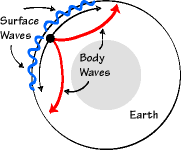
When you look at a seismogram the wiggles you see are an indication that the ground is being, or was, vibrated by seismic waves. Seismic waves are propagating vibrations that carry energy from the source of the shaking outward in all directions. There are many different seismic waves, but all basically of four types:

[**http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/waves\_and\_interior.html**](http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/waves_and_interior.html)

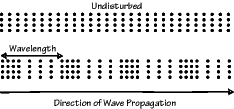
**(TEXT ADAPTED)**

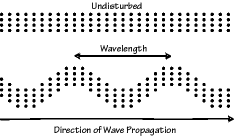
* Compressional or P (for primary)
* Transverse or S (for secondary)
* Love
* Rayleigh

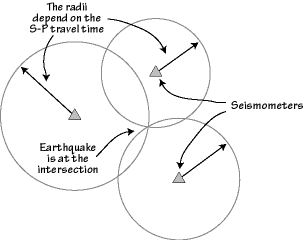
An earthquake radiates P and S waves in all directions and the interaction of the P and S waves with Earth's surface and shallow structure produces surface waves. Near an earthquake the shaking is large and dominated by shear-waves and short-period surface waves. These are the waves that do the most damage to our buildings, highways, etc. Even in large earthquakes the intense shaking generally lasts only a few tens of seconds, but it can last for minutes in the greatest earthquakes. At farther distances the amplitude of the seismic waves decreases as the energy released by the earthquake spreads throughout a larger volume of Earth. Also with increasing distance from the earthquake, the waves are separated apart in time and dispersed because P, S, and surface waves travel at different speeds.

Seismic waves travel fast, on the order of kilometers per second (km/s). The precise speed that a seismic wave travels depends on several factors; most important is the composition of the rock. It allows us to use observations recorded on seismograms to infer the composition or range of compositions of the planet. But the process isn't always simple, because sometimes different rock types have the same seismic-wave velocity, and other factors also affect the speed, particularly temperature and pressure. Temperature tends to lower the speed of seismic waves and pressure tends to increase the speed. Pressure increases with depth in Earth because the weight of the rocks above gets larger with increasing depth. In regions of uniform composition, the velocity generally increases with depth, despite the fact that the increase of temperature with depth works to lower the wave velocity.

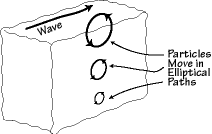
Seismic waves can be distinguished by a number of properties including the speed the waves travel, the direction that the waves move particles as they pass by, and where and where they don't propagate. The first two wave types, P and S, are called **body waves** because they travel or propagate through the body of Earth. The latter two are called **surface waves;** they travel along Earth's surface and their amplitude decreases with depth into Earth.

**P-waves** are the first waves to arrive on a complete record of ground shaking because they travel the fastest (their name derives from this fact - P is an abbreviation for primary, first wave to arrive). They typically travel at speeds between ~1 and ~14 km/sec. The slower values correspond to a P-wave traveling in water, and the higher number represents the P-wave speed near the base of Earth's mantle. The velocity of a wave depends on the elastic properties and density of a material. P-waves are sound waves. The vibration caused by P waves involves a volume change, alternating from compression to expansion in the direction that the wave is traveling. P-waves travel through all types of media - solid, liquid, or gas. As a P-wave passes, the ground is vibrated in the direction that the wave is propagating.

Secondary, or **S waves**, travel slower than P waves and are also called "shear" waves because they don't change the volume of the material through which they propagate. S-waves are transverse waves because they vibrate the ground in a direction "transverse", or perpendicular, to the direction that the wave is traveling. As a transverse wave passes, the ground moves perpendicular to the direction that the wave is propagating. Even though they are slower than P-waves, the S-waves move quickly. Typical S-wave propagation speeds are on the order of 1 to 8 km/sec. The lower value corresponds to the wave speed in loose, unconsolidated sediment, and the higher value is near the base of Earth's mantle. An important distinguishing characteristic of an S-wave is its inability to propagate through a fluid or a gas because S-waves are waves that shear the material. In general, earthquakes generate larger shear waves than compressional waves and much of the damage close to an earthquake is the result of strong shaking caused by shear waves.

We can use the fact that P and S waves travel at different speeds to locate earthquakes. When an earthquake occurs the P and S waves travel outward from the region of the fault that ruptured and the P waves arrive at the seismometer first, followed by the S-wave. Once the S-wave arrives we can measure the time interval between the onset of P-wave and the onset of S-wave shaking. We can measure that difference from a seismogram and if we also know the speed that the waves travel, we could calculate the distance by equating the measured time difference. That means that we can estimate the distance an earthquake is from a seismometer. The earthquake can be in any direction, but must be the estimated distance away. Geometrically that means that the earthquake must be located on a circle surrounding the seismometer, and the radius of the circle is about eight times the observed wave travel-time difference (in kilometers). If we have two other seismometers which recorded the same earthquake, we could make a similar measurement and construct a circle of possible locations for each seismometer. If we plot three or more circles on a map we could find that the three circles will intersect at a single location - the earthquake's epicenter.

**Love waves** are transverse waves that vibrate the ground in the horizontal direction perpendicular to the direction that the waves are traveling. They are formed by the interaction of S waves with Earth's surface and shallow structure and are dispersive waves. The speed at which a dispersive wave travels depends on the wave's period. In general, earthquakes generate Love waves over a range of periods from 1000 to a fraction of a second, and each period travels at a different velocity but the typical range of velocities is between 2 and 6 km/second. Another important characteristic of Love waves is that the amplitude of ground vibration decreases with depth - they're surface waves. Love waves are transverse and restricted to horizontal movement - they are recorded only on seismometers that measure the horizontal ground motion.

**Rayleigh waves** are the slowest of all the seismic wave types and in some ways the most complicated. Like Love waves they are dispersive so the particular speed at which they travel depends on the wave period and the near-surface geologic structure, and they also decrease in amplitude with depth. Typical speeds for Rayleigh waves are on the order of 1 to 5 km/s. Rayleigh waves are similar to water waves in the ocean (before they "break" at the surf line). As a Rayleigh wave passes, a particle moves in an elliptical trajectory that is counterclockwise. The amplitude of Rayleigh-wave shaking decreases with depth.