Key points from Lecture 23 of ASTR 350

1. Because the distance changes induced by gravitational waves are extremely small (fractional distance changes $\sim \Delta L/L \sim 10^{-21}$ and less for events that have been detected), direct detection of gravitational waves requires extremely sensitive and well-designed instruments.
2. The first attempts were made by Joseph Weber right here at the University of Maryland(!), starting in the 1960s. He looked for resonant excitation of metal bars. The idea was that, just as if you push a swing even very gently at its natural frequency you can get the swing up to high amplitudes, if a gravitational wave hit the resonant frequency of a bar then the bar might ring strongly enough to be picked up by sensors. Weber thought he had made such detections but it was soon clear that these were merely statistical fluctuations in the data.
3. Starting in the 1970s different groups applied another approach: laser interferometers, similar to those used by Michelson and Morley when they looked for variations in the speed of light. It took 40 years, but on September 14, 2015 a signal was finally detected by the LIGO instruments in the US. By now, nearly 100 events have been seen using LIGO and Virgo (a European laser interferometer), and recently a Japanese detector named KAGRA joined the endeavor.
4. For all but the loudest events, you need more than sensitive instruments. You need sophisticated computer solutions of Einstein's equations, which are so horribly complicated that they can't be solved exactly by hand. These solutions are compared with the data to establish detections and to determine the properties of the detections.
5. Once, and only once, in the first three observing campaigns, has a counterpart been seen electromagnetically. This was GW170817 (17=2017, the year; 0817=August 17), which was the inspiral and merger of two neutron stars. This led to a wealth of information about gamma-ray bursts and neutron stars. It was lucky that the event happened as close as it did (just 40 Mpc away), but people were prepared and made the most of it.
6. Gravitational wave detections have yielded a spectacular return of fundamental physics and astrophysics. Among other things, they have facilitated new tests of theories of gravity, and dark matter, and have revealed a population of black holes that we didn't know existed (about 30 times the mass of our Sun).