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THE RISE OF MOUNTAIN RANGES AND THE EVOLUTION OF HUMANS: A CAUSAL RELATION?

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Abstract

Evidence of several types shows rapid and accelerating 'uplift' of essentially all major mountain ranges of the world, albeit each with respect to a different frame of reference. The last few million years of this 'uplift' is simultaneous with the evolution of *Homo sapiens*, an evolution quantified well by an exponential increase in cranial capacity. Apparently, the rise of mountains challenged adventurous hominids with the instinct to strive for increasingly higher goals, and *Homo sapiens*, with steadily swelling heads, survived as the fittest.

It is a bold claim to make of mountains, that they contributed a third dimension of height and depth, to man's intelligence' (George Winthrop Young 1957)

Introduction

The road to scientific truth is paved with grains of fact mined, often at great cost, from ridiculous theories, based on apparent, but false correlations. Thus, a first step surely is to demonstrate that the correlation of two phenomena is significant. Let us consider the apparent and definitely significant correlation of increasing 'uplift rates' with the evolution of *Homo sapiens*.

Not only did the Earth's landscape change rapidly toward the end of the Cenozoic Era, but apparently also the Earth's most advanced animal species, *Homo sapiens*, evolved at the same time. While the rapid evolution of human beings in the last few million years seems undeniable, less appreciated is evidence for contemporaneously accelerating 'uplift rates' of mountain ranges throughout the world.

Every geologist (personal communication, *ad nauseam*) knows that his or her favourite mountain range rose yesterday, geologically speaking. With advances in geomorphology, fission tracks and $^{40}Ar/^{39}Ar$ dating, paleobotany, modern geodesy, and other forms of quantitative geology, we now have the means of quantifying uplift rates of minerals, rocks, benchmarks, mountains, etc. with respect to all sorts of frames of reference: sea level or the geoid, the centre of the Earth, or even the surface of the Earth itself. With this quantification, and ignoring the different reference frames, it is clear that 'uplift rates' of

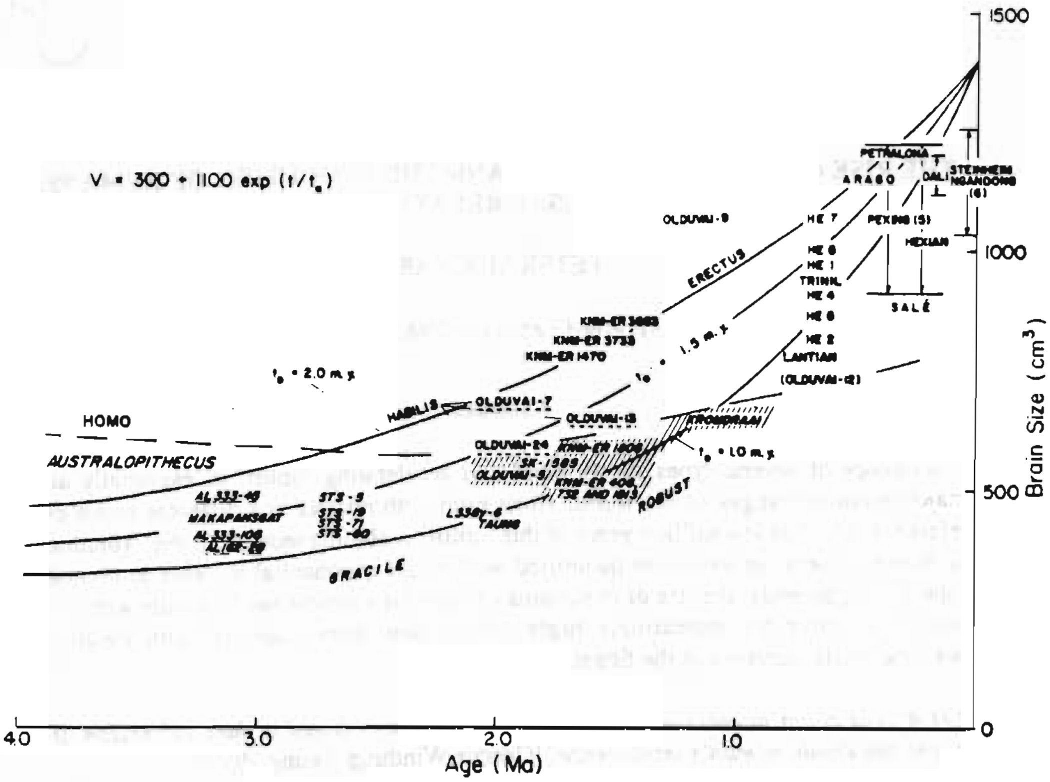


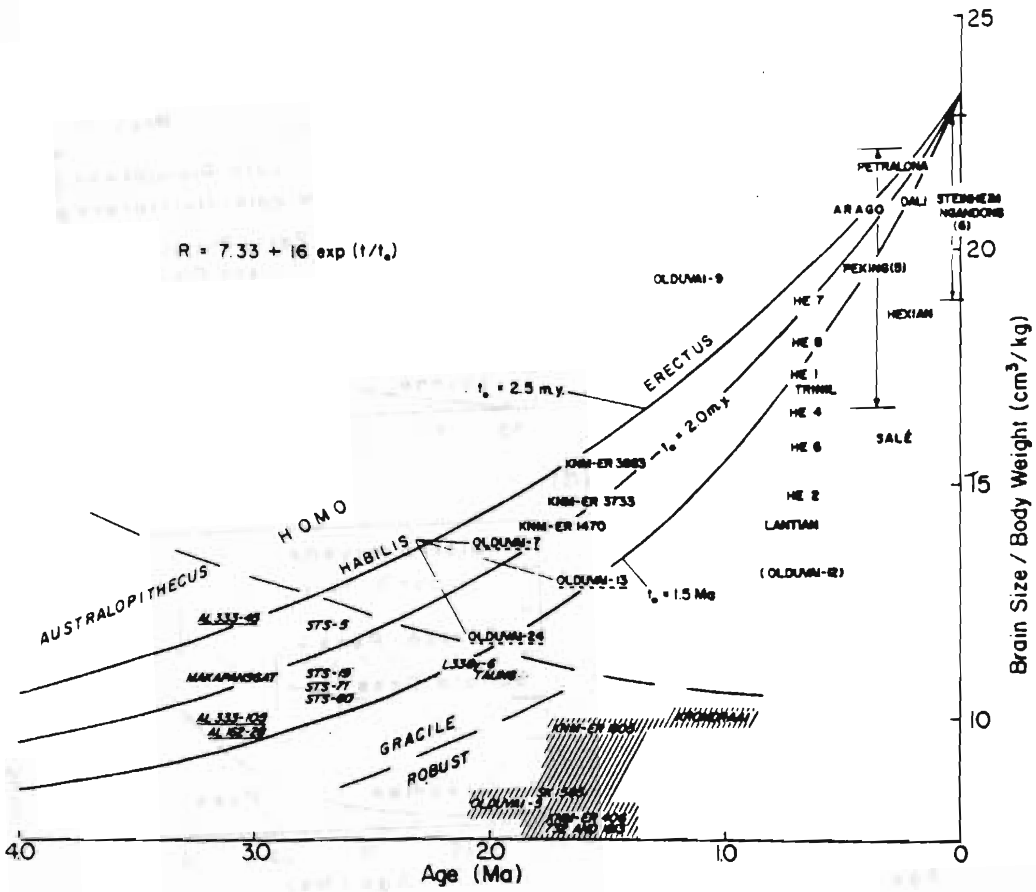
Fig. 1. Plots of measured or cranial capacities (or brain sizes) of individual fossil hominids as a function of their estimated ages, both as individual data (left) and scaled by estimates of body weights (right). Measured brain sizes and ages are given by Day (1986) or Holloway (1970, 1973, 1983a, 1983b). Dashed lines separate specimens of *Australopithecus* and *Homo* genera. Values for *Homo erectus* are underlined by dashed lines; those for robust australopithecines are surrounded by hatching; and for the gracile form, those for *A. afarensis* are underlined, and those of *A. africanus* are surrounded by dots. Average body weights used to scale data in the lower figure are a 40 kg for gracile australopithecines, 60 kg for robust australopithecines, 50 kg for *Homo habilis*, 55 kg for *Homo erectus*, and 60 kg for *Homo sapiens*. Exponential

mountain ranges throughout the world, measured with respect to different reference frames, show a globally synchronous increase.

The implication of the contemporaneity of rising mountains and human evolution is obviously that one may be the cause of the other. Let us present the evidence for both phenomena and quantify their correlation, before discussing their theoretical implications.

Evolution of hominids

The basic framework of Darwinian evolution is widely accepted, and palaeonthropological investigations have revealed a sequence of pre-humans that have evolved through at least two genera, *Australopithecus* and *Homo*, since about 4 Ma, and with numerous possible ancestors in the period 20 to 8 Ma (e.g., Ciochon and Fleagle 1987). Moreover, the fossil record includes highly evolved bipedal primate species (*Australopithecus robustus* and/or *Australopithecus boisei*) that became extinct only 1-2 Ma, presumably because of their inability to adapt or to compete with the more advanced *Homo erectus*. The successes of Darwin's theory and of recent palaeoanthropological investigations are undeniable, but among the important unanswered questions is: Why did the species *Homo sapiens* evolve when it did?



curves, passing through 1400 cm³ (top) and 23.33 cm³/kg (bottom) for *Homo sapiens* at present and asymptotically reaching back to 300 cm³ (top) and 7.33 cm³/kg (bottom) are shown for different time constants. (Implicitly I assume that *Homo sapiens* did not evolve rapidly from a totally brainless creature.)

Choosing a date for the beginning of hominid evolution can be somewhat arbitrary, and the paucity of hominid fossils dating from roughly 8 to 4 Ma renders any inferences of the earlier ancestors of *Homo sapiens* speculative (e.g. Ciochon and Fleagle 1987, Lewin 1984). All fossils of hominids with ages between roughly 4 Ma and about 1 Ma have been found in Africa, and all species of the genus *Australopithecus* and the initial species of the genus *Homo*, *Homo habilis*, seem to have evolved only in Africa. Moreover, simultaneously with the emergence of the genus *Homo*, at least one species of *Australopithecus* became extinct (Leakey and Walker 1976). *Homo sapiens* apparently then evolved within the last half million years, but by 0.5 Ma, *Homo erectus* had dispersed throughout the eastern hemisphere, later to be recognized as fossils in Europe and Asia (e.g. 'Peking man', 'Java man', etc.).

How is one to determine the significance of the appearance and evolution of these creatures, *vis à vis* 'uplift rates'? The most distinctive attribute of modern *Homo sapiens* is its large cranial capacities, or brain sizes. A rapid growth in brain size of *Homo sapiens* and its ancestors (Day 1986; Holloway 1970, 1973, 1983a, b), whether treated as individual data or scaled by their average body weights, reveals a rapid increase in its capacity for intellectual profligacy since 4 Ma (Fig. 1). For both,

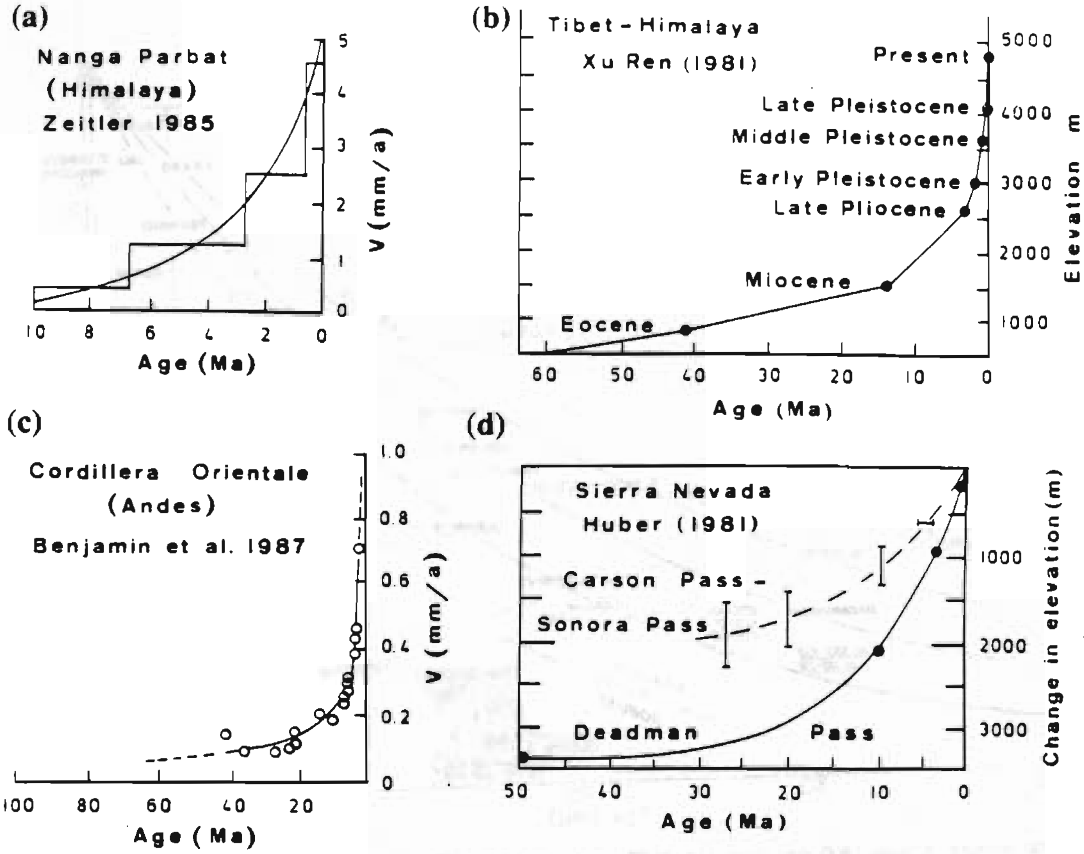


Fig. 2. Inferred 'uplift rates' from four regions and based on different types of data: (a) Pakistan Himalaya based on fission-track and ^{40}Ar/^{39}Ar ages (from Zeitler 1975), (b) southern Tibet and north slope of Himalaya based on Palaeobotanical finds (from Xu Ren 1981), (c) Cordillera Orientale of the Bolivian Andes based on fission-track ages (from Benjamin *et al.* (1987), (d) Sierra Nevada, California, based on geomorphogical observations (from Huber 1981), who showed the inferences of Slemmons *et al.* (1979) also.

exponential functions with time constants of a couple of million years fit the growth of cranial capacities. The steeper curve for cranial capacities scaled by body weight is a result of the growth of average body weight of hominids over the past 4 Ma.

These curves, thus, serve as quantitive standards against which causally related, quantifiable phenomena should be compared.

The evolution of mountains

The evidence for uplift of mountain ranges contemporaneous with human evolution derives from different approaches, each with its own reference frame and sources of uncertainty. Different procedures allow measures of the rates or former positions of rocks and minerals with respect to the Earth's surface, of benchmarks with respect to the geoid, of fossil habitats with respect to present day climates (presumably controlled largely by elevation), etc. Let us ignore climatic change and other astronomical phenomena; let us avoid the semantic distinctions between the mountains and the rocks comprising them; and let us ignore the short wavelength variations associated with the approximation of the Earth's surface by discrete benchmarks on it. Thus, by equating uplift of the Earth's surface relative to sea level and relative to itself, we follow the customary tradition of ignoring distinctions among uplift rates, regardless of their reference-specific frames. Nevertheless, we use 'uplift rate', with quotation marks, as a reminder that we may have ignored subtle distinctions that could be important (for instance, the sunspot cycle).

Himalaya

Gansser (1981) ascribed the sharply incised landscape of the Himalaya, with its deep canyons separating the grandest mountains of the world, to the most recent, 'morphogenic', tectonic phase. During this phase, unusually rapid uplift of the chain was the dominant factor affecting the landscape. More suggestive, quantitative evidence for rapid 'uplift' derives from ages of different minerals with differing blocking temperatures, either for fission tracks or for argon retention. Zeitler's (1985) extensive dating of samples around Nanga Parbat (though this is structurally unusual) yielded an accelerating 'uplift rate' over the past 10 Ma (Fig. 2a), with the average rate reaching a maximum of 4.5 mm/a since 0.7 Ma. Although his average rates for nearby areas are lower, they too show an acceleration during the past 10 Ma.

Accelerating uplift of the Himalaya is implied also by paleobotanical finds from southernmost Tibet. Pollen and spores of plants that presently flourish at elevations of 1000-3000 m have been discovered in late Miocene, Pliocene, and Pleistocene sedimentary rocks now at elevations of 4000 m and higher (e.g. Xu Ren 1981, Guo Shuang-xing 1981, Mercier *et al.* 1987). Xu Ren (1981) inferred that the rate of uplift accelerated from 0.04 mm/a in early Tertiary time, to about 0.1 mm/a in late Miocene/Pliocene time, to about 1 mm/a in Quaternary time (Fig. 2b). He inferred that the whole of the Tibetan plateau rose along the curve shown in Figure 2b, but Mercier *et al.* (1987) showed that a regional separation of the data suggests that the uplift of Tibet would have been a little slower.

Clearly, the application of present day environments to fossils deposited when climates were different and unknown makes the assignment of present to past elevations risky. Nevertheless, the remarkably high altitudes of 5700/5900 m of late Pliocene sediment containing spores and pollen of tropical forests, which now grow at 250-3000 m, probably cannot be ascribed solely to climatic change, and therefore would seem to indicate some recent uplift.

Andes

Fission track ages from the Cordillera Orientale of Bolivia reveal an accelerating 'uplift rate' of these rocks (Fig. 2c), approaching 1 mm/a (Benedict *et al.* 1987). This acceleration is qualitatively consistent with the history of denudation reflected by deep Mio-Pliocene stream incision in northern Chile and presumed to result from recent 'uplift' (Hollingworth and Rutland 1968, Rutland *et al.* 1965). Similarly, from the range of altitudes where late Miocene ignimbrites are widespread, Audebaud *et al.* (1973) inferred a rising of the Peruvian Andes (of roughly 4000 m) since deposition was taking place on presumably very gentle topography.

Sierra Nevada

Geomorphological surfaces, dated by the ages of volcanic rocks that cover them and that subsequently have been incised, indicate an accelerating 'uplift rate' (Fig. 2d) (e.g. Christiansen 1966, Dalrymple 1963, Huber 1981, Slemmons *et al.* 1979). Drainage before about 10 Ma crossed the Sierra Nevada from east to west. In their lower reaches, the ancient stream beds have been fossilized by 10 Ma volcanic flows and tuffs. The gradients of these ancient stream beds are much greater both than those of the presently flowing rivers, and than the probable gradients at 10 Ma. For instance, Huber (1981) noted that the present gradient of 22.3 mt (mt is millitilt, a gradient of 1 m/km) for one such stream, the San Joaquin River, is much steeper than the likely gradient of about 1 mt when a large, meandering river deposited alluvial gravel now overlain by the vocanic rock. Thus, a large westward tilt of the Sierra Nevada apparently occurred since roughly 10 Ma (Christiansen 1966, Huber 1981). From the presence of roughly 3.5 million year old basalts along the walls of deep canyons, Dalrymple (1963) and others inferred that uplift was well underway by that time. Huber (1981) argued that the steep slope of a Pliocene formation in the foothills of the Sierra Nevada was due to a tilting of an initially gentler slope. From the estimated tilt, he extrapolated 100 km eastward an uplift of 950 m of the crest of the Sierra Nevada since about 3.5 Ma, and, by similar logic, a smaller, but significant uplift since 0.6 Ma. His inferred uplift history shows an accelerating rate (Fig. 2d).

Other ranges

In addition, geomorphological evidence from the Alps (Trümpy 1973), from the Pyrenees, from the High Atlas of Morocco (de Sitter 1952), and from the Tien Shan (or 'Heavenly Mountains') in Asia (Krestnikov *et al.* 1979) has been used to infer recent rapid 'uplift' of these ranges.

Time correlation

The growth of cranial capacity (Fig. 1) clearly tracks closely the uplift of mountain ranges (Fig. 2), even if the 'uplift rates' of the various mountain ranges differ by a factor of two or more. A perceptive reader might be concerned that cranial capacities are measured in units different from those of mountain ranges, but obviously the volume of rock that has risen above sea level would increase if the mountains themselves rose, and the distinction between cm^3 and km^3 is merely one of scale, not dimension.

Thus, the correlation in time of brain size and 'uplift rates', if less convincing for uplift rates, of mountain ranges is firmly established.

Cause and effect

In seeking a cause and effect relationship, let us first prove that the evolution of human beings is not responsible for the rise of mountains.

The accelerated erosion caused by human activity might seem to be a cause of increasingly rapid denudation, of an accelerating incision of canyons and, therefore, of an apparent increase in uplift rate. Although logically sound, this suggestion cannot be the explanation for the global synchroneity of rapid 'uplift rates'. First, the complete lack of hominid fossil finds from the western hemisphere suggests that such animals simply were not there when the Andes and the Sierra Nevada rose. Secondly, the evolution of the genus *Homo* from *Australopithecus* being confined to the African continent, when mountain ranges on other continents were rising, seems to absolve hominids of responsibility for these high chains. Thirdly, and perhaps most importantly, the rise of modern mountain ranges seems to have begun before 10 Ma, well before the first hominids walked erect. The oldest fossil species that walked erect seems to have been *Australopicus afarensis*, some 3 to 4 Ma (Johnson and White 1979, Leakey and Hay 1979). Thus, late Cenozoic uplift began several million years before the genera *Homo and Australopithecus* emerged, and in geographical regions to which *Homo sapiens* later immigrated.

By *reducto ad absurdum*, it seems most probable that rise of mountains led to the selection from their predecessors of strong, fervent *Homo sapiens*, those with a 'zest for life', stimulated by the attractive, if challenging, new mountainous habitat.

The possibility that the rise of mountain ranges triggered, or caused in some way, the evolution of hominids is not without inconsistencies. The mountain ranges that seem to have risen recently lie far from the loci of hominid evolution in Africa. Thus, if there is a causal relationship, either the concentration of fossil hominids in Africa constitutes a sampling bias that has failed to reveal other centres or sources of hominid evolution, or the impact of mountainous topography came later in the evolution of the genus *Homo*, when it had already migrated to Europe and Asia. Indeed, considerably more effort has been devoted to searching for hominids in Africa than elsewhere, thus recursively high-grading their apparent concentrations in Africa. Nevertheless, it is the latter of these possibilities that seems more worthy of pursuing.

Notice that if rates of 1 to 2 mm/a were to characterize uplift in Europe and rates of 4-5 mm/a were appropriate for the Himalaya, then all of the mountains throughout the world would have formed since hominids walked erect, and roughly half of the present elevations of the respective mountain ranges could have developed in the last million years. Such a change clearly would have affected the landscape enormously, and no hominid could have failed to notice this.

For stronger evidence that morphological changes in the landscape, with the formation of high, spectacular mountain ranges, affected the evolution of humans, we must transfer our attention to the broad vein of cultural anthropology. Indeed, there is an enormous tradition in human cultures that pays deep respect to, and holds great affection for, mountains, mountain ranges, and high plateaus. In many societies, the gods inhabit the mountains, such as Zeus's Mount Olympus or Shiva's hair in the headwaters of the Ganga in the Himalaya. Some of the world's great ancient civilizations developed in the mountains, such as the Inca in the Andes, or the Tanguts, Tibetan-style people who conquered the old Chinese capital city Chang-an (Xian) in the 8th century (Snellgrove and Richardson 1980). Mountains have always been a refuge, whether for Carthusian monks in the Chartreuse in the Alps, the Afghans in the 1980s, or private citizens on vacation. Moreover, nearly all of us who have travelled among indigenous mountain peoples have been impressed by the hospitality and the overall human concern expressed by these seemingly 'higher beings' for their fellow humans. Finally, a literature survey of writers of the last century indicated that the individuals in Western countries who have responded most to the lure of the mountains are those with a thirst for new experiences and the unknown, those who not only respond to natural challenges, but who, for whatever 'pointless objective' (Shipton 1938), seek them.

Thus, if the evolution of mountainous terrain is an important contributor to the evolution of humans, I suspect that the cause lies in the selection of those strong early *Homo sapiens* with a zest for life and a curiosity of the unknown, from others who preferred to laze at home in the lowlands where, granted, life was easy, but unchallenging.

Future problems

One strong note of caution is called for, however. Clearly a continued uplift of mountains, with the consequent expansion of brain sizes, threatens *Homo sapiens* with certain extinction. Taking as a typical density for brains of 10^{-3} kg/cm^3, the dimensionless ratio of brain weight to body weight will reach 1, when $t/to = 4.13$, or at $t = 8^{+4}_{-2}$ million years (Fig. 1). This is a 'critical time', for at this stage, all human appendages will have become assimilated by the brain, thereby transforming humans into pure processing units with neither input nor output devices. For instance, they will lack relatively dense teeth needed for mastication of constructional body input. More seriously, the cranium itself either will be transformed to brain, making 'boneheads' of them all, or will disappear, leaving them with soft heads. Hence, humans will basically have grown too intelligent for their own good, where 'good' certainly must include the apparatus and capability of carrying out the necessary functions for species continuance. Even before this 'critical time', humans probably will have lost the capability of defending themselves against other predators.

Ironically, at nearly the same moment in the history of the Earth when humans have developed techniques to recognize the impact of the uplift of mountains on hominid evolution, they have, perhaps through a higher form of natural selection than Darwin imagined, cleverly begun to reverse this trend toward imminent extinction. The impact of human development on the environment, though much criticized for its disruption of the landscape, may in fact be a Darwinian response to the increasingly swelled heads of *Homo sapiens*. If continued, the accelerated erosion, brought on by deforestation, clear cutting, strip mining, overgrazing, road building, destruction of vegetation by acid rain, fires, development of ski resorts, and other brutal methods of removing vegetative cover (Neustadtl 1987), will destroy the mountains faster than they can form, and hence diminish the rate of uplift.

Although deforestation began more than 2000 years ago in Greece, Phoenicia, and

China, its rescue of *Homo sapiens* became apparent only in the twentieth century with the growth of modern clinical psychology. This systematic diminution of cranial capacities, better known by the non-technical term 'head-shrinking', not only offers proof of the cause and effect relationship between the rise of mountains and the evolution of humans, but also of psycho-socio-Darwinism applied to the mountains. Thus, we all should be glad that the recent attention focussed on increasing 'uplift rates' is a passing fad that will lead to a more rigorous analysis, and a more careful monitoring, of both uplift and subsidence of the Earth's surface.

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