Summary of Lecture 20

Key points include:

1. Here we focus on high-mass stars, which we define as stars that begin their lives with masses $M > 8M_\odot$.
2. The early stages of the lives of such stars are similar to those for lower-mass stars: (1) on the main sequence, high-mass stars fuse hydrogen to helium, (2) when the hydrogen in the core largely runs out, the core is inert helium and the hydrogen fuses in a shell; at this stage the star becomes a red giant, (3) the star's core contracts and becomes hot and dense enough to fuse helium to carbon, (4) the star then settles on the "helium main sequence".
3. For stars with low enough mass (such as the Sun), it ends there. More massive stars can fuse carbon to oxygen, oxygen to neon, and another step or two. At each step, less energy per mass is released in fusion, and the core has to be hotter and fuse more rapidly, so each step takes much less time than the step before.
4. If fusion proceeds all the way to iron, then no more energy can be released by fusion (or by fission). Thus the inert iron builds up and no more energy is released. At that stage, it is degeneracy pressure (remember white dwarfs?) rather than radiation that holds up the core against gravity.
5. When the iron core gets to $\sim 1.4\ M_\odot$ (which is about the Chandrasekhar mass, i.e., the limiting mass for white dwarfs, because in a broad sense the iron core is like a hot iron white dwarf!), it can't hold itself up any more against gravity, and it collapses.
6. Prior to the collapse, the radius of the iron core was about 1000 km. As the core contracts (basically in free fall!), electrons combine with protons to make neutrons, and that combination releases neutrinos. The core contracts to around 15 km and then the neutron degeneracy pressure takes over. This causes the core to bounce, which sends a blast wave outward the explodes the star. This is a *supernova*!
7. The supernova has so much energy that it creates a lot of heavy elements. That is, even though going from (say) iron to a heavier element *requires* energy rather than *releasing* energy as in fusion, since the energy is there, heavier elements can be created.
8. This is one way that elements heavier than hydrogen are produced. Another way, which we won't discuss in this lecture, involves neutron stars spiraling into each other (or possibly into stellar-mass black holes).

9. Supernovae have been seen, historically, from our Milky Way galaxy. The last naked-eye supernova was actually in a small galaxy near the Milky Way (the Large Magellanic Cloud), on February 24, 1987. Tycho Brahe and Johannes Kepler both saw supernovae during their lives. But they're rare, happening perhaps once per century per galaxy like the Milky Way.
10. As a summary: low-mass (initial $M < 8\ M_\odot$) stars live gentle, slow lives and end up as white dwarfs. High-mass (initial $M > 8\ M_\odot$) stars live fast, die young, and leave beautiful corpses (neutron stars or black holes).
11. We'll learn more about those corpses in future lectures...