Panel 5: Pliocene-Pleistocene (5.33 Ma to now)

During the Messinian (the last stage of the Miocene) the connection between the Atlantic and the Mediterranean was closed off by tectonic uplift. As would be the case if the same thing happened today, the rivers flowing into the Mediterranean could not replace the water lost by evaporation, and with its Atlantic connection blocked, the Mediterranean Sea slowly evaporated, becoming a desert a mile or more below sea level! Rivers entering the Mediterranean basin, like the Nile, eroded deep canyons, cutting down to the desert floor. At 5.33 Ma Atlantic water spilled over into the deep basin, catastrophically eroded a new entrance at Gibraltar, and suddenly refilled the Mediterranean Sea. This refilling event is used by geologists to mark the beginning of the Pliocene Epoch.

Since the time scale **(A)** is regularly updated and improved, its divisions can change. For example, in GTS 2004, the Pliocene-Pleistocene boundary was placed at the end of the Gelasian stage; after much deliberation, in GTS 2012 it has been moved to the beginning of the Gelasian. The numerical calibration of time-scale divisions can also change on the basis of new and improved radiometric dating. As opposed to the subjective periodizations of history used by historians of written history (e.g., "Renaissance," "Industrial Revolution"), time-scale construction in geology is rigorous, quantitative, and based on standard procedures accepted by geologists everywhere, and is constantly being improved.[1]

The gradual cooling of Earth's climate since the Late Cretaceous (Panel 3), and since the early Eocene temperature maximum (Panel 4), has led finally to glaciation in the Pleistocene. This is shown clearly in the oxygen isotope ($^{18}O/^{16}O$) record from the tiny shells of benthic (bottom-dwelling) single-celled foraminifera[2] **(B)**. Three regimes have been recognized in the Pliocene-Pleistocene record of temperature and ice volume: (1) In the Pliocene there was nearly constant temperature with a slightly noisy signal. (2) In the Gelasian and most of the Calabrian the average temperature declined slightly, with symmetrical fluctuations having a 41-kyr (41,000) period; this is the period of the obliquity (axial tilt) of the Earth's rotation axis. (3) For about the last 1 Myr, the fluctuations have greater magnitude and a 100-kyr period, which is the period of Earth's orbital eccentricity. These fluctuations over the last 1 Myr are asymmetrical, with slow increase in ice volume followed by a sudden warming and melting. The asymmetry probably reflects the fact that covering Canada with ice is a slow process because all the snow has to be brought in as evaporated sea water, and ice accumulation is constantly reduced by flow of the glaciers to lower, warmer areas where it melts; by contrast, there are no restrictions on how fast glaciers can melt if the climate warms.

The original way of dating rocks was by paleontology. Fossils allow you to put rocks into chronological sequence, and to say that a particular fossil and the rocks that contain it are of Pliocene age, for example. In the 20th century, geologists learned how to date some (but not all) minerals, and the rocks that contain them, in years before the present, based on radioactive decay. Beginning in the 1960s, a third method was discovered, based on the fact that the Earth's magnetic field preferentially aligns close to the Earth's rotation axis, occasionally reversing from pointing roughly north, as it does today (N = normal polarity) to pointing roughly south (R = reversed polarity). The resulting geomagnetic polarity time scale is now an important tool for Earth historians.[3] Much early work on the geomagnetic polarity time scale was done on the Pliocene-Pleistocene, where originally four polarity zones were recognized **(C)** — Brunhes (N), Matuyama (R), Gauss (N) and Gilbert (R). Subsequent work showed that there were shorter intervals of the opposite polarity in each of these zones except for the Bruhnes, and eventually a new scheme was developed that numbers polarity chrons from C1 (Brunhes and part of the Matuyama) back to C33, in the Late Cretaceous, before which there was the Cretaceous Long Normal Chron.[4] Although the named intervals do not go back farther than the Gilbert, those four names are still used in the study of early humans by paleoanthropologists.

Paleoanthropology **(D)** is particularly difficult because of the rarity of these "hominid" fossils and the impossibility of extracting DNA from any but the most recently extinct lineage, the Neanderthals.[5] There is little agreement on the genetic relationships; the one shown here[6] is by no means universally accepted. Two famous fossils are critical for understanding human origins. Lucy (*Australopithecus afarensis*, 3.2 Ma) showed that walking upright came before our large brain.[7] Ardi (*Ardipithecus ramidus*, 4.4 Ma) has a strange big toe showing that climbing trees came before walking.[8]

An important result of careful and detailed paleoanthropologic research is the recognition that human ancestors lived exclusively in Africa until less than 2 million years ago. The fossil record is now interpreted as showing two separate "Out-of-Africa" migrations. **(E)** The first migration, beginning about 1.8-1.7 Ma, led to the widespread occupation of Eurasia by *Homo erectus* and its descendants. A second migration, beginning about 60 thousand years ago, has spread *Homo sapiens* all over the globe. These migrations should not be thought of as intentional exploration and colonization, but as the very gradual and unintentional spread of people over thousands of generations.[9]

Among the features that make us human **(F)** are language, tools and the use of fire.[10] Sadly, language before writing has left no trace, and languages evolve so rapidly that hypothetical ancestral languages reconstructed on the basis of comparisons between modern descendent languages are useless back beyond a few thousand years. Stone tools[11] are the basis for archaeologists' time-scale units, like Paleolithic and Mousterian. Intentional fire use may be the most uniquely human activity, but the evidence[12] is very scant and uncertain until the last few hundred thousand years (Panel 6).