Panel 4: Cenozoic (66 Ma to now)

Beginning with the Chicxulub impact and mass extinction 66 million years ago, this panel shows the entire Cenozoic Era, during which mammals dominated the land fauna. The Geologic Time Scale 2012 **(A)** shows the division of the Cenozoic into periods, epochs, and stages, based on fossils and now dated radiometrically.[1] These subdivisions continue back through the entire Phanerozoic, although the stages and even the epochs are too brief to show on the preceding panels. The divisions in the GTS-2012 at first look like the divisions historians apply to Human history — Renaissance, Enlightenment, etc., but are in fact very different. The humanistic divisions are subjective, and can be used in different ways by different authors; there is no general agreement about the exact meaning of these terms. By contrast, each formal subdivision of the Geologic Time Scale has been fixed by the international geologic community after long, rigorous discussion, and its base is defined by a physical marker in the best available sedimentary rocks of that age.

The polarity of the Earth's magnetic field **(B)**, either normal – pointing near the north rotation pole as at present, or reversed – pointing near the south pole, has provided an additional way to calibrate the geologic time scale, and is also formally specified in the GTS. The sequence of polarity chrons is well known through the Cenozoic, and with lesser resolution back through the Phanerozoic, interrupted by at least one long normal and one long reversed chron, normal in the Cretaceous and reversed in the Carboniferous-Permian.[2]

Probably the most important Big-History trends of the Cenozoic were the rise of primates, leading to humanity, and the gradual cooling **(C)** from the very warm Eocene to the current glacial age. The ratio of the two oxygen isotopes, ^{18}O and ^{16}O, in marine fossils reflects the ocean temperature, because the ratio of ^{18}O to ^{16}O incorporated in shells varies with water temperature, and because ^{16}O is preferentially evaporated from the ocean surface and stored in glaciers, enriching the ocean in ^{18}O. There are many data sets of oxygen isotopes in marine fossils of different ages, from different kinds of fossils and different geographic and depth settings. One such set, compiled by E.L. Grossman and used here,[3] clearly shows the Cenozoic temperature decline.

Cenozoic geological events **(D)** were dominated by ongoing dispersal of the fragments of the Pangea supercontinent, which began in the Jurassic (see the zoomable maps in Panel 3). Because continents cannot disperse indefinitely on a spherical planet, collisions must take place. Collision between Africa-Arabia and Eurasia closed off the western Tethys, generating the Alps and the Zagros Mountains of Iran, and the jostling of microplates and small continental fragments, like Corsica and Sardinia, in the collision zone has produced the complex small seas and mountain belts of the Mediterranean. The greatest collision was between the rapidly northward-moving Indian continent and the south margin of Asia. This collision, dated in different places and by different methods as 60-50 Ma,[4] has generated the enormous elevated zone of the Himalayas and Tibet, which continue to deform today, because collision slowed but did not stop the India-Asia convergence.[5]

As explained in the drawing, the temperature decline during the Cenozoic may have resulted from geologic events, like uplift of plateaus and changes in ocean circulation, but these have proven very hard to date.

During the late Miocene Messinian stage, tectonic uplift closed the Gibraltar inlet and resulted in evaporation of the Mediterranean Sea down to a deep desert, as discussed in Panel 5.[6] When the Atlantic Ocean broke through the Gibraltar barrier, the deep Mediterranean desert suddenly refilled, at 5.33 Ma; this event is taken as marking the start of the Pliocene and the next panel.

Following, in our Big-History way, the branches of the tree of life leading to humanity **(E)**, we see the history of primates leading to *Homo sapiens*. In this DNA-based reconstruction, the branching from the ancestral mammals to the many modern orders, including primates, took place in the middle of the Cretaceous (Panel 3), earlier than the time covered by this panel, which thus begins well along in the evolutionary sequence of the primates. However, DNA-based trees are more reliable for the pattern of relationships than for the dates of the branching nodes, which rely on the questionable assumption that the rate of mutations is constant.

Based on reliably-dated fossils, there is a striking Cenozoic increase of the maximum size of mammals **(F)**, rising from around 50 kg in the Paleocene to 15,000 or more kg in the second half of the Cenozoic. This is generally attributed to the K-Pg mass extinction at 66 Ma having removed the dinosaurs, thus freeing the mammals to occupy the large-animal niches.

In contrast to the DNA-based evolutionary tree, the evidence from well-dated fossil mammals places the main divergence, and the origin of mammalian orders like the primates, in the Paleocene and Eocene **(G)**. The details are controversial, because the earliest Cenozoic mammals were tiny and their fossils, especially teeth, must be collected on fine-mesh screens, and because suitable fossil-bearing sediments are largely limited to eastern Montana. It is striking that the evolutionary burst of the early Cenozoic mammals immediately followed the extinction of dinosaurs at 66 Ma. Another extremely significant biological event occurred in the late Oligocene and early Miocene, with the spread of grasslands, which now cover about 40% of the land surface.[7] Grass has been important in feeding large numbers of herbivorous browsing animals. The appearance of Genus *Homo* took place about 2.5 Ma and is shown in detail in Panel 5.