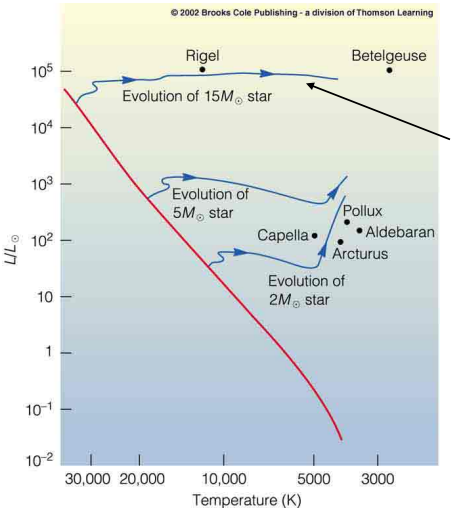
The Aging of High Mass Stars is Completely Different



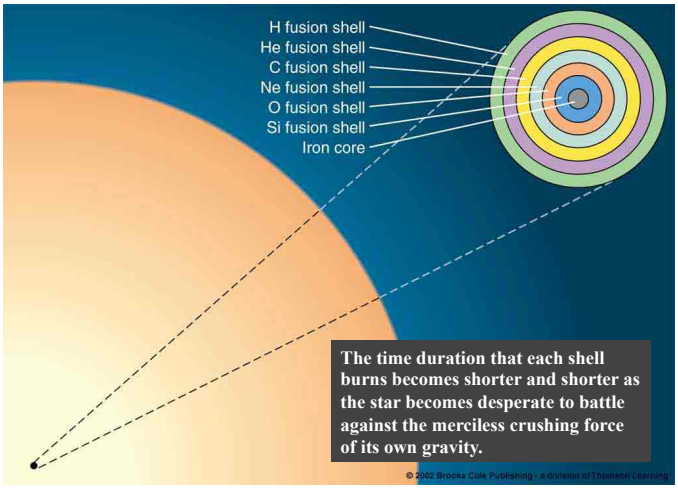
Whereas low mass stars ultimately become white dwarfs, higher mass stars ultimately blow themselves to high heaven.

The same stages happen, but no helium flash or horizontal branch… just straight to the super giant phase!

The nuclear burning shells also build up, but now there is high enough temperature and pressure to burn carbon into neon, into oxygen, into silicon, and finally into iron.

The iron core never burns.

Massive stars undergo multi-layered shell burning.



Hydrogen ……. 7 million yrs
Helium ……..… 500 thousand yrs
Carbon ……..… 600 yrs
Oxygen ……. 1/2 yr
Silicon …….. 1 day
Iron collapse … 0.1 second

BOOM- Supernova

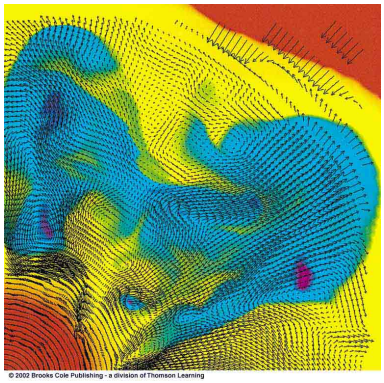
Before and After photos of SN 1987A.

In an instant… more energy than all the stars in all galaxies in the universe.

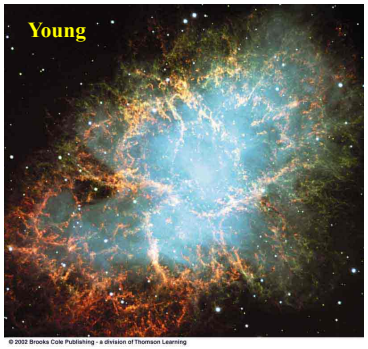
The core collapses and becomes a big neutron ball (called a neutron star). Sometimes it becomes a black hole.

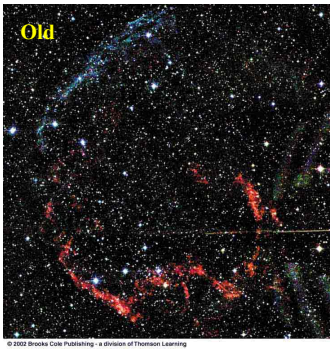
This results in many neutrinos being emitted into space.

Then the envelope bounces off of it!



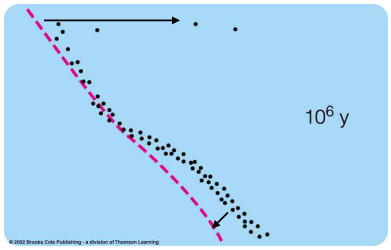
Supernovae Remnants in Our Galaxy





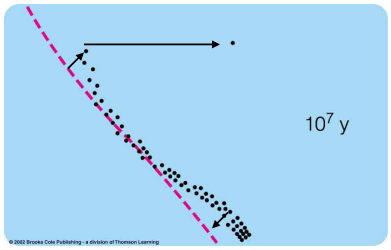
Supernova in a distant galaxy.

HR Diagram Changes as a cluster Ages: 10^6 – 10^7 yrs



O B A F G K M

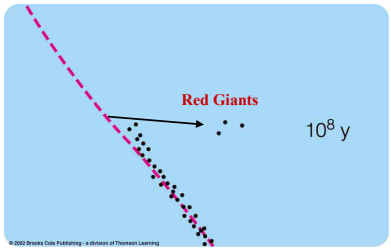
10^6 yrs: The massive stars have already formed and some have aged into super giant stars. The majority of stars, the low mass stars, have not fully formed yet and are making their way down to the main sequence line.



O B A F G K M

10^7 yrs: The O stars have already vanished as supernovae! The B stars are beginning to become super giant stars. The low mass stars are still being born. Recall they take 100 million years to birth.

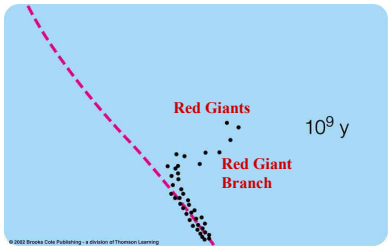
HR Diagram Changes as a cluster Ages: 10^8 – 10^9 yrs



O B A F G K M

10^8 yrs: The O and B stars have all vanished as supernovae! The A stars are becoming red giant stars. The low mass stars are not on the main sequence.

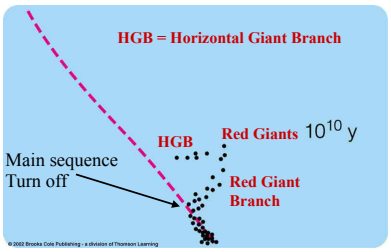
10^8 yrs = 100 million yrs



O B A F G K M

10^9 yrs: The A stars have all become red giant stars. The F stars are forming the red giant branch (on their way to becoming red giant stars), and the G stars are just beginning to move off the main sequence.

HR Diagram Changes as a cluster Ages: 10^{10} yrs



10^{10} yrs: The O, B, and stars are all gone. The A and F stars are on the horizontal giant branch. The G stars are on the red giant branch, and the K and M stars are firmly on the main sequence.

This all means that we can use the HR diagram of a cluster to tell the clusters age!

We just look at the placement of all the stars and see where the main sequence ends. This location is called the main sequence turn-off. We also look to see if there is a horizontal giant branch, which forms at 10 billion yrs.

Examples of some real star clusters.