Geological Time Scale, Rock Dating, and Fossils

A. Rocks and fossils

1. Types of rocks — igneous, metamorphic, sedimentary
2. sedimentary in layers, sometimes with traces of what look like organisms
3. uniformitarianism — principle that processes happening today happened in the past and will happen in the future
4. people noticed, starting >150 years ago in England, as railway grades were cut, that some rock was layered, and that traces of what looked like organisms were in the rock. They also noticed that the further they dug down, the less the traces of organisms looked like the organisms found on the planet today.
5. By comparing known graves with traces of what looked like organisms, people came to the conclusion that in fact the traces were or organisms that had previously lived. Archaeology provided the link between present day life and rock-fossils (fossil: trace of living organism)
6. People studied fossils extensively for the past ~150 years. They dug carefully through rock layers, and noticed that some fossils disappeared, others came into being. These so-called paleontologists divided the history of life-bearing rock into Eras, Periods, and epochs.
7. The eras, periods and epochs are divided by "extinction events", a place in the rock where few (epoch), more (period) or many (era) species disappeared from the rock. Here is the Geological Time Scale. **(SHOW OVERHEAD)**
8. In the past 50 years or so, people have been able to put absolute time dates on these boundaries due to radioactive dating.

B. Radiodating

1. Radioactive decay unaffected by any known physical or chemical process — and people have really tried, because it would make them really famous.
2. Half life: given a certain quantity of a radioactive substance, 1/2 of the amount will decay into something else in a certain set period of time. 1/2 of the rest will disappear in the same amount of time. This is called the half-life of the substance, and it is a constant. This is just like exponential population growth, where the population of, for instance, the Untied States, doubles every 40 years — except that nothing short of nuclear processes affects radioactive decay, whereas lots of things might affect population growth.
3. Equation for radioactive decay, which is the exponential decay equation: $N_0 = N_t e^{rt}$ where N_0 is the amount of the substance at time 0, N_t is the amount at some time t in the future, e is 2.718281828 (base of natural logarithms), r is the decay constant (proportion that decays in a single time unit) expressed in the same units as t, and t it the number of time units between time 0 and time t. If you solve this equation for t, you get: $t = \frac{1}{r}\ln\frac{N_0}{N_t}$. $(N_0 = N_t e^{rt} \equiv \frac{N_0}{N_t} = e^{rt} \equiv \ln\frac{N_0}{N_t} = rt \equiv \frac{1}{r}\ln\frac{N_0}{N_t} = t)$

4. For instance, for $^{87}Rb \rightarrow ^{86}Sr$, one atom in 70,422,535,211 decays each year. The inverse of 70,422,535,211 is the decay constant, $1.42x10^{-11}$ (i. e., the decay constant is 1/70,422,535,211). If we find a rock that has 3% ^{86}Sr and 97% ^{87}Rb, and we are sure that all the ^{86}Sr came from decay of part of the ^{87}Rb, we calculate the age of the rock as $t = \frac{1}{1.42x10^{-11}} \ln \frac{1.0}{.97}$. This is $\frac{\ln 1.03}{1.42x10^{-11}} = \frac{.0296}{1.42x10^{-11}}$ = 2,084,507,042 years, or a little over 2 billion years old.
5. Various isotopes used for different age ranges — $^{14}C \rightarrow ^{14}N$ for up to 40,000 years, to $^{238}U \rightarrow ^{206}Pb$ for 5-50 billion years.
6. usually try to date from igneous rocks on top and bottom of fossil bearing sedimentary rocks

C. Fossils

1. Fossil = any trace of past life (word means something that is dug up)
2. Fossil record spotty and biased — best preserved are organisms with hard parts living in or near shallow waters where they can be quickly buried with sediment.

2a. Fossils may be replacement fossils, where minerals (rock) replace organic matter or bone; or the actual organic matter may be preserved (coal balls, acid bogs, ice).

3. Even for shallow water marine fossils, estimates of proportion of species represented by found fossils range from 1 in 60 to 1 in 150; for terrestrial vertebrates it is much smaller, and for insects very much smaller yet.
4. there are large temporal and geographic gaps in the fossil record
5. species from fossils are *morphospecies*, that is, they are classified on their looks, rather than on whether they can breed, since reproductive capabilities are difficult to determine from fossils
6. earliest fossils (bacteria-like) are from about 3.8 BYA; multi-cellular organisms date from about 700 Ma (Ediacarian), large numbers of hard-shelled fossils date from ~ 570 Ma (Cambrian). The two biggest extinctions mark the Permian-Triassic (Paleozoic - Mesozoic) boundary, and the Cretaceous-Tertiary (K-T) (Mesozoic - Cenozoic) boundary. These occurred at 225 Ma and 65 Ma. The 65 Ma extinction was at least partly caused by an asteroid impact at Chicxulub in the Yucatan peninsula of Mexico. The cause of the 225 Ma extinction is unknown. The periods are also marked by extinction events, particularly where they correspond with changes in types of rocks laid down.
7. The end-Permian event caused the extinction of maybe 90% of living species (one estimate is 96% of marine species); the end-Cretaceous event caused the extinction of maybe 70% of living species (one estimate is 60-75% of marine species).