Group						
AL	**Hunt**	Paige	**Quinn**	Jamie	**Devkota**	Bishwash
AR	**Prater**	Zane	**Fernandez**	Elizabeth	**Schott**	Connor
BL	**Smith**	Jaihan	**Fernandez**	Corey	**Thompson**	Natalie
BR	**Tlustos**	Travis	**White**	Erin	**Wood**	Noelle
CL	**DeMeyer**	Lauren	**Oconnor**	McKenna	**Burdette**	Lily
CR	**Gunalan**	Vishnu	**Shrimplin**	Skylar	**Morris**	Riley
DL	**Golovin**	Anita	**Pappageorge**	Lauren	**Mongillo**	Hailie
DR	**Lee**	Tony	**Gregory**	Brinley	**Beezley**	Claire
EL	**Tomczyk**	Aaron	**Ehardt**	Bella	**Adkins**	Leo
ER	**Desmond**	Sarah	**Aleman**	David	**Davis**	Jackson
FL	**Holtgrewe**	Emily	**McGeough**	Natasha	**Stringer**	Jason
FR	**Shell**	Brookelynn	**Green**	Kailey	**Ausler**	Kiara
GL	**Keeney**	Alex	**Takeuchi**	Fuka	**Brown**	Tatianah
GR	**Byrum**	Faith	**Evans**	Hannah	**Ziff**	Caitlin
HL	**Jones**	Justice	**Rosentreter**	Riley	**Tucker**	Kali
HR	**Swartz**	Alicia	**Barr**	Abigail	**Ashlin**	Bradley

AL	**Knight**	Cassidy	**Bourcier**	Savannah	**Pike**	Alena
AR	**Stirewalt**	Robert	**Ellis**	Alexander	**Roberts**	Jay
BL	**Stinnett**	Nic	**Hunter**	Kris		
BR	**Still**	Martin	**Price**	Elijah		
CL	**Kolath**	Caroline	**Petinaris**	Joanna		
CR	**Davis**	Samantha	**Brown**	Quincy		
DL	**Stiers**	Alexis	**Bayer**	Caeden		
DR	**Hunt**	Taylor	**Chabino**	Conner		
EL	**Yoss**	Aaron	**Czeschin**	Kyle		
ER	**Lambeth**	Gabe	**Cherukumilli**	Shan		
FL	**Ayers**	Carley	**McBurney**	Sullivan		
FR	**Bowe**	Ava	**Adams**	Autumn		
GL	**McPike**	Aiden	**Bradshaw**	Jenny		
GR	**Todd**	Ana	**Maune**	Cole		
HL	**Saucedo**	Brithny	**Sauceda**	Emma		
HR	**Coomes**	Austin	**Govero**	Brady		

Test 2 on April 3 in class..

Sample Tests and study guide on the course web page now.

Group project 1 is due on April 1.

Evolution for stars <8M_{Sun}:

Protostars: energy from gravity

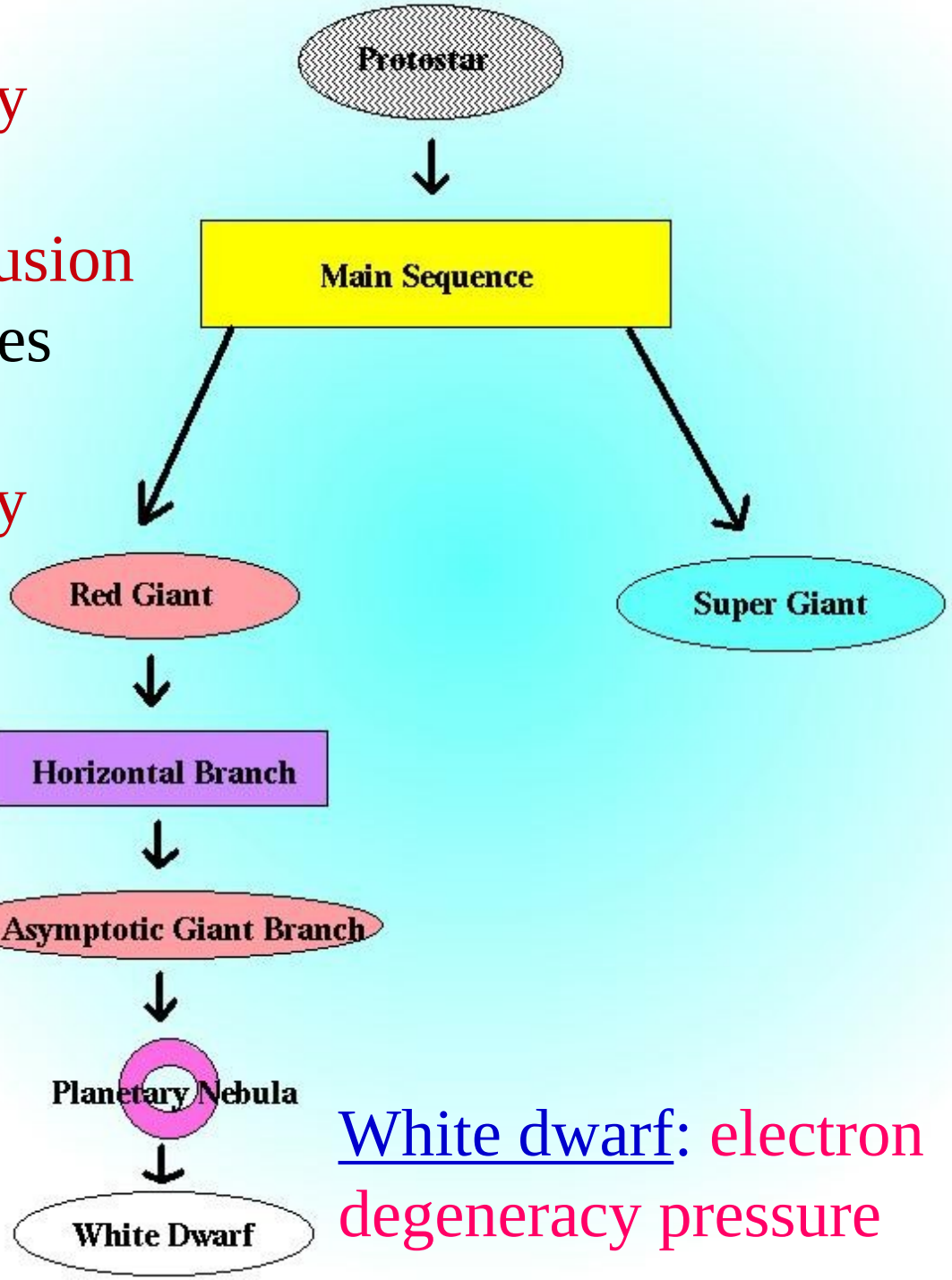
Main Sequence: energy from fusion converting H to He in their cores

Red giants: energy from gravity

Horizontal branch: fusion of He to C

AGB: energy from gravity

Planetary nebula: energy from gravity and spasmodic shell He fusion (and shell H fusion).



White dwarf: electron degeneracy pressure

Important points:

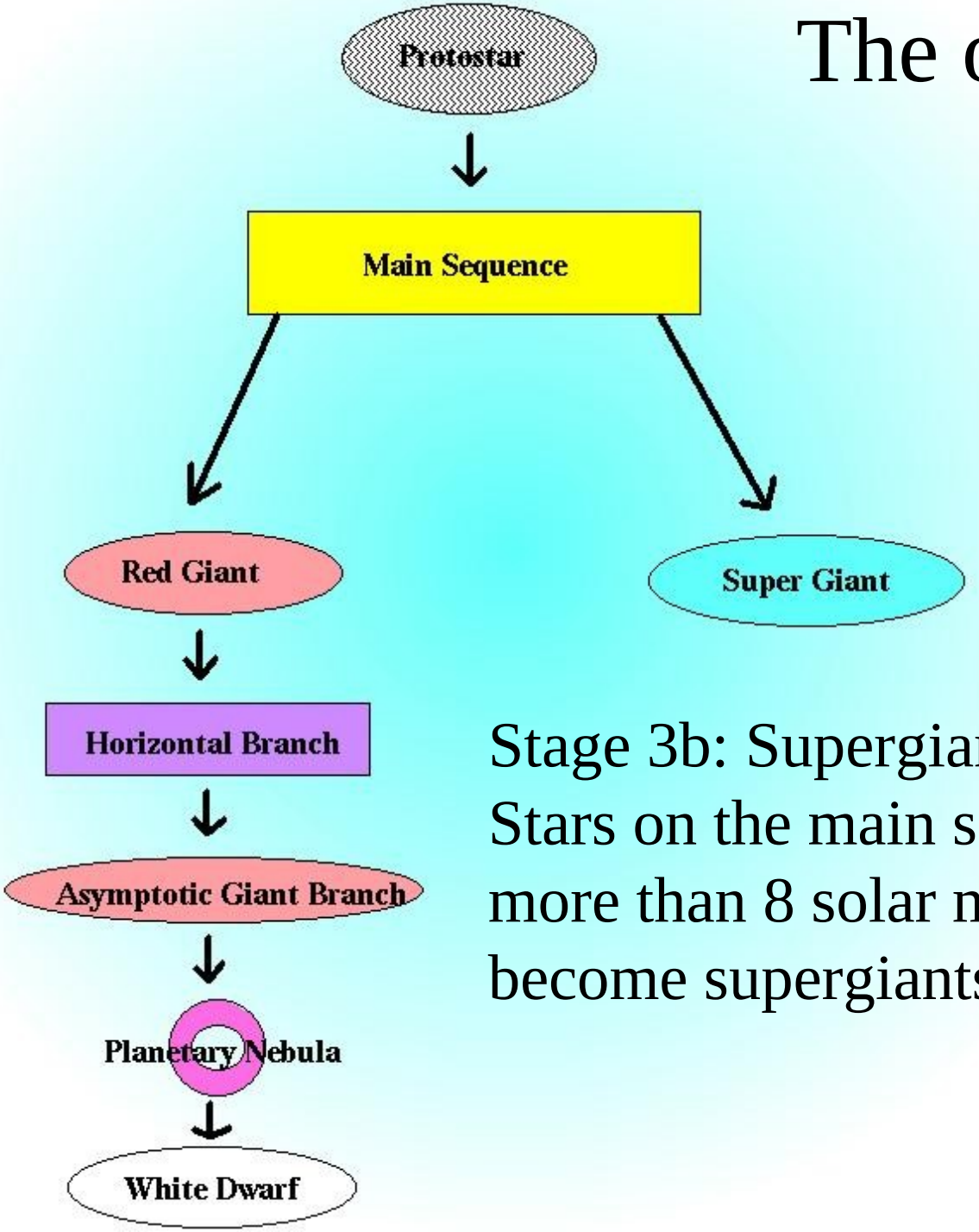
Most stars end up as white dwarfs.
About 60% the mass of the Sun but the radius (size) of the Earth.
Support is electron degeneracy pressure.
They generate no energy, and over time cool to lower and lower temperature.
A few white dwarfs in binaries will get enough mass to supernova

Enrichment

Takeaway: low-mass stars can make elements up to Pb and this is recycled into the galaxy during the planetary nebula phase.

All the nitrogen and oxygen in our atmosphere, that you're breathing right now, was made within stars!

The other side



Stage 3b: Supergiants.
Stars on the main sequence with more than 8 solar masses will become supergiants.

Supergiants

The cores of more massive stars are already hotter.

As they have more mass, they get more energy from gravity without having to change their size much.

Supergiants are able to begin converting He to C/O very soon after exhausting H in their core.

Supergiants

The cores of more massive stars are already hotter.

As they have more mass, they get more energy from gravity without having to change their size much.

Supergiants are able to begin converting He to C/O very soon after exhausting H in their core.

But their cores are hotter than on the main sequence, so the envelope expands.

Supergiants

Supergiants are able to begin converting He to C/O very soon after exhausting H in their core.

When that's depleted, they convert C to O, Ne, Na and Mg

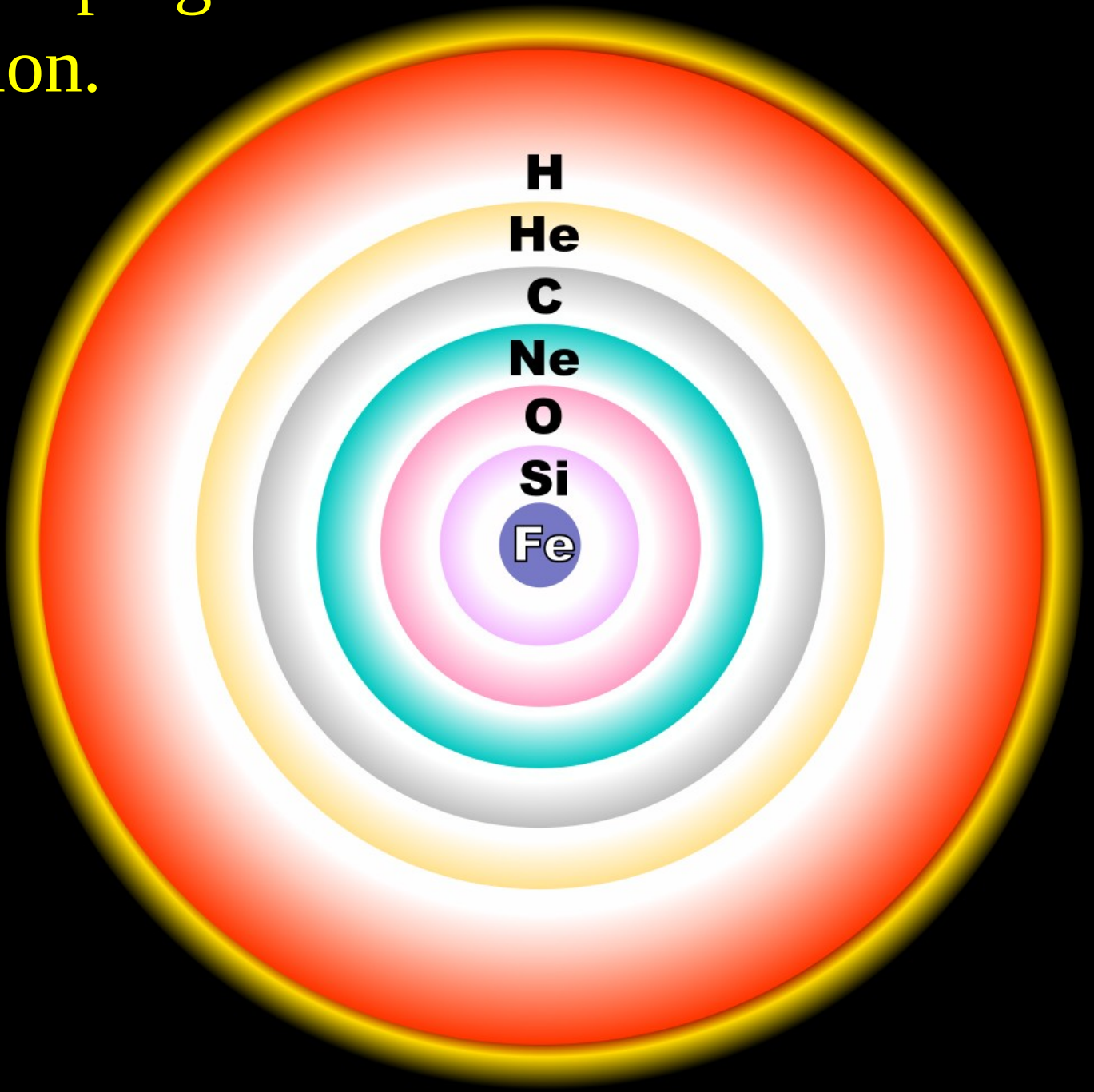
When that's depleted, they convert O to Mg, S, P, and Si

Then Si to Co, Fe, and Ni

Between each nuclear burning stage, the shell expands and the core contracts, heating up before it can burn the next fuel.

Late structure of a supergiant:

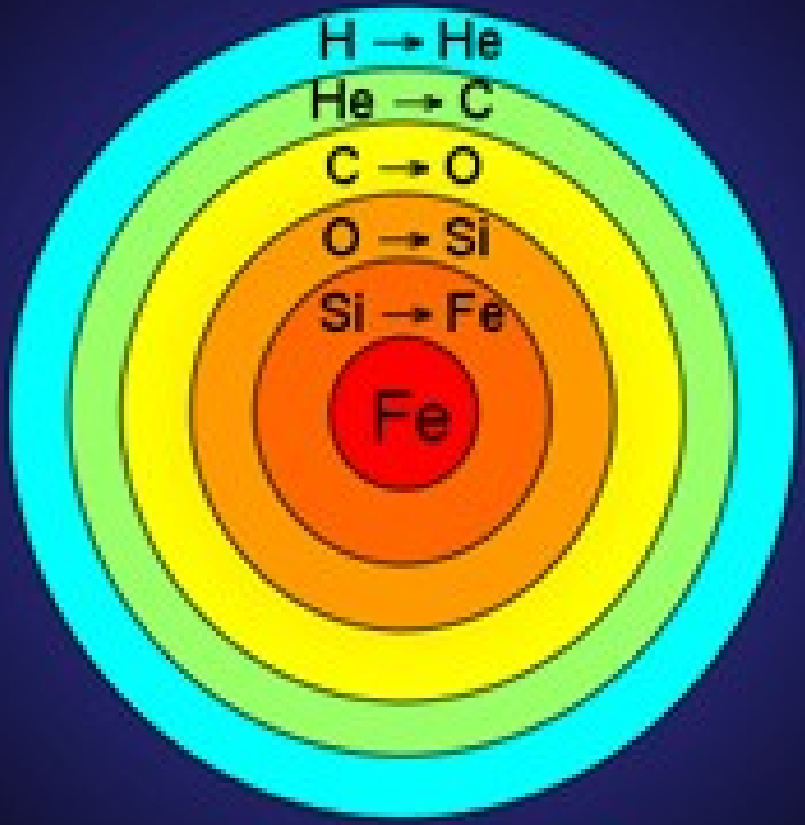
Like an onion.



Fuel Sources

Source	Temp	Density	Energy out
H	4 million K	10-100 g/cc	6.55 MeV
He	100 million K	1,000 to 1 million g/c	0.61 MeV
C	600 million K	0.1 to 100 million g/c	0.54 MeV
O	1 billion K	1 billion g/cc	0.3 MeV
Si	3 billion K	3 billion g/cc	0.18 MeV

Supergiant Fusion Timescales



For a 25 solar mass star:

Stage	Duration
H → He	7×10^6 years
He → C	7×10^5 years
C → O	600 years
O → Si	6 months
Si → Fe	1 day
Core Collapse	1/4 second

So what happens when you've built up an Iron core?
What can Iron do to support itself?

Time to do HW3.

Put everything away except your homework and your phone with the clicker app open.

No talking.

Put the row letter where you want it passed back next Monday.

1) About what fraction of stars have planets?

A) Nearly 0%
B) 10%
C) 50%
D) 90%

2) Which star is the coolest?

A) Yellow
B) Red
C) Orange
D) Violet
E) Blue

3) What is the temperature of a star with a peak in its spectrum at 250 nm?

A) 250 K
B) 5,500 K
C) 11,600 K
D) 42,300 K

4) A cloud forms four stars. Which star is the hottest?

A) 12 M_{Sun}
B) 3 M_{Sun}
C) 0.8 M_{Sun}
D) 0.4 M_{sun}
E) They are all the same.

5) A cloud forms four stars. Which star is the faintest?

A) 12 M_{Sun}
B) 3 M_{Sun}
C) 0.8 M_{Sun}
D) 0.4 M_{sun}
E) They are all the same.

6) A cloud forms four stars. What is the total luminosity of all 4 stars?

A) 47 L_{Sun}
B) 312 L_{Sun}
C) 2312 L_{Sun}
D) 6033 L_{sun}
E) $4L_{sun}$.

7) A cloud forms four stars. After 3 billion years how many are still on the main sequence?

A) 4
B) 3
C) 2
D) 1
E) 0

8) A cloud forms four stars. After 15 billion years how many are still on the main sequence?

A) 4
B) 3
C) 2
D) 1
E) 0

9) Why must stars evolve?

A) They don’t.
B) To change color.
C) Because stars are moving (in motion).
D) Stars are using fuel which is limited.

10) What is the source of energy for our Sun?

A) Gravity
B) Fusion H → He
C) Nothing, it needs nothing.
D) Fusion He → C/O
E) Luminosity

11) Red star and blue star in a binary. What else do I know about these two stars?

A) The blue star is hotter.
B) They are at the same distance.
C) The red star is larger (the blue star is smaller).
D) They started at the same time.
E) All of the above are true.

Bonus questions 12) How will our Sun end?

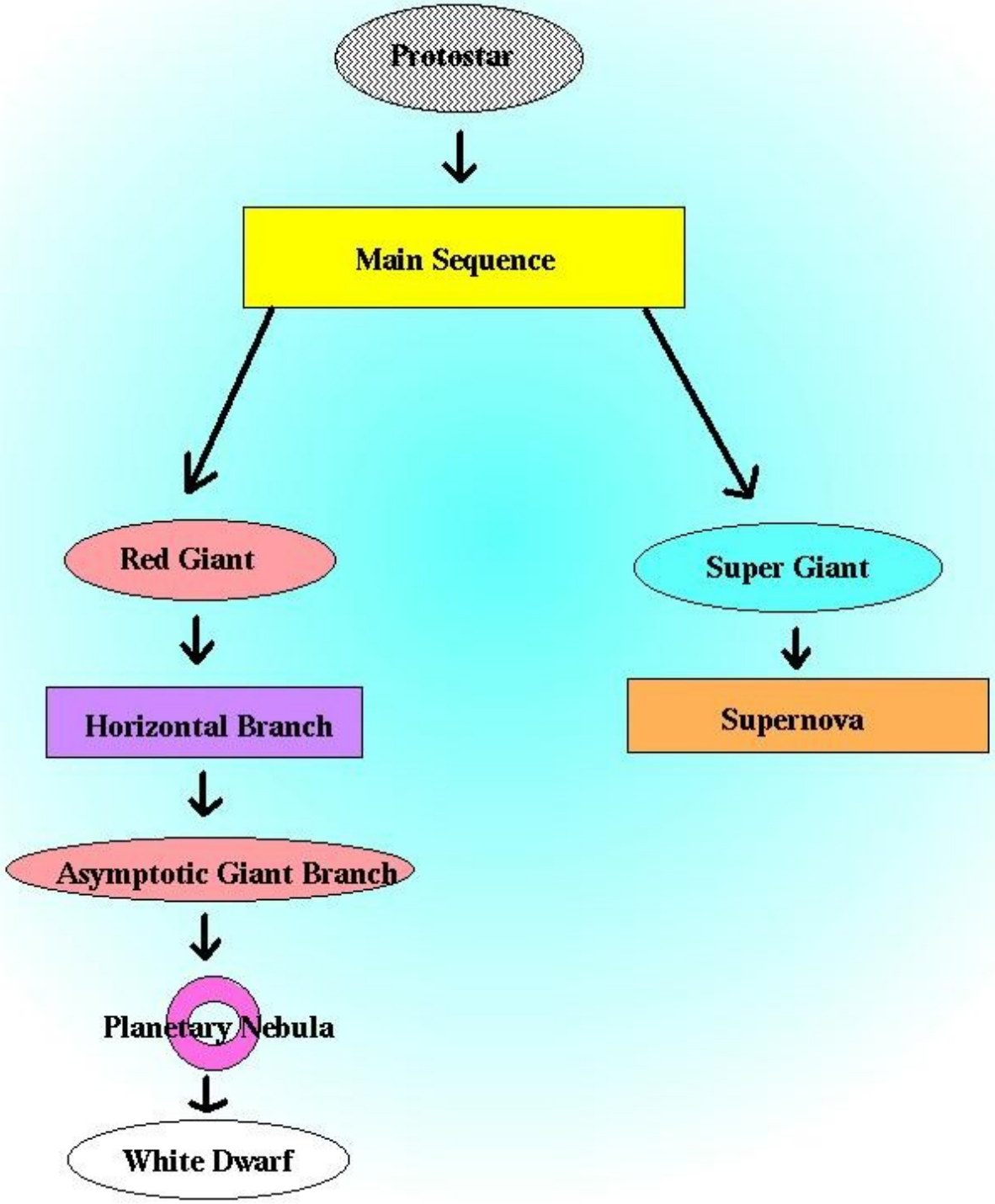
A) Explode
B) Shine forever
C) White dwarf
D) Supergiant

Be sure your name and row letter are on it.

Pass it to your right, please.

So what happens when you've built up an Iron core?
What can Iron do to support itself?

NOTHING!


Protostar
Main Sequence
Red Giant
Super Giant
Horizontal Branch
Supernova
Asymptotic Giant Branch
Planetary Nebula
White Dwarf