broad band) over the past 8,000 years.

There is a point illustrated in Prideaux (1973) which is even more striking, and confirmatory (his p. 63). Five major styles of tool manufacture, derived from Cro-Magnon man in France, are indicated by their periods of dominance. Clearly these data are 'linear'. That is – upon inspection of the tool industry – they are basically equal-incremental in providing increased modal capability or power amplification to man. We have plotted the bands, each with a stepwise increment to the next style, and found them basically covering our narrower 8,000 year test of linearity, and furnishing a sense of about 7 classes ('major styles') of tools over the entire 40,000 year history of man (Tab 1). Each class seems to scale at about 6,000–7,000 years. That is, the band width for each tool tradition is about ± 3,500 years up through today. We would attempt to capture the sense of this linear proposition with regard to the brain of the tool-using hominoid, modern man, by the metaphor that we today marvel as much at the constructions of the earliest pyramids and temples (e.g., 5,000–6,000 ybp) as they would marvel at our achievements, and the same sense of marvel would hold between each pair of adjacent traditions. Neither an ancient nor an contemporary tool-user would find the other's engineering a great deal easier than his own, even given knowledge of the detailed cultural heritage that the other worked with. That reciprocity for each pair of traditions is a real measure of linearity. On the other hand, both cultures would view the accomplishments of a prior age – e.g. the capability for preserving and using fire – as archaic, even if deeply representative of man-like characteristics (see Zyelebil 1984).

The historical[10] 'linear' changes in tool-making and hence 'culture' raise the question whether man's process of initial unidirectional diffusion and subsequent remixing might have been influenced by the 'progressive' linear evolving historical property of tool-making [11]. We would tend to surmise that each new tool culture might have influenced (and probably did influence) the history of that particular phase [12].

Indeed we anticipate no serious objection to accepting that, from the Perigardian to the Azilian, each tool tradition had an influence on the life style of that particular phase [13].

The question this assumption leaves with us is: What was the technoligical culture in the 15,000–18,000 ybp time frame (i.e. the Solutrean, transforming into the Magdalenian in western Europe); and how might or did this culture influence the remixing process? If technique influenced remixing at all, then the remixing process would be different for man than for other species [14]. We shall not explore this question here; we simply admit that it exists, as yet unresolved.

Boundary Conditions, Kinetics and Kinematics of the Human Condensation

We have defined a first phase process for man. Hopefully we have set the stage for describing a second phase physical process, one in which man remixes and precipitates into place. Physical modelling likes to have clear the boundary and initial conditions, and the kinetics of the operative field processes that it must deal with. What now are the kinetic character and larger boundary conditions for the human species after its initial expansion? We leave that for a future study.

Footnotes

1) In offering the numerology contained in this paragraph, we have mixed the points of view of the social scientist, with regard to the character of human interaction, and of the physical scientist, with regard to the more general physical properties of the scaling of atomistic interactions.

2) Consider the degree of breed divergence in the horse, in grains, above all in the dog, over periods as brief as 2,000 to 5,000 years. Admitting that these changes were largely driven by (a) human desires, (b) climatic changes, (c) facilitated forms of selection pressure, we contend that man's dispersion into diverse niches was also a powerful "driver".

3) A uniform density expansion would not be implausible in physics. But the value and extent of any animal's available habitat are limited by specific climatic conditions (among others – e.g., access, food, water and predation). It is common for large-bodied animals to achieve a limited range and condense in clumps in a limited number of places (niches). Man, more like insects, expands (in Phase I) to a wide habitat limit, but not at high density. Why? (1) No challenge from any large predators (in particular, after a certain level of total development, he could handle essentially all the possible large predators). Man, himself a small predator, was disease limited rather than predator limited. (This tended to bound his life expectancy to only a fraction of his life span, even with many adaptations; however, such limitation is not unusual for a great many wild species.) (2) Omnivore characteristics including superb predation ability (with tools) that gave him a very wide range of foods. The introduction of fire, ancient by the time of modern man, further diminished toxity of foods. One may infer that the basic limitation on man's habitat were prey density (which for an omnivore is nearly equivalent to biomass density as an index of food availability), water supply, and shelter from temperature extremes: all these are directly or indirectly climate-determined.

4) We assume that the climatic conditions 40,000–15,000 ybp were relatively constant, the trough of the last 100,000 year ice age cycle.
5) There should be no difficulty in speculating that, if breeding pools have become differentiated (via genetic, albeit point, mutations), the tool-using cultures of such breeding pools are also quite likely to have become differentiated. The rates of change need not be the same, but they are quite likely to be at least vaguely comparable: that is, the *ratio* of those rates can only be of some modest magnitude. It will hardly be 1; it is quite likely to lie in the 1–10 range and much less likely to be found in the 10–100 range. This is a notion that we may have to explore in greater detail.
6) To cite one piece of positive evidence, there exist a few drawings and sculpture from the Magdalenian period in France, from about 14,000 ybp (see Van Doren Stern 1969, pp. 101, 158, 159) that (a) suggest specific persons rather than generalized drawings created with abstract artistic license, and (b) that strongly suggest *one* differentiation into 'caucasoid' racial stock. We will not comment on the quality of a few female torso drawings (pp. 162–164) except to invite comparison with drawings of Matisse.
7) This is still infinitely more than the mark of a past generation of birds, or plants, or insects in an area. *Their* mark is even more subtle, smaller, represented by increments in soil, small modifications in patterns of other geological-geographic-climatic processes. Even these are not negligible, however, since (see for example Lovelock 1974 or Hart 1978) by their action they have transformed the surface processes on the earth. The size of the trace is really a matter of time scale.
8) Any 'senior' grown-up of the present has in his or her memory bank the notion that the age of exploration of earth's space (1500–2000 AD) has 'just' come to an end. The exploration of the tropics, the polar expeditions, the conquest of the last tall mountains, the exploration of the ocean depths, etc., are all associated with the near final time slot, perhaps 1900–1950 (give or take one generation).
9) Experience with military environmental physiological problems clearly indicates the central role that operations under these four conditions play in any attempts to move and prepare man logistically for movement over any even modest distance. See Newburgh 1949.
10) To the present; but also out to some future time perhaps capable of estimate, as we have estimated it for a future publication.
11) We emphasize 'progressive' because of all of the processes associated with man this is the only one that has – thus far and for some time yet – a unidirectional arrow of historical change.
12) This is perhaps a proper large scale application of the Marxian thesis that the tools of production determine the mode of production, though neither at the scale nor in the way that Marx and Engels intended. History, which in this picture includes prehistory, is *not* the history of a class struggle between 'owners' of tools and 'users' of tools. Rather it is a species evolution, facilitated – perhaps for the first time, or at least the first time at such rapid rates – by 'epigenetic' change. This theme requires a great deal more biological thought. One would have to explore all other tool users, e.g., insects, birds, to locate and understand tool facilitation, if any, of their history of evolution.
13) At least given the understanding that such influence might be circular, A causing B, and B causing A (but each linked via different processes and time scales).
14) Perhaps not *all* species. The self-limiting character of coral reefs strikes a biological note worth contemplating.

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Summary

The following is a caricature of the dynamics of man at the end of his Phase I constant density expansion on earth (at 12,000–15,000 ybp). It is a physical-physiological summary, offered in the spirit of a 'back-of-the-envelop' physicist's calculation.

Earth's diameter, D – 12,800 km

Earth's surface area, πD^2 – 514,719,000 km^2

Earth's land surface (one-third) – 150,000,000 km^2

Adult weight of man, W – 70 kg

An appropriate mean velocity for 70 kg mammal – 6 km/hr

An appropriate maximum daily roaming range for a 70 kg carnivorous mammal – 30 km

An appropriate group range (habitat) for a hunter-gatherer band – 2,500 km2

An appropriate band size – 100 persons

Effective population density – 0.04 persons/km^2

Total nominal population – 6,000,000 persons

Nominal life expectancy appropriate to a 70 kg mammal (single exponential – approximately 1/3 life span) – 30 yrs

Death rate (= equilibrium population/life expectancy) = 3 persons per year per 100 persons = 0.03 per year

Man's diffusion rate – 1.5 km/yr

Man's expansion rate (see Fig 1 – width of land mass x diffusion rate) = 16,000 km x 1.5 km/yr = 25,000 km^2/yr

Man's final growth rate (Terminal, Phase I) – 1000 persons per year

Malthusian constant (birthrate – deathrate) – 1000/6,000,000 = 0.0002 per year

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