Friday, February 10, 2017

Canvas does a funky computation that gives the wrong total grade. The correct total is given in the column “EXAM 1 Cumulative out 100,” NOT the column “Total.”

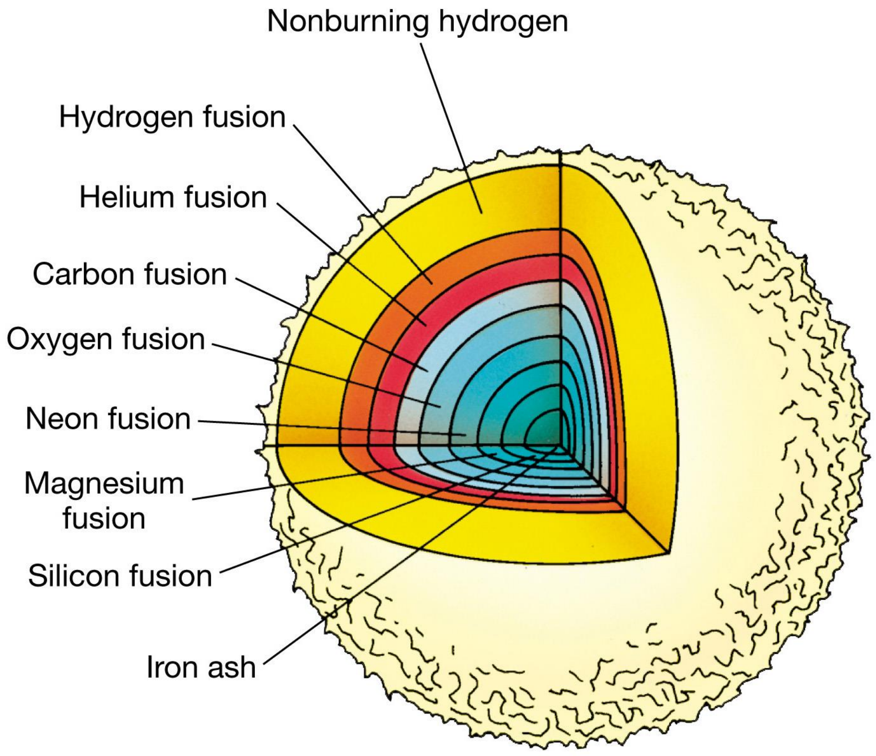
Astronomy in the news?

UT astronomers Rachel Livermore and Steve Finkelstein discover the faintest distant galaxies every seen using “gravitational lensing” by foreground galaxies.

Goal: to understand the origin of Type II, Ib, Ic

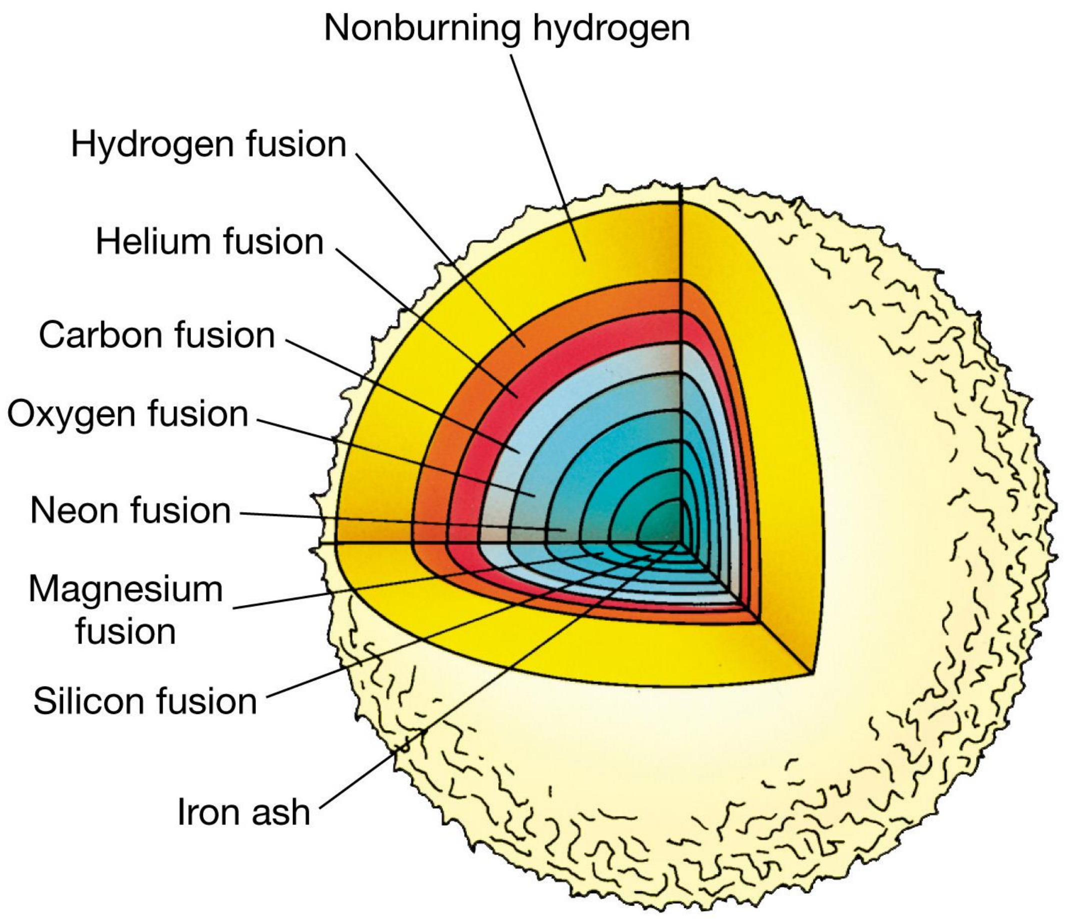
How does a massive star get from hydrogen to iron, and why iron, and what then?

Reading: Chapter 1, Section 2.1 (forces, neutrinos), Chapter 2, Section 2.1, 2.4, 2.5, Chapter 6, Sections 6.4, 6.5 (jets, but not polarization), Betelgeuse interlude, end of Chapter 6.



Goal:

To understand the roles of thermal pressure, charge repulsion, and the strong nuclear force in controlling the way massive stars evolve.



Stars with mass less than about 8 solar masses are supported by **thermal pressure** on the main sequence and during the thermonuclear burning of helium to make carbon and oxygen.

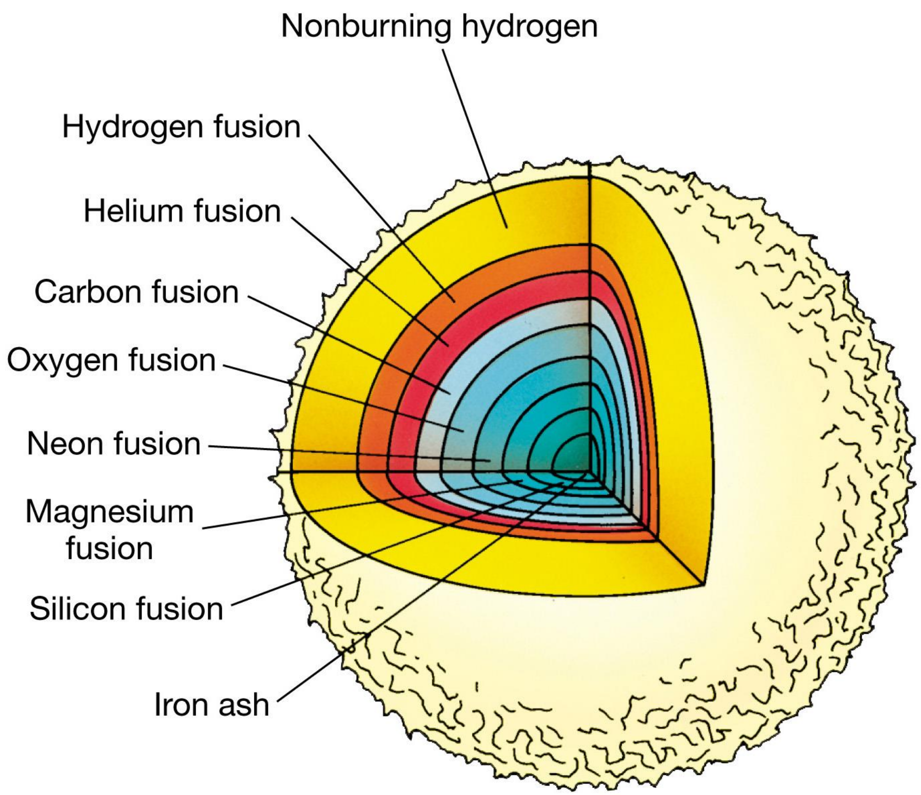
By the time the carbon/oxygen core forms, it is small, high gravity and dominated by the **quantum pressure**, independent of temperature, basically a white dwarf waiting to be born when the envelope is ejected as a planetary nebula.

Stars with mass more than about 12 solar masses are always supported by the **thermal pressure**, not the quantum pressure, until they die.

Red giant envelopes are always supported by **thermal pressure**.

Between about 8 solar masses and about 12 solar masses, transition between thermal pressure and quantum pressure, is complicated, will not discuss in any detail.

Massive stars form layers of ever heavier elements, eventually iron because they are always supported by the thermal pressure.



Charge repulsion does not provide the pressure to support the star, but it is critical in demanding that heavier fuels get hotter before they can burn. Stars supported by the thermal pressure automatically do that.

One minute exam

Why do you have to heat a nuclear fuel to make it burn?

→ Charge repulsion keeps nuclei apart

← The strong nuclear force keeps nuclei apart

↑ To break chemical bonds

↓ To break apart iron

One minute exam

What is the importance of iron in massive stars?

➡ It produces a great deal of energy

⬅ It absorbs energy

⬆ It has more gravity than lighter elements

⬇ It combines with oxygen and produces rust

Goal

To understand what happens after a massive star forms an iron core

Iron core collapse leads to a neutron star (or maybe a black hole).

Neutron Star - mass of Sun, but size of small city,
~ 10 kilometers in radius, density of atomic nucleus.

Huge gravity - surface is now ***much closer*** to the center!

Supported by quantum pressure of neutrons and nuclear forces.

Iron core of massive star absorbs energy.

When iron core forms - star is doomed to collapse.

Iron core collapses in about 1 second to form a ***neutron star*** (or maybe a black hole), composed essentially of all neutrons. Neutrons are formed when protons and electrons combine.

$p + e \rightarrow n + \nu$ ***neutrino***,

Action of Weak Nuclear Force (Chapter 1.2)

One neutrino is generated for every proton that is converted, a star's worth of protons

$\Rightarrow$***<u>lots of neutrinos</u>***

During iron core collapse, essentially all protons and electrons are converted to neutrons with the emission of a ***neutrino.***

Neutrinos have a tiny mass, no electrical charge, interact little with normal matter, only through weak nuclear force (Chapter 1.2).

Normal stellar matter is essentially *invisible* to neutrinos.

100x more energy is created in iron-core collapse to a neutron star than is needed to explode the star

But

$\Rightarrow$99% of the energy of collapse is carried off by neutrinos (Ch 1.2)

One minute exam

What is the importance of neutrinos in massive stars?

➡ They cause the collapse of the iron core

⬅ They carry off most of the energy of collapse

⬆ They convert electrons into protons

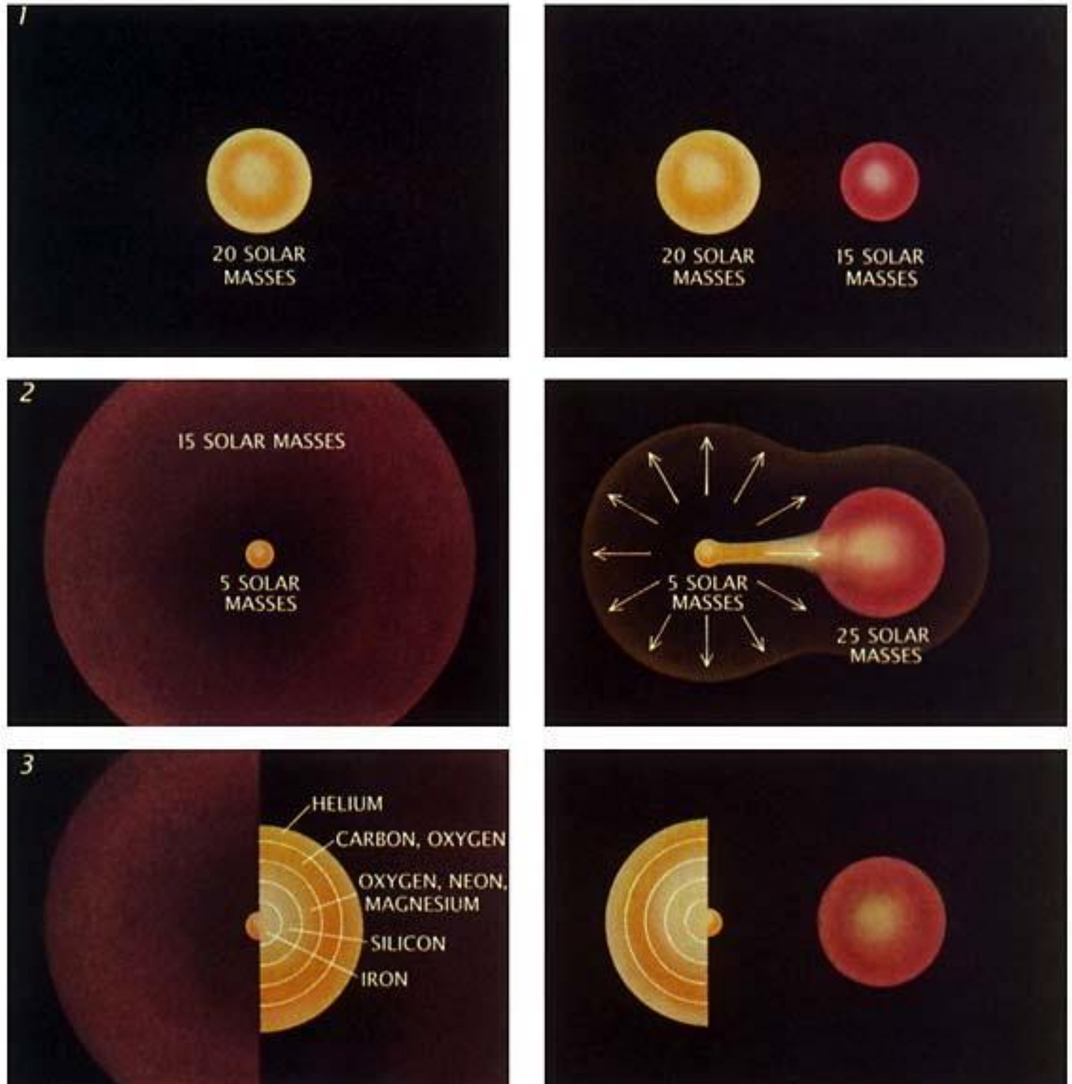
⬇ They eject the outer envelope of the star

Goal

To understand how the iron core process works in Type II, Type Ib, and Type Ic supernovae.

To understand how they are alike and why and how are they different.

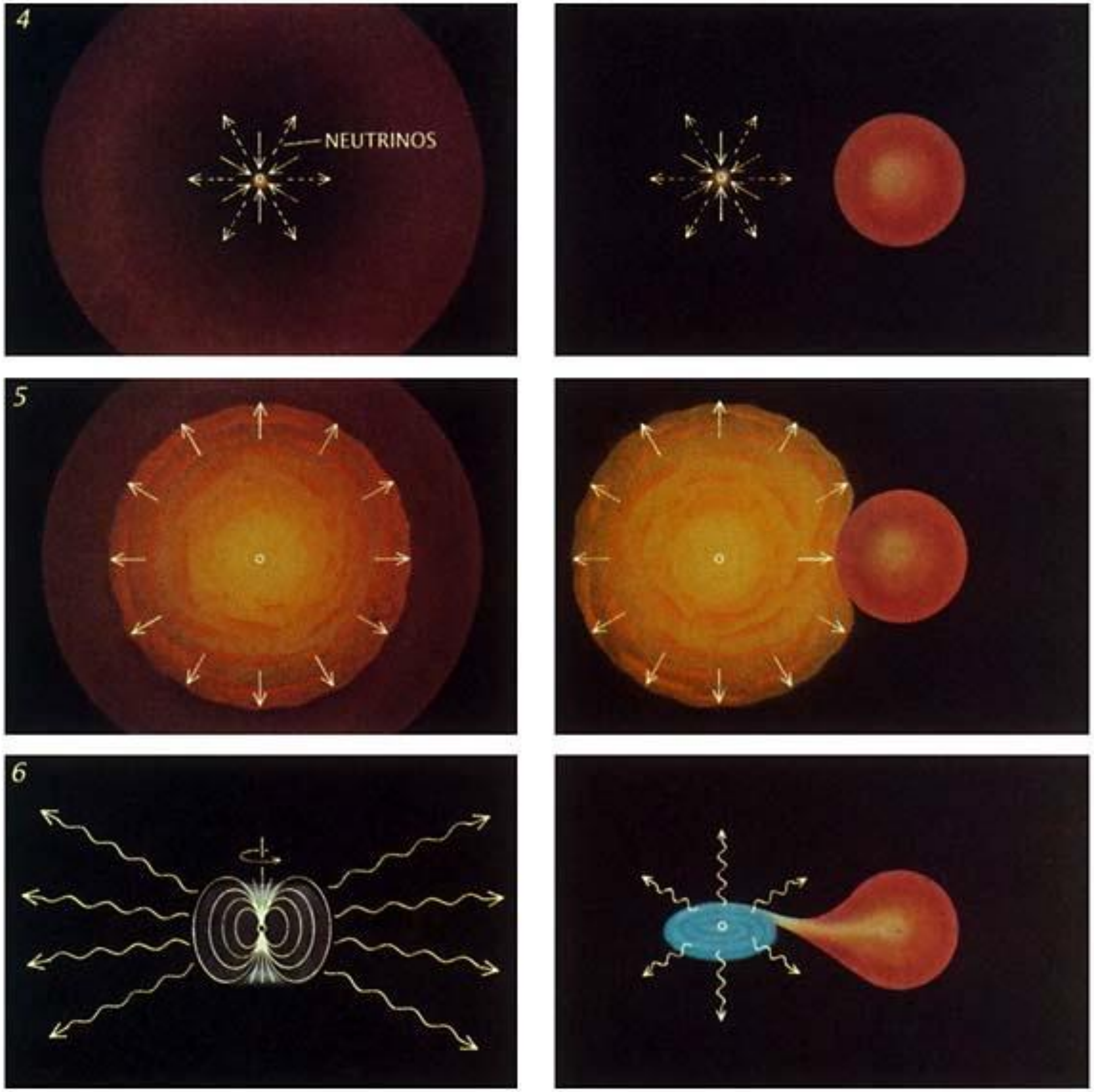
Single star: Type II   Same star in binary: Type Ib/c



Same evolution inside star, thermal pressure, regulated burning, shells of heavier elements, *whether hydrogen envelope is there or not*.

Single star: Type II

Same star in binary: Type Ib/c



Both types leave behind a neutron star

Rotating, magnetic radio pulsar.

Neutron star in binary system, X-ray source

One minute exam

What is the fundamental property that leads Type II, Type Ib and Type Ic to core collapse?

➡ They lose their outer envelopes

⬅ They explode in the spiral arms of spiral galaxies

⬆ They are supported by thermal pressure

⬇ They produce lots of neutrinos

Goal

To understand how the collapse of an iron core can trigger a supernova explosion

When a neutron star forms, get huge energy from dropping from size of Earth or White Dwarf to size of Austin.

100 times more energy than is needed to explode off the outer layers of the massive star.

That does not guarantee an explosion!

The outer parts of the star, beyond the neutron star, are ***transparent to the neutrinos***, the neutrinos flood out freely and carry off most of the energy, about 99%.

Is 1% of the neutrino energy left behind to cause the explosion?

Tough problem! 1.5% is plenty, 0.5% is too little.

Collapse of iron core to form neutron star is halted by the repulsive strong nuclear force at very close distances, high compaction of neutrons (somewhat uncertain)
+ quantum pressure of neutrons

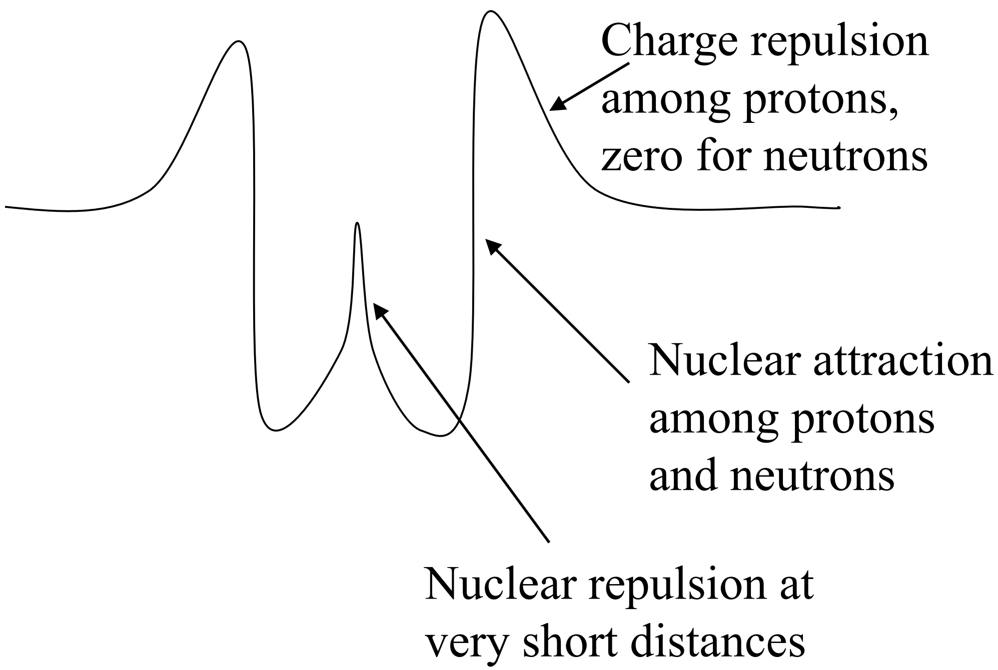
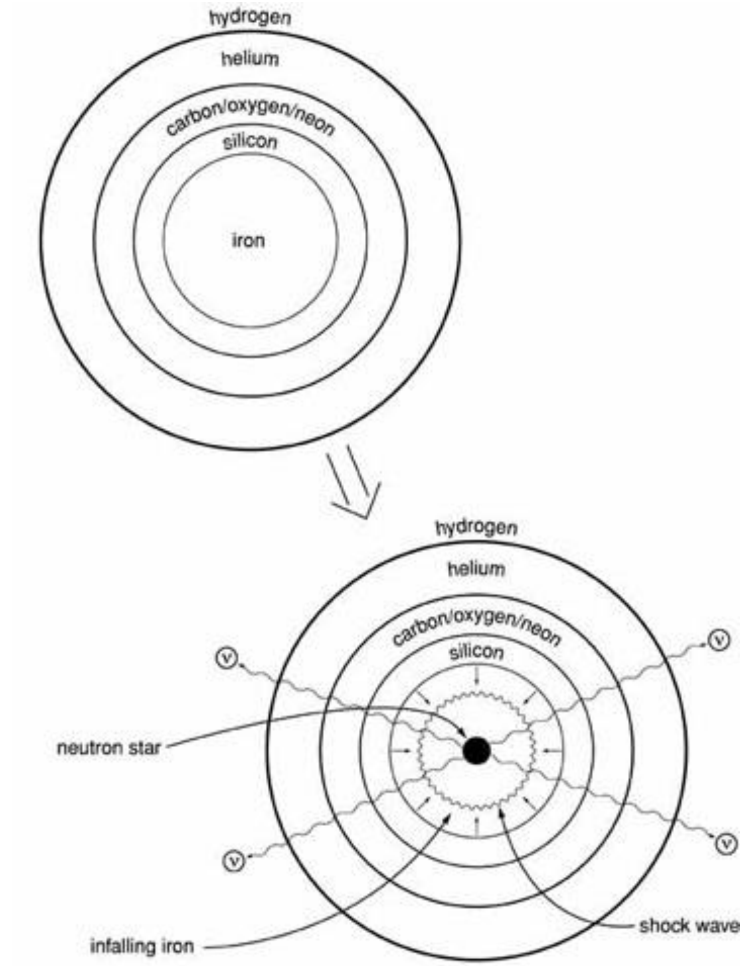


Fig 6.1



Maximum mass of a neutron star is 1.5 to 2 solar masses