Table 1: Lengths of isolation intervals and ages and delta increases of Sahara temperature when summers occur at perihelion, as plotted in Figure 10. The savannas occur following the perihelion maximum of insolation, after each isolation interval in column 2.

Age (ka)	isolation interval (ka)	delta (˚F)	Age (ka)	delta (˚F)	Age (ka)	delta (˚F)
12	71	4.2	34	3.0	808	3.9
83	22	5.2	61	3.5	826	4.1
105	22	5.8	151	4.2	845	4.4
127	71	6.3	175	5.4	865	5.3
198	22	6.8	267	3.5	886	4.5
220	22	7.0	292	5.3	906	2.9
242	72	5.3	354	2.6	938	5.3
314	20	5.6	371	2.7	959	7.6
334	76	5.4	389	3.1	980	6.7
410	75	4.0	429	3.0		
485	21	5.8	446	2.8		
506	73	5.4	465	4.7		
579	21	7.1	528	3.4		
600	21	7.0	557	4.2		
621	72	5.9	650	3.1		
693	21	6.6	672	5.6		
714	74	5.6	735	3.9		
788	?	4.8	751	2.4		
			770	3.1		

was converted into a broad savanna by somewhat stronger West African monsoons. Stronger monsoons were generated by atmospheric pressure differences larger than today, caused by increased heating of northern Africa relative to the ocean area to the southwest. But savannas could only occur in the glacial climate cycle after the Eurasian deglaciations were completed, thus ending the extreme aridity of the coastal zone with monsoon strength still somewhat greater than today.

The separation between brief pluvial intervals ranged from ~20 ka to ~76 ka during the Pleistocene because deglaciation of the Eurasian ice sheet was sometimes incomplete when ice sheet growth resumed. Similar variations probably occurred through much of the Pliocene. During the brief times of savanna connections, the genetically altered populations of the coastal zone would increase their numbers, extend their range into the larger Africa, and mingle with the then currently un-modified population south of the Sahara. The precise way by which speciation occurred is a subject of speculation. An isolation interval of only ~20 ka may be too short to evolve the unique characteristics of a new species, and cross breeding with the larger unmodified population in the greater Africa and the coastal zone after the savanna connection was made could have diluted the genetic changes and altered the combined larger population only slightly, with resulting slow evolution. Even the longer intervals of ~76 ka might not have been an adequate length of time. But a population having relatively unchanged new genetic characteristics would likely have remained in the coastal zone during the brief times of savanna connections. If so, the accumulation of new characteristics would have continued there through multiple cycles until reproductive isolation enabled the preservation of a new species in the fossil record south of the Sahara. The cyclic isolation of earlier hominids in the coastal zone may have started with savanna-like connections soon after 4.2 Ma BP near the beginning of the Pliocene when the Mediterranean Sea was reconnected to the Atlantic[2]. Soon after 3 Ma BP the evolution of the isolated hominids would probably have been accelerated when longer intervals of environmental stress were brought on by the onset of large-scale glaciations. Without this four million year-stream of evolutionary pulses from the coastal zone, the earliest species of *Homo* precursors might well have remained comfortably adapted to the more equable environments south of the Sahara, and never have evolved to the *Homo sapiens* level.

9.3 Concluding remarks

The concept of cyclic evolution in the Moroccan coastal zone, based on orbital effects, embodies a repetitive refuge in which hominid evolution occurred over most of Plio-Pleistocene time. It is an especially attractive explanation for the *Homo* family and its predecessors who seem to have lived on savannas like the dry environment of the coastal zone. The environmental climate factors varied broadly and repeatedly within each climate cycle because of Heinrich-like events that usually originated in Canada and because of orbital effects on African monsoons. Permanent hominid adaptations to any one special food or any other way of life were not likely.

The cyclic evolution concept also offers answers to the questions posed in the introduction of this paper: (1) Why did hominids evolve in Africa and not elsewhere in the world? Only in the Moroccan coastal zone would have been found the repetitive conditions of a small and confined population in highly stressful environments during the last 4 Ma. In a dry and sometimes quite arid environment, competition between tribal elements within the hominid population for scarce resources may have been a guiding factor during the cyclic evolution. If so, only in the Moroccan coastal zone would the critical selective factors of physical ability, mental ingenuity, and social cohesion have been applied repeatedly to small hominid populations. Each successive climate cycle therefore offered the possibility of developing those traits to a greater extent. (2) Why did apes and other primates that might have shared the coastal zone at the beginning of each isolation fail to evolve like the hominids? In that isolated environment, starvation would have been an ever-present threat. Therefore, any competitors that could be successfully hunted would have been viewed as prey, and may have been eliminated early in each cycle after the isolation began.

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