Death of high mass stars

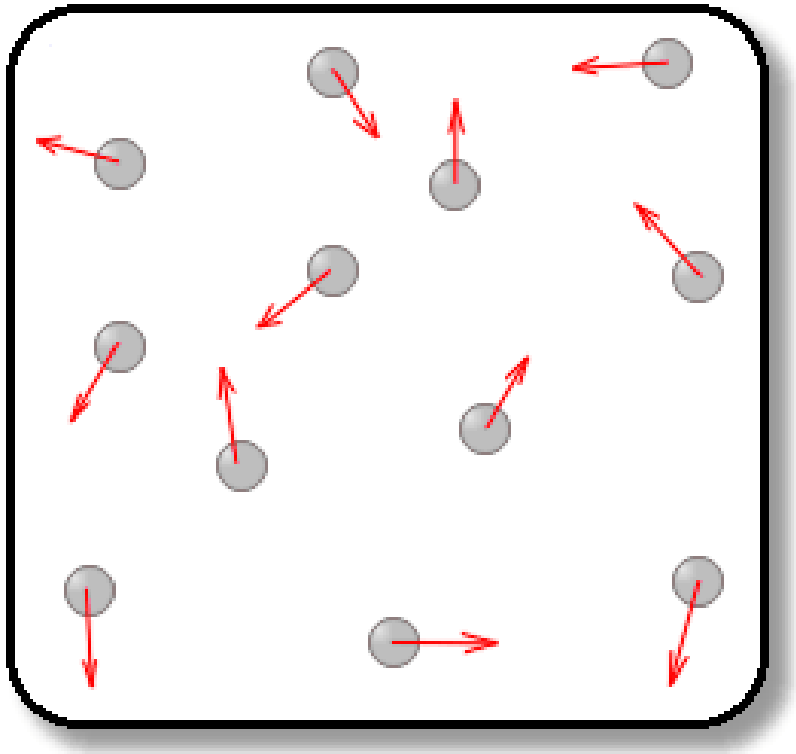
- Degenerate gases
- Evolution of high mass stars
- Where were the elements in your body made?

The HR diagram for a cluster of stars shows stars with spectral types A through K on the main sequence and stars of type O and B on the (super) giant branch. What is the approximate age of the cluster?

A) 1 Myr
B) 10 Myr
C) 100 Myr
D) 1 Gyr

Pressure and Temperature

- Pressure is the force exerted by atoms in a gas
- Temperature is a measure of how fast the atoms in a gas move



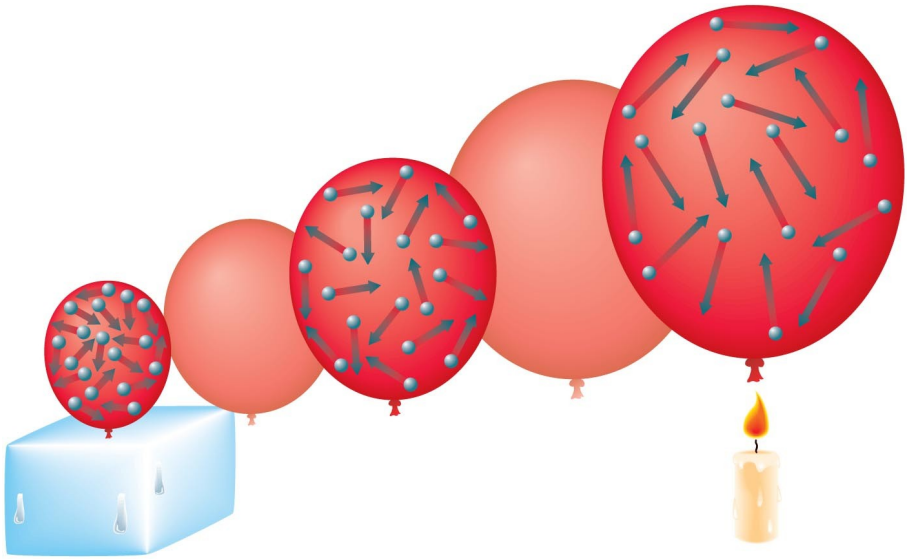
- Hotter → atoms move faster →higher pressure
- Cooler → atoms move slower → lower pressure

Do cold balloon demo

Degenerate gas

- Very high density
- Motion of atoms is not due to kinetic energy, but instead due to quantum mechanical motions
- Pressure no longer depends on temperature

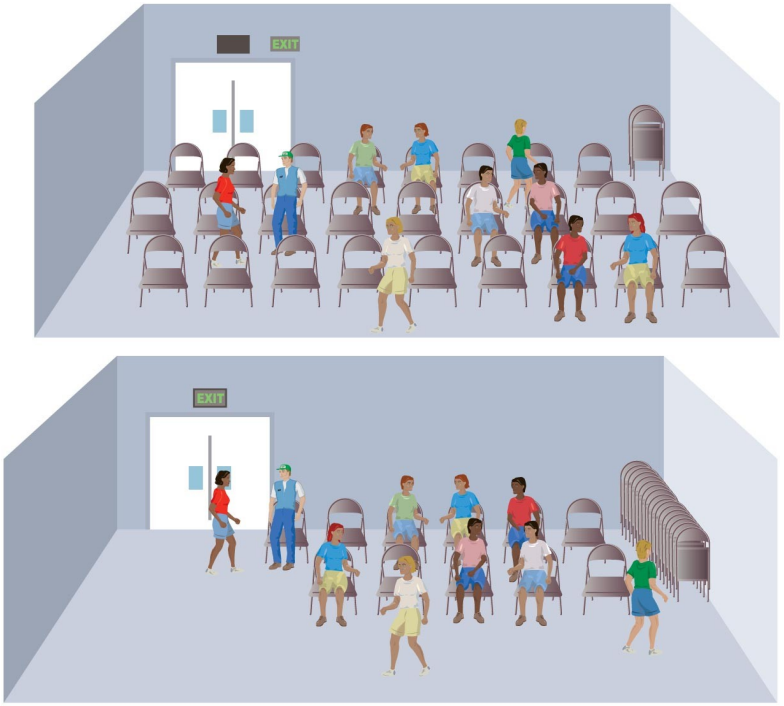
- This type of gas is sometimes found in the cores of stars



Thermal Pressure:

Depends on heat content

The main form of pressure in most stars

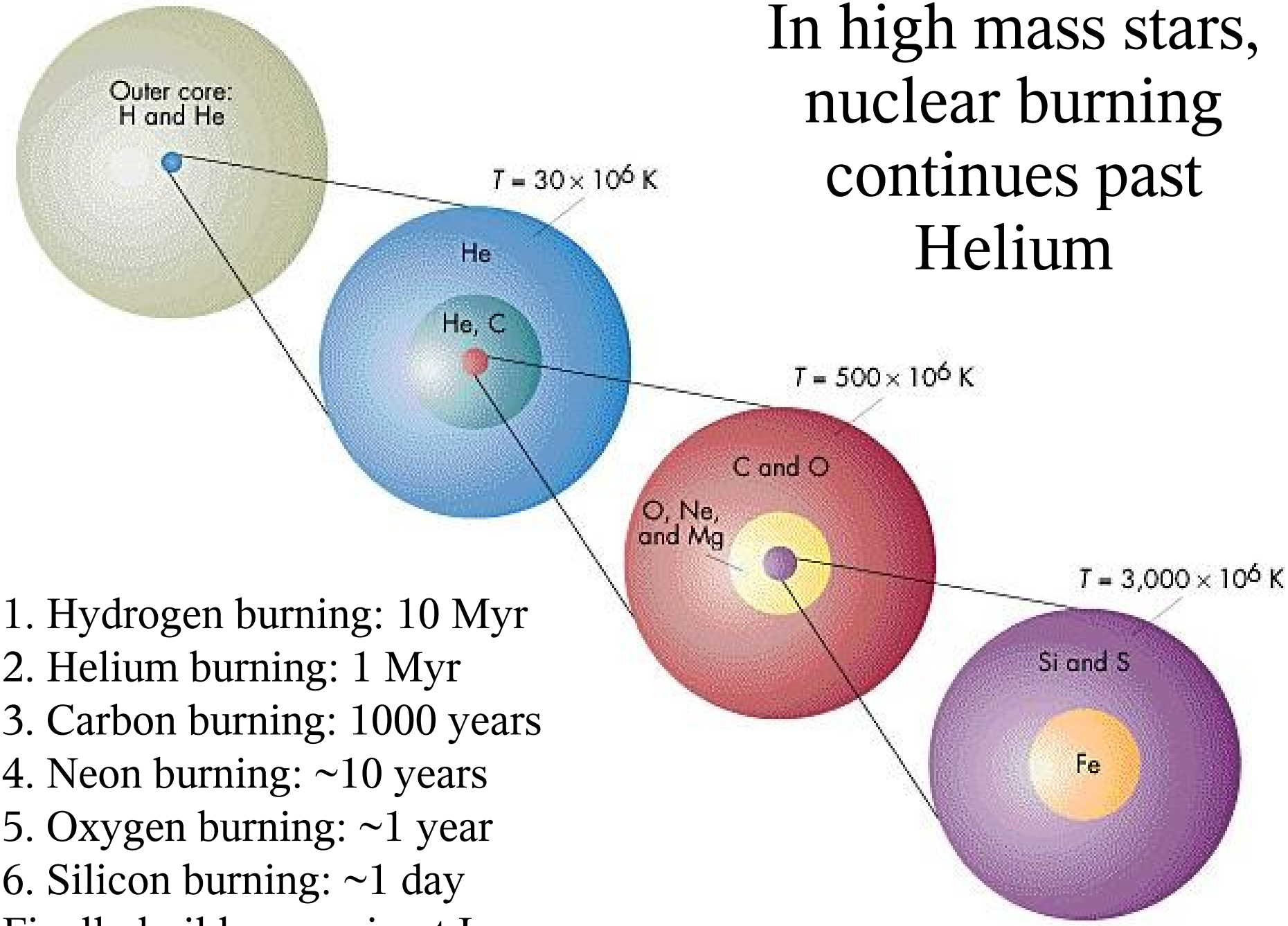


Degeneracy Pressure:

Particles can't be in same state in same place

Doesn't depend on heat content

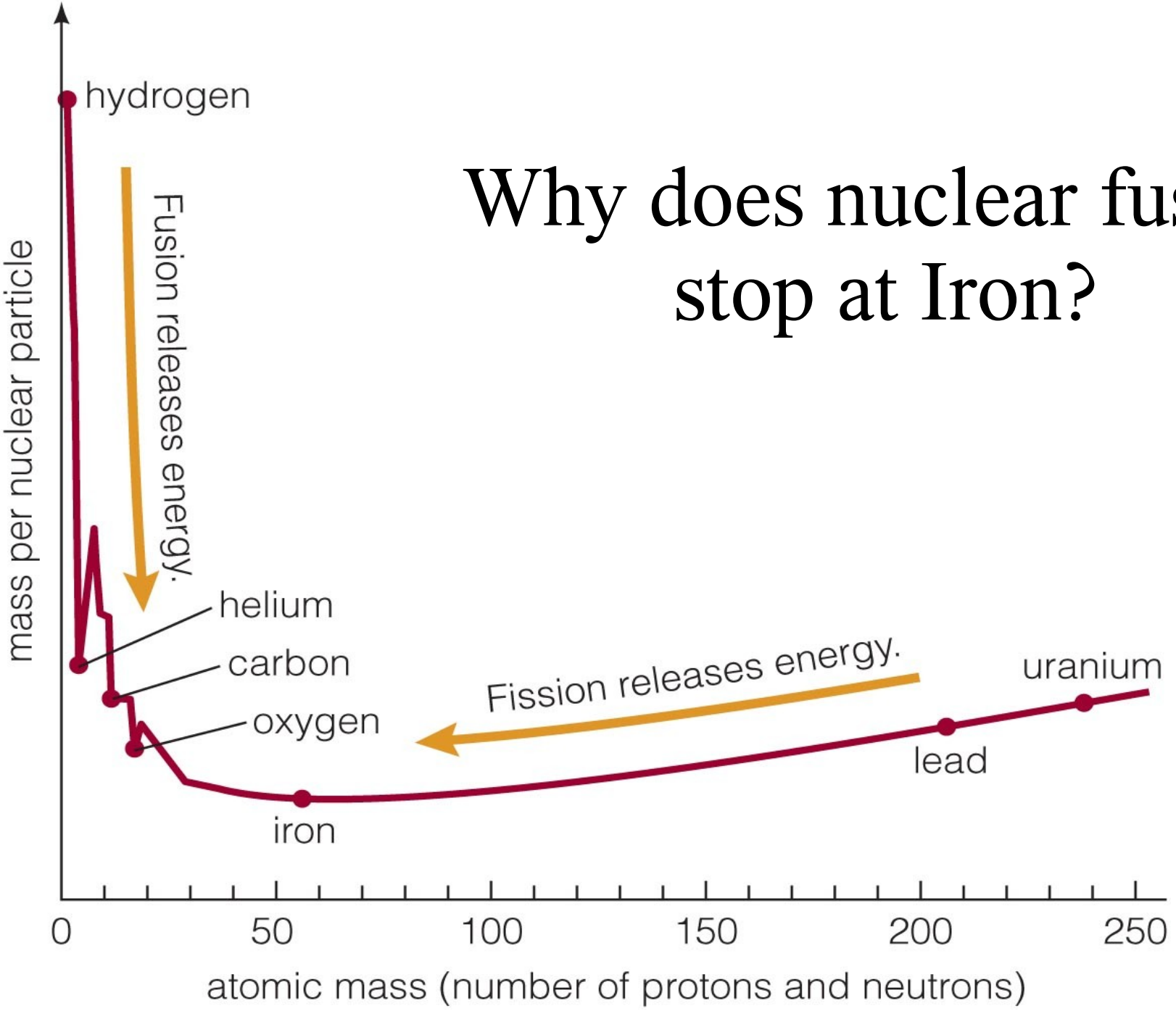
In high mass stars, nuclear burning continues past Helium



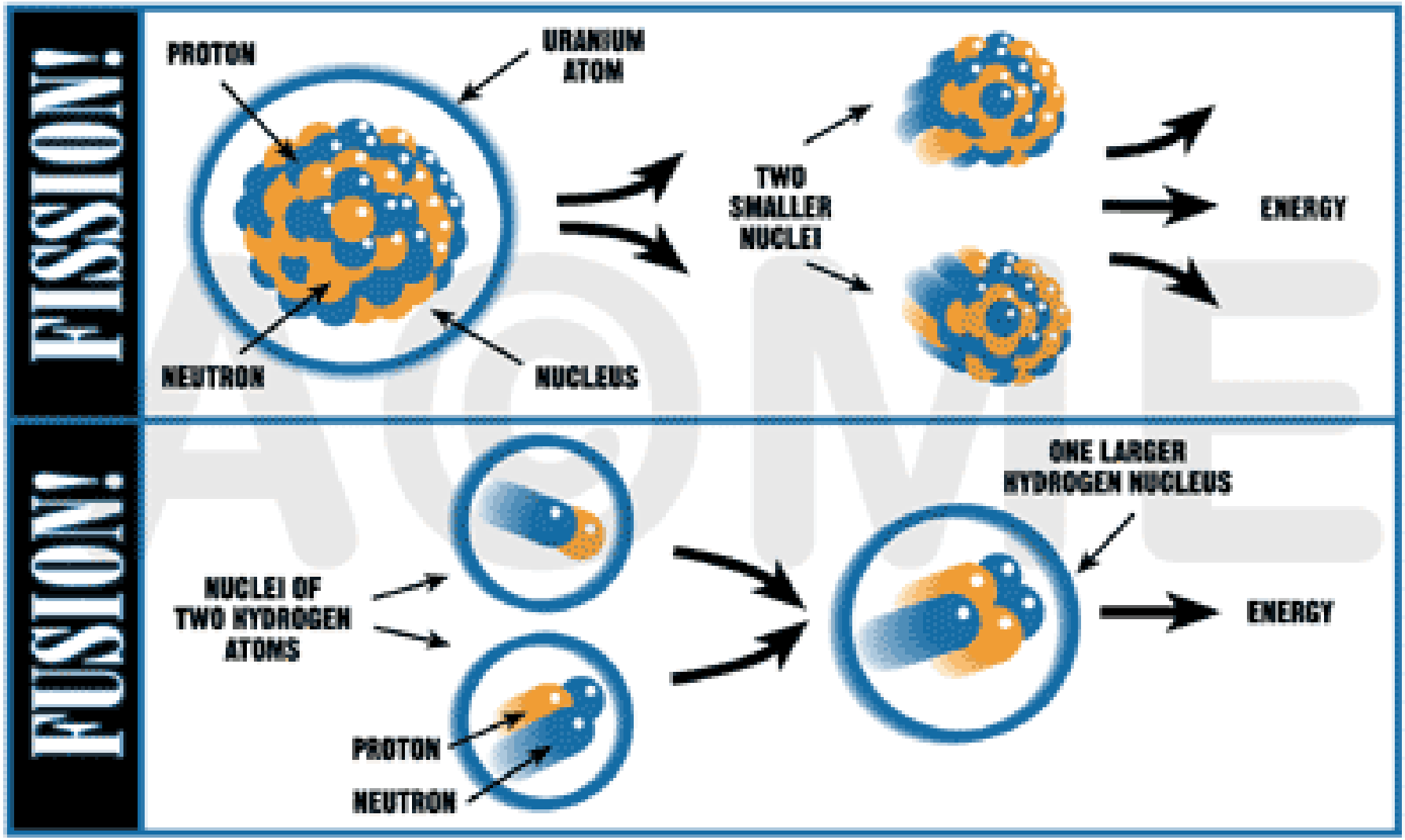
1. Hydrogen burning: 10 Myr
2. Helium burning: 1 Myr
3. Carbon burning: 1000 years
4. Neon burning: ~10 years
5. Oxygen burning: ~1 year
6. Silicon burning: ~1 day

Finally builds up an inert Iron core

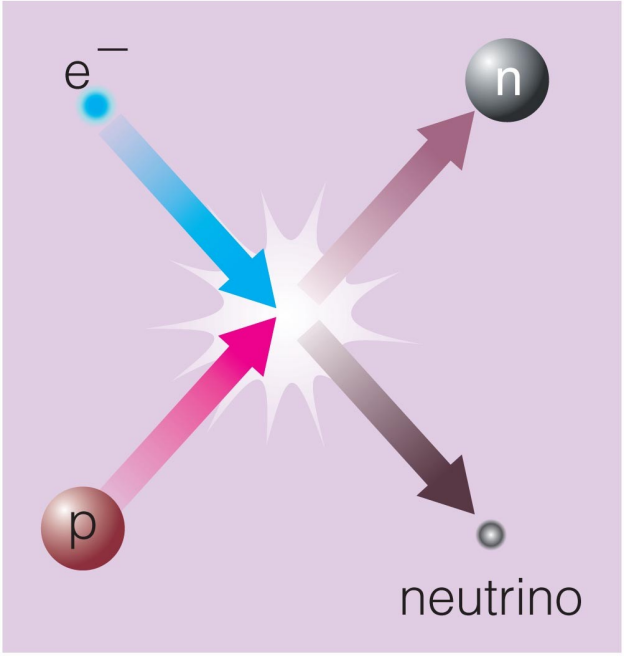
Why does nuclear fusion stop at Iron?



Fusion versus Fission

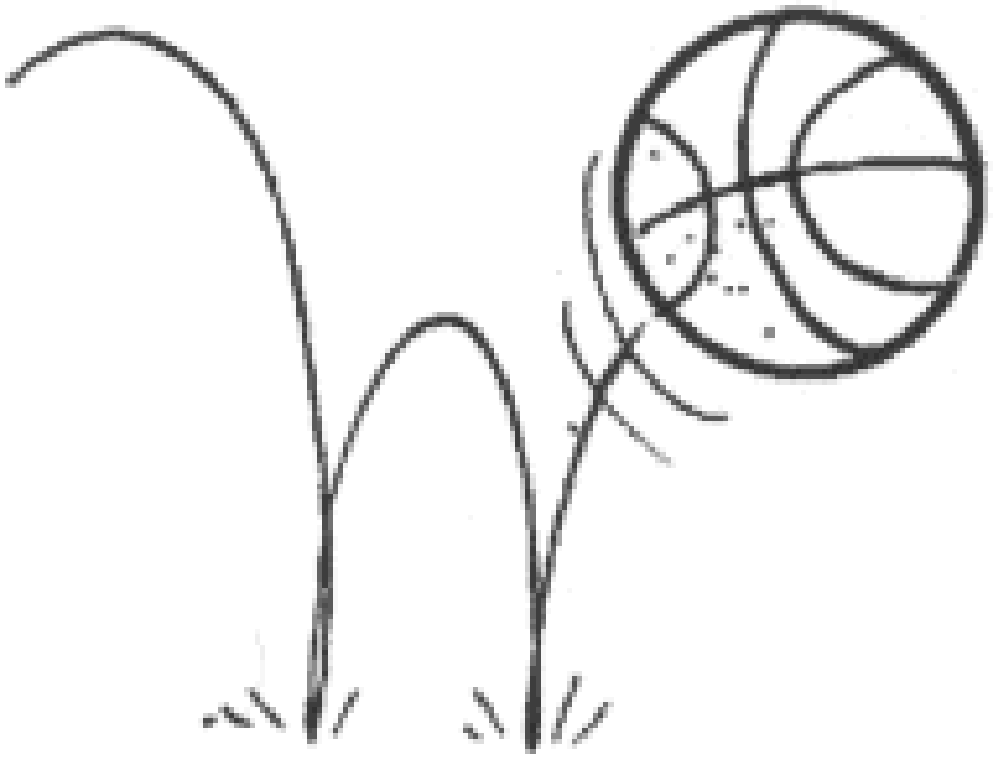


Core collapse

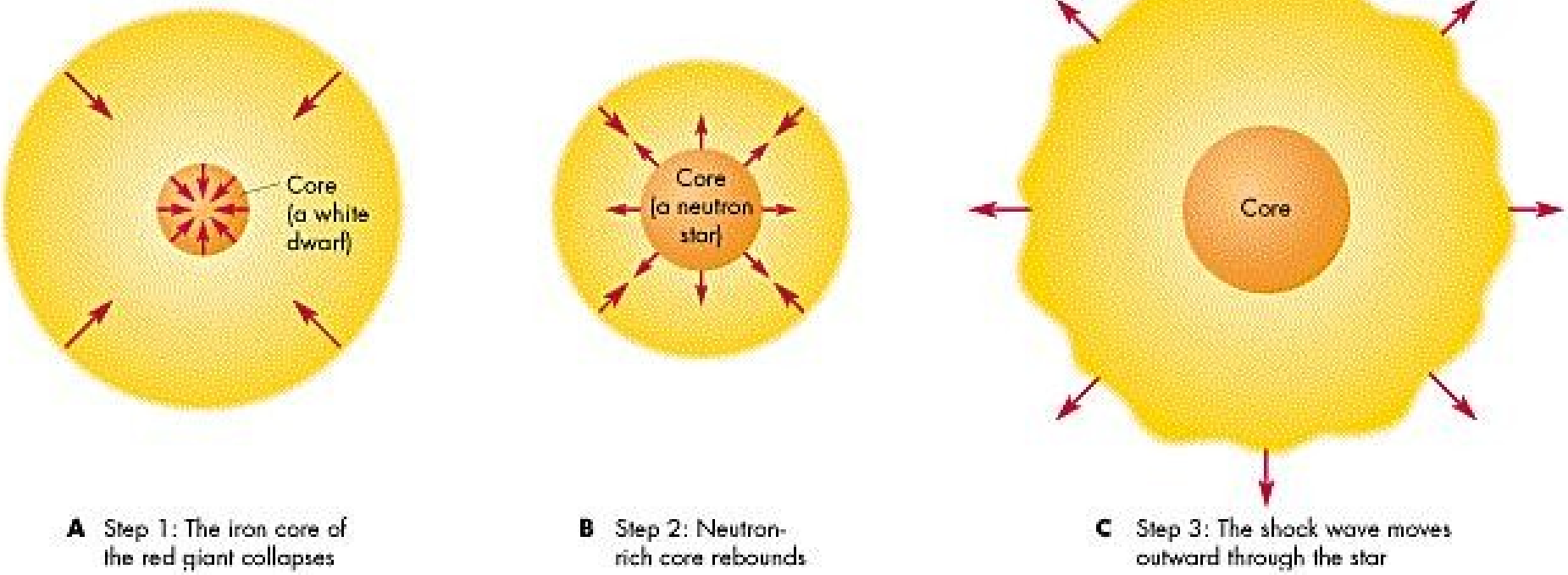


- Iron core is degenerate
- Core grows until it is too heavy to support itself
- Core collapses, density increases, normal iron nuclei are converted into neutrons with the emission of neutrinos
- Core collapse stops, neutron star is formed
- Rest of the star collapses in on the core, but bounces off the new neutron star

If I drop a ball, will it bounce higher than it began?



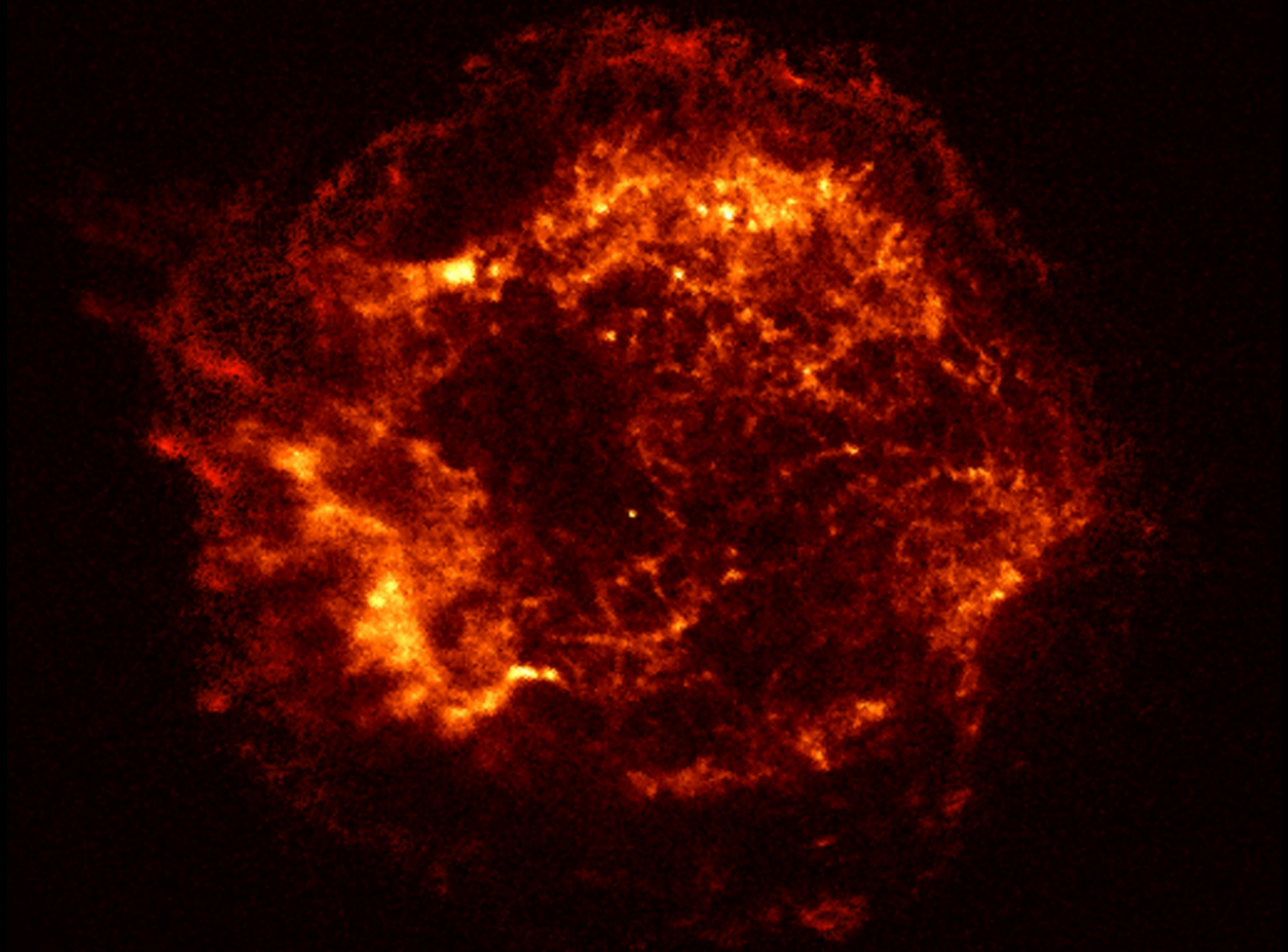
Supernova explosion



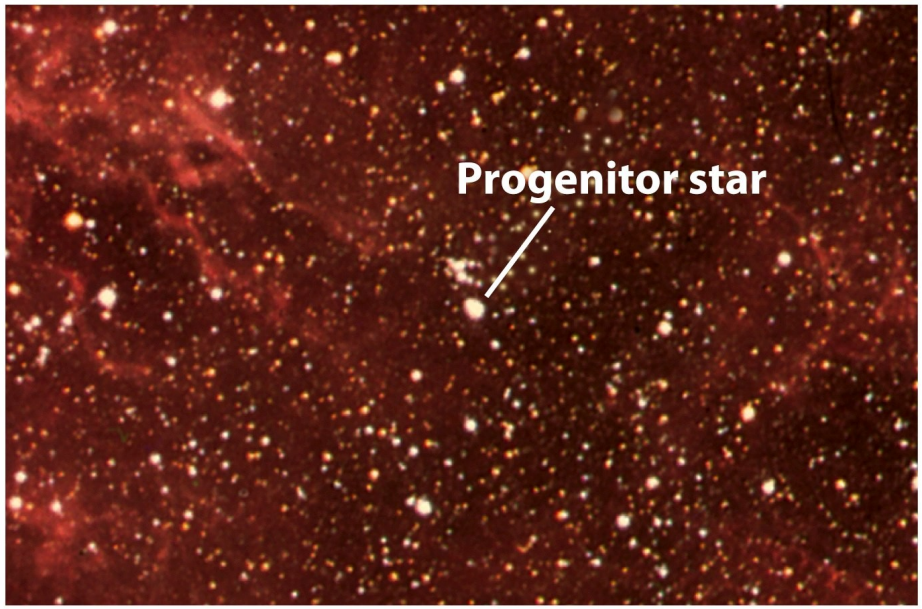
A Step 1: The iron core of the red giant collapses

B Step 2: Neutron-rich core rebounds

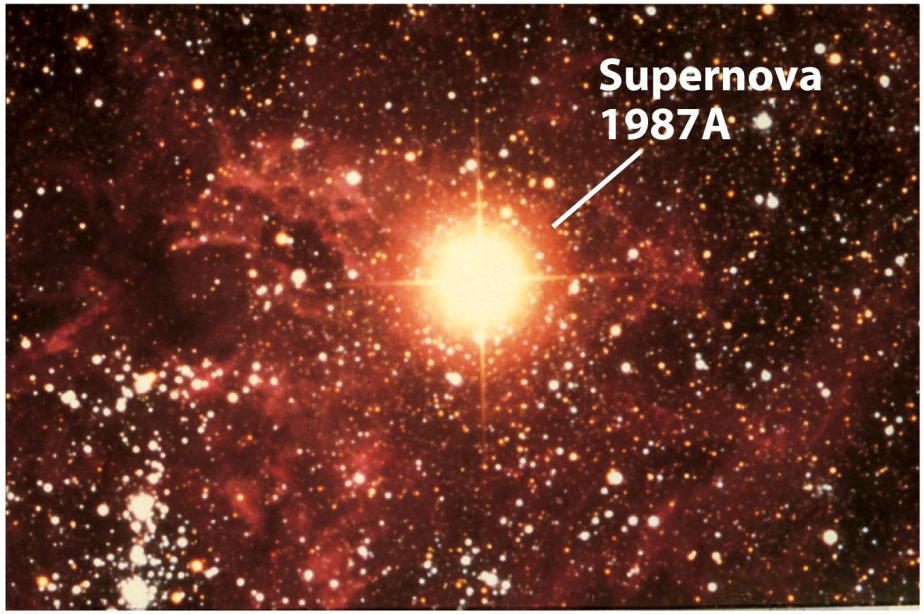
C Step 3: The shock wave moves outward through the star



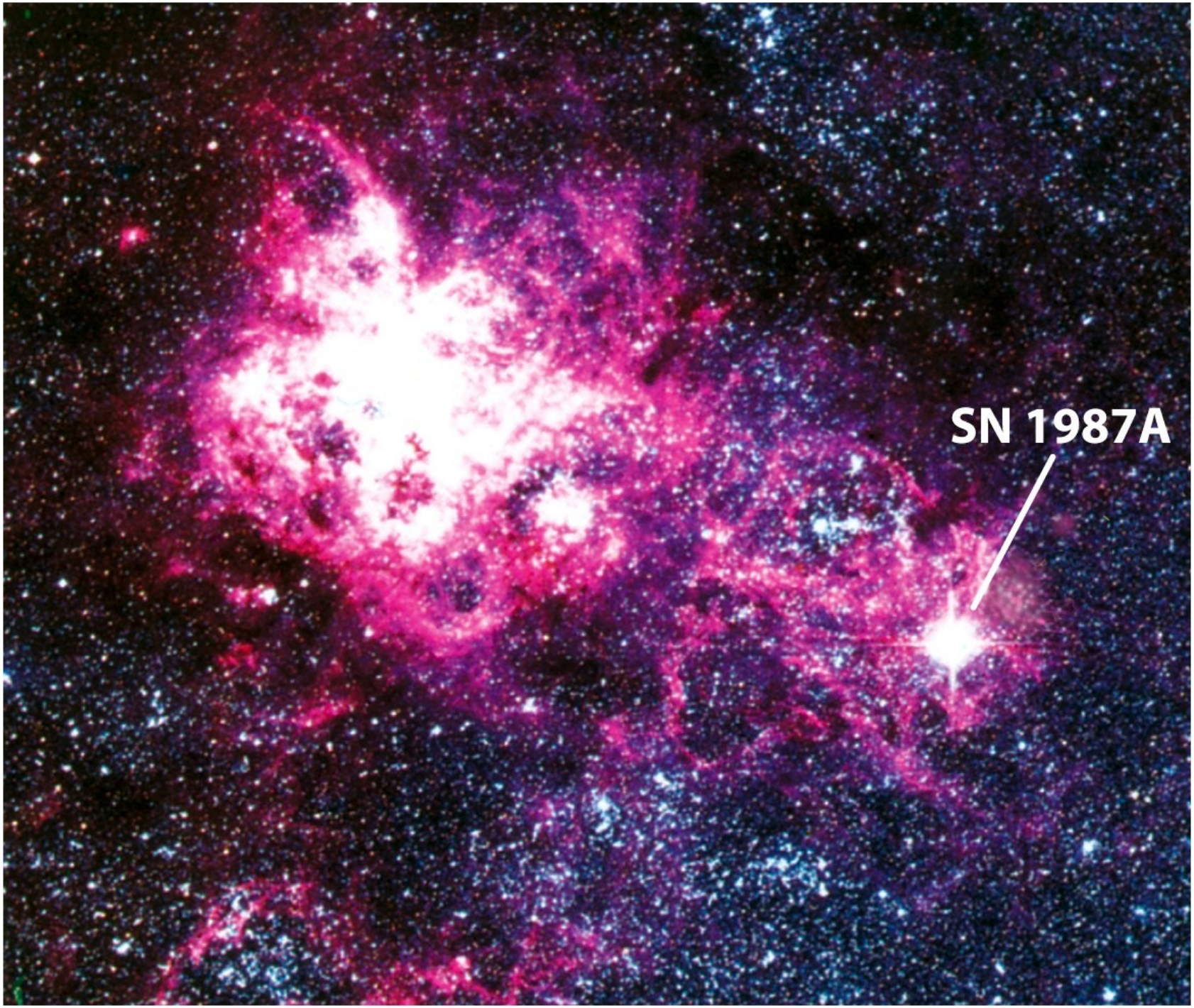
In 1987 a nearby supernova gave us a close-up look at the death of a massive star



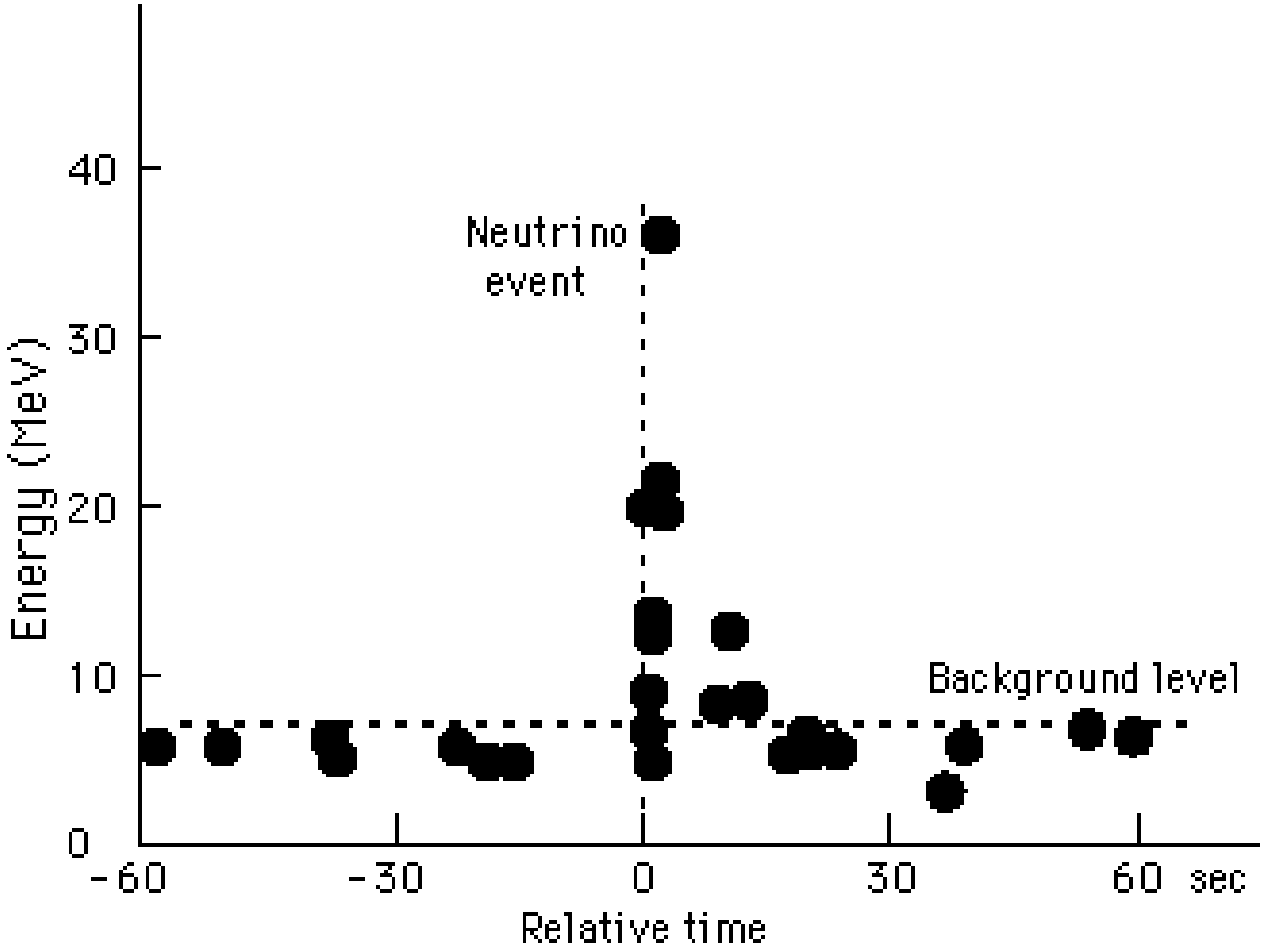
Before the star exploded



After the star exploded


SN 1987A

Neutrinos from SN1987A



Where do the elements in your body come from?

- Solar mass star produce elements up to Carbon and Oxygen – these are ejected into planetary nebula and then recycled into new stars and planets
- Supernova produce all of the heavier elements
  - Elements up to Iron can be produced by fusion
  - Elements heavier than Iron are produced by the neutrons and neutrinos interacting with nuclei in the supernova explosion

How does the life of a high mass star differ from the Sun's life?

A) It forms much faster

B) It lives a shorter time on the main sequence

C) It makes elements heavier than carbon via fusion

D) When it dies it explodes in a tremendous supernova explosion

E) All of the above

Review Questions

- How does the evolution of a high mass star differ from that of a low mass star?
- How can the age of a cluster of stars, all formed at the same time, be determined?
- Why does fusion stop at Iron?
- How are heavy elements produced?