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Human Sociogeophysics – Phase II
The Diffusion of Human Ethnicity by Remixing

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Abstract: The spread of the species, man, on the surface of the earth has been described physically in two initial phases. In a first phase, 40,000–15,000 ybp, man spread to occupy all of the temperate and periglacial regions of the earth as a constant density occupational expansion of about 0.04 persons per sqkm. As of 15,000 ybp, the population might be estimated to be about 4 million, the birth (and death) rate to be about 0.03 per year, and the Malthusian constant (the net increase of population – birth minus death rate) to be about 0.0002 per year. This phase represented a diffusion of ethnicity (breeding populations) with little remixing. In a subsequent second phase, e.g., 15,000–2,000 ybp, through the Mesolithic, Neolithic, and post-Neolithic phases, while condensations to agriculture and to civilizations took place, even though the population grew to about 180 million with considerable remixing, the Malthusian constant effectively did not change. Thermodynamically (that is as the irreversible thermodynamics of a hydrodynamic field), this result suggests that the persisting demography of a viable species has to be driven by a positive definite Malthusian growth constant beyond a zero thermodynamic equilibrium. It is also suggested that if that constant is globally zero or negative, the species will die. The possible existence of various stability regions (transformations in dynamic states) is also implied.

Introduction – the Constant Density Phase I Expansion

In (Iberall, Wilkinson 1984), we outlined the first phase expansion of man *(homo sapiens sapiens)* over much of the life of the subspecies, from 40,000–15,000/12,000 ybp (years before present). We characterized it as a near constant density expansion at the unit density value of 0.04 person per sqkm.

It was possible, from the data presented therein, plus some common knowledge and a few simple ideas, to reason physically-physiologically to an estimate for a most important sociophysical quantity, the net rate of change of population (birth rate minus death rate), whose specific measure we call the Malthusian constant.

The Malthusian constant is the net percentage growth rate of a human population per year. The contemporary human population has recently grown at a net rate of 2 % a year; but it is generally conceded that such rates are biohistorically a recent, probably a transient phenomenon, unsuitable for relating to prehistoric rates of growth.

The assumption of an extended period of constant density human expansion, however, offers a more acceptable source for a biohistorical estimate. We summarize the following (drawn from the description in Iberall, Wilkinson 1984), in the spirit of a "back-of-the-envelope" physicist's calculation.

Earth's surface area is about 500 million sqkm ($13{,}000^2 \pi$ km^2); of this, about 150 million sqkm (one third) is land surface, of which approximately 100 million sqkm lies outside of the deep arctic regions and is "available" for human habitation.

The adult weight of man (the male value) is about 70 kg. An appropriate maintainable mean traveling speed for a 70 kg mammal would be 6 km/hr. An appropriate maximum daily roaming range for an omnivorous mammal with such a speed is about 30 km.

Therefore, an appropriate group range (habitat) for a hunter-gatherer band of such mammals is $30^2 \pi$ sqkm, say about 2500 sqkm.

Given the assumed effective population density of 0.04 person/sqkm, an appropriate hunter-gatherer band size is 100 persons. The given population density of 0.04 per sqkm yields, on a 100 million sqkm land surface, a total nominal near-equilibrium population of 4 million people in perhaps 40,000 bands.

Next we estimate the mortality characteristics of this roaming hunter-gatherer mammal: specifically, the relation between its lifespan and its life expectancy. The human lifespan, about 90 years, is appropriate to a 70 kg mammal. Estimating human life expectancy requires a small note.

Some sources of mortality are age-dependent, others not. The mortality rate M will be determined by a Gompertzian mortality relation $\ln M = a + bA$ where A is age, b the age-mortality coefficient, and a the non-age-related mortality coefficient. In protected civil society, the constant a is small. In the wild (for humans, in the hunter-gatherer society), a is so large as to swamp bA. If bA were zero or negligible, the probability of death at each age would be the same; the fraction of each cohort surviving, plotted against age, would "decay exponentially", as the same percentage of the survivors died in each period; somewhat more than half each cohort would be dead halfway through the lifespan; and the life expectancy would be less than half the lifespan. One would thus surmise that human life expectancy in the wild would be less than half the lifespan, but not inordinately less. One third of lifespan seems a reasonable figure. This would give the roaming hunter-gatherer a nominal life expectancy of 30 years. This is not inconsistent with archaeological and anthropological findings from the stone age to recent times.

The turnover in an equilibrium population P of 4 million with a life expectancy E of 30 years is P/E = 4,000,000/30 = 130,000 persons per year being born and dying. The birth and death rates required to keep such a population constant are therefore 130,000/4,000,000, or 33 per thousand, about 3 % per year, the reciprocal 1/E of the life expectancy.

But in order to have completed the occupation of the available habitat (a process assumed to have taken place at constant density), the human population had to be clearly expanding rather than constant. The birth rate must have exceeded the death rate, a difference which constitutes the net "Malthusian constant" for that epoch. How much must that constant have been?

We have calculated man's diffusion velocity to be on the order of 1.5 km per year (that is on the order of one roaming range, 30 km, per 20 year generation). Since most of the east-west temperate zone expansion had already taken place, say by 30,000–20,000 ybp, one visualizes the final unmixed diffusion as being north-south. An east-west cut across all the available land areas available for north-south diffusion suggests that the 'width' of the diffusional occupation of new territory is about 16,000 km. The diffusion rate thus is about 25,000 sqkm per year.

The new occupation of 25,000 sqkm per year at an effective density of 0.04 per sqkm suggests a final net growth of population of 1000 persons per year. An average net growth of the human population by 1000 persons/year, when compared with the final earth's nominal unmixed population of 4 million, implies a Malthusian constant (birthrate less deathrate) of 1000/4,000,000 = 0.025 % a year, about one one-hundredth of the contemporary growth rate.

The Malthusian constant K loosely is also a reciprocal measure of the "doubling time", D, D = .7/K. Thus the doubling time of the expanding human population was about .7/.00025, on the order of 3000 years. This may be compared with doubling times on the order of a generation among many contemporary populations.

We assumed that there was little remixing among separated ethnic groups up to and during the final phase of human expansion, and that remixing did not become a significant aspect until a second period of settlement, i.e., during what has become known as the Mesolithic, Neolithic, and post-Neolithic periods of culture. We are ready to pursue our physical story of settlement into this second remixing phase. With the initial occupation of suitable habitat completed, some change had to ensue. It might have been in the birth and death rate components of the Malthusian constant, in the population density, or in life style. We intend to use the Malthusian constant to probe at the nature of the change.

Second Phase Growth

We now attempt a simplified physical characterization of the global sociocultural field during what we shall call the second phase growth of the human population, the population increase during the period from 15,000 ybp to say 6,000–5,000 ybp (the period of creation of urban civilizations). We shall ground this, however, upon an estimate in round numbers of the Malthusian constant for a somewhat longer 12,000 year period – roughly 14,000–2,000 ybp – because it is only as of 2000 years ago that we have good estimates of local population for two large land areas, the Han and Roman empires. The better estimate is obtained from the first census of the Han. A comparable (but somewhat smaller) estimate is available for the Roman empire at its peak. Loosely (to one significant figure) both empires had populations on the order of 60 million and land areas on the order of 5 million sqkm. Thus, their average density was on the order of 12 persons per sqkm (McEvedy, Jones 1978).

Judging from urban civilizations, e.g., current distributions in the United States, we are aware that one finds spike-like population density distributions for urban areas and very low density distributions for rural counties outside the cities. Population density distributions around the urban spikes tend to fall off exponentially (Hassler 1977). To take the average density of these empires as the average world population density would clearly be an overestimate, given the concentration of high density population centers in these Empires (which had rather homogeneous cores) and the exponential character of peri-urban falloffs (see for example, *The Cambridge Encyclopedia of Archaeology*, 1980, Fig 32.2 for China at AD 1–2). Let us nevertheless begin by producing such an overestimate.

From the estimated Phase I density of 0.04 persons per sqkm 14,000 ybp to an urban density empire of 12 persons per sqkm 2000 ybp is a three hundred fold increase of population in 12,000 years. If $e^{12{,}000K} = 300$ then $K = .0005$ or .05 % per year. Thus .05 % per year is an *overestimate* of the net population growth rate (the second-phase Malthusian constant) over that period of 12,000 years.

A likely close estimate would be to assign 60 million persons to each of these two empires and on the order of 60 million to all the rest of the world area (mostly in South Asia), or 180 million total estimated population (McEvedy and Jones estimate 170 million). This would bring K down:

$$e^{12{,}000K} = 40$$

$$K = 0.0003 \text{ per year}$$

It would clearly be an *underestimate* to assign 60 million to each of the two empires and nothing to the rest of the world. This would lead to the *underestimate* of $K = 0.00025$.

Despite the gross character of the overestimate and underestimate, the Malthusian constants requires to produce them are of the same order, and on the same order as the first phase constant. If K ranges between 0.025 % per year and 0.05 % per year for this period, lying quite close to 0.03 % per year, we may fairly conclude that during the second phase of mixing and human condensation (not simple diffusion), condensation so intense that local densities changed in some regions as much as 10 to 100 fold, the net growth rate of population did not significantly change. Thus *there is no need to posit a change in net population growth rate as between Paleolithic and civilized humanity.* The entire increase in population density can be accounted for, on the contrary, by positing a fundamentally stable rate of global growth throughout the period – regardless of the fluctuations, remixings and ingatherings – with the fundamental changes involving the closure of the ecumune (complete occupation of the geographic "niche" for man) and the acquisition of an ability to support dense populations in particular territories [1]).

A Physical Model of Second Phase Growth

We propose to seek physical models of social processes. *The social process we now wish to model is, we conclude, not to be described by a global change model but by a model that displays profound local variations during a continuous global process.* During a global expansion of population, of a continuous nature, altered only by the closure of the human niche (in that sense, global change from an open to a closed system), global population moved from roughly homogeneous density to extreme heterogeneity of density. Population spikes formed: dense concentrations and settlements in an otherwise sparse field. Is there a physical analog to such criticality processes that can produce a local condensation – to the social process that eventuates in the formation of settlements, of cities, of "civilization"?

We have described a field process which we have variously called a 'hopping' Brownian motion (a physical characterization – Iberall, Soodak 1985) or a hiving or swarming behavior (a biological characterization). It involves the random walk character of Brownian motion, plus condensation to a center. In another image, one might think of star bursts, the multiple displays of some rocket fireworks. This process may be seen in radioactive decay, in the continuing formation of stars in spiral galaxies, in the initial formation of galaxies (a forthcoming theory of Iberall, Soodak), in speciation whether 'gradual' or 'punctuate' (see, for example, Rose, Doolittle 1983), in first order matter condensation (see, for example, Iberall, Soodak 1985).

What can account for the field process of 'hopping' Brownian motion? Let us consider one such theoretically well developed field process, that which occurs within a nuclear reactor field. The chain reaction in a nuclear field consists of a set of local collisions (condensations) producing star bursts producing further local collisions – overall a swarming, hiving motion. In order for a nuclear reactor to continue it must have a global yield greater than unity. If a nuclear reactor has such a reaction yield *then* local regions can furnish yields significantly greater than unity. The local inhomogeneities of continued hiving requires a global 'pressure' to support it.

The nuclear reactor field process contains within it a general kind of explanation for the field process of hopping Brownian motion, which can then be transferred to analogous hiving processes. The yield 'greater than unity', for instance, is equivalent in a biosphere to a positive definite Malthusian constant (i.e., birth rate at least slightly greater than death rate). In a general sense, where local field processes show persistently sustained hopping Brownian motion, look for a positive definite Malthusian constant in the global field process. *Where a sufficiently positive Malthusian constant is found in a global field process characterized by Brownian random-walk diffusion, extreme local inhomogeneities (hivings, swarmings, condensations to a center urbanizing, evolution) are predictable, and sufficiently explained by detailing the process.*

If one accepts the generality of this type of physical model, then it contains within it the kernel of a real physical theory of demography. If there is a net population pressure globally, however small, then a small *spatial* diffusive growth in population is possible. However, if the field is confined, once the initial diffusive process has filled the available territory, and if the positive growth rate persists (positive population pressure), then there will be local hiving and condensations. Such population condensations can coexist with the hunter-gatherer gas-like state.

The problem that a second order (or 'second' level) physical theory would have to confront is the hiving rate (i.e., number of hivings per unit time), for example the number of radioactive counts per unit time, or the number of population 'hivings' per unit time. Such a second order physical theory of demography would constitute a theory of fluctuations of population in the social field. This, then, is the theoretical background behind the remixing and diffusion problem during the second condensation phase of man's growth on earth.

Theoretical Implications

This relationship between the sustained pressure and a resultant field of fluctuations is not uniquely associated only with living systems. However in this case of its application to human behavior, it leads to further reflections on both human behavior and non-living matter systems. We are hereby suggesting several rather fundamental ideas with regard to evolution or growth of population. First: population pressure for growth (measured by the Malthusian constant) is a real pressure, similar to the physically measurable pressure in a gas; both are socially cooperative processes caused by the interactions of individual entities. In all such cases, the social pressures should be treated as realities, not metaphors (Iberall, Soodak, Arensberg 1980). Why a sustained global population pressure persists is not answered by this theory. It might be presumed to develop from genetic or epigenetic considerations internalized within the species.

Second: in a closed system with expanding pressure, not only will local hivings and swarmings occur; local diminution to zero is also possible, despite and even during such global expansion. Local hivings need not be stable in space or over time; rather sudden swarming and dispersal is quite possible. The global pressure in no way guarantees the stability of the local hivings; the collapse of a local concentration in no way contraindicates or undermines the global process.

Third: despite our finding for the first and second phases, the Malthusian constant for the human population presumably can change, and at times has changed, rather dramatically, at some times. Sustained processes of emigration and immigration tend to even out (reduce to near equilibrium) the field. Still, there may be reason for caution even in the analysis of periods where a change seems self-evident. In their ideas on the demographic transition, demographers are perhaps accustomed to perceive or picture a birth rate running parallel to and significantly above the death rate, while on the other hand (Braudel 1981, Vol. 1, pp. 72–73), for example, depicts matching birth and death rates in particular eras during the 15th to 18th centuries, and points out that "only with the eighteenth century did births gain over deaths". Even then "counterattacks were still possible . . . These alarms showed how precarious was [this] improvement of very recent origin . . . still subject to reverses, still at the mercy of the ever-hazardous balance between the demand for food and the possibilities of making it through production".

Fourth: when the Malthusian constant changes markedly, equally dramatic effects on the distribution of population may be expected. Hiving itself is dependent upon the maintenance of positive global pressure. In its absence the field tends to even out. Zero population growth ought then to result in spotty diffusion of the population through the environment. This suggests that we may have to discuss more phases in the expansion process of man; e.g., the global expansion (east and west) of population after the 18th Century (connected perhaps to startup events in the 16th and 17th Centuries), and the condition of geodemography after that explosion ends.

Fifth: there are thermodynamic consequences of system closure. At *some* time scale it would seem necessarily true that a species (or biosphere) will eventually exhaust any closed environment and accordingly die out 2) more likely it will be caught in an ecumene-wide fluctuation or catastrophe beyond the life-form's ability to adapt, with the same result, extinction. We might suggest scalings: 2500 sqkm territories will support a single hunter-gatherer culture for only a few generations (Iberall, Soodak, Arensberg 1980); 65,000 sqkm territories will show serious deterioration of human culture in perhaps 10,000 years (the Tasmanian experience furnishes evidence of this scale); and 150,000,000 sqkm (earth size) may support high ordered life, perhaps, for a time scale on the order of 10 billion years 3). This scales area with the 2/3rds power of time, a scaling law worth theoretical exploration. *Some* relationship between ecumene area and biotic lifespan must in any event be presumed to exist; likewise between the capacity of a species or biota to enlarge its range and to extend its tenure in the universe.

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1) Another way to view the point is to assert that the global rate of population growth for the human species is not a very sensitive variable over most of history and prehistory, and that sensitivity and variation has been displayed primarily at the local process level. Such a view was implicit in Stevenson's immediate criticism of G. Udny Yule's presidential address to the Royal Statistical Society, in which Yule presented the logistic law of population change. Stevenson recognized that the global law and local law of population could not be described by one theory (Yule 1925).

2) That time scale might depend on its own free convective mixing. (See, for example, Iberall, Cardon 1979.)

3) At the level of large scale earth fluctuations, it is not necessary to invoke a particular or unique catastrophe theory, e.g., collision with a single asteroid. There are many sources of geophysical fluctuations that may affect the lives of species. A number of geophysical processes at continental scale are discussed by Iberall, Cardon 1980. More recently a theory for near 30 million year mass extinctions of living species based on stellar entrainment (by a solar binary) of remote cometary material has been suggested.

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