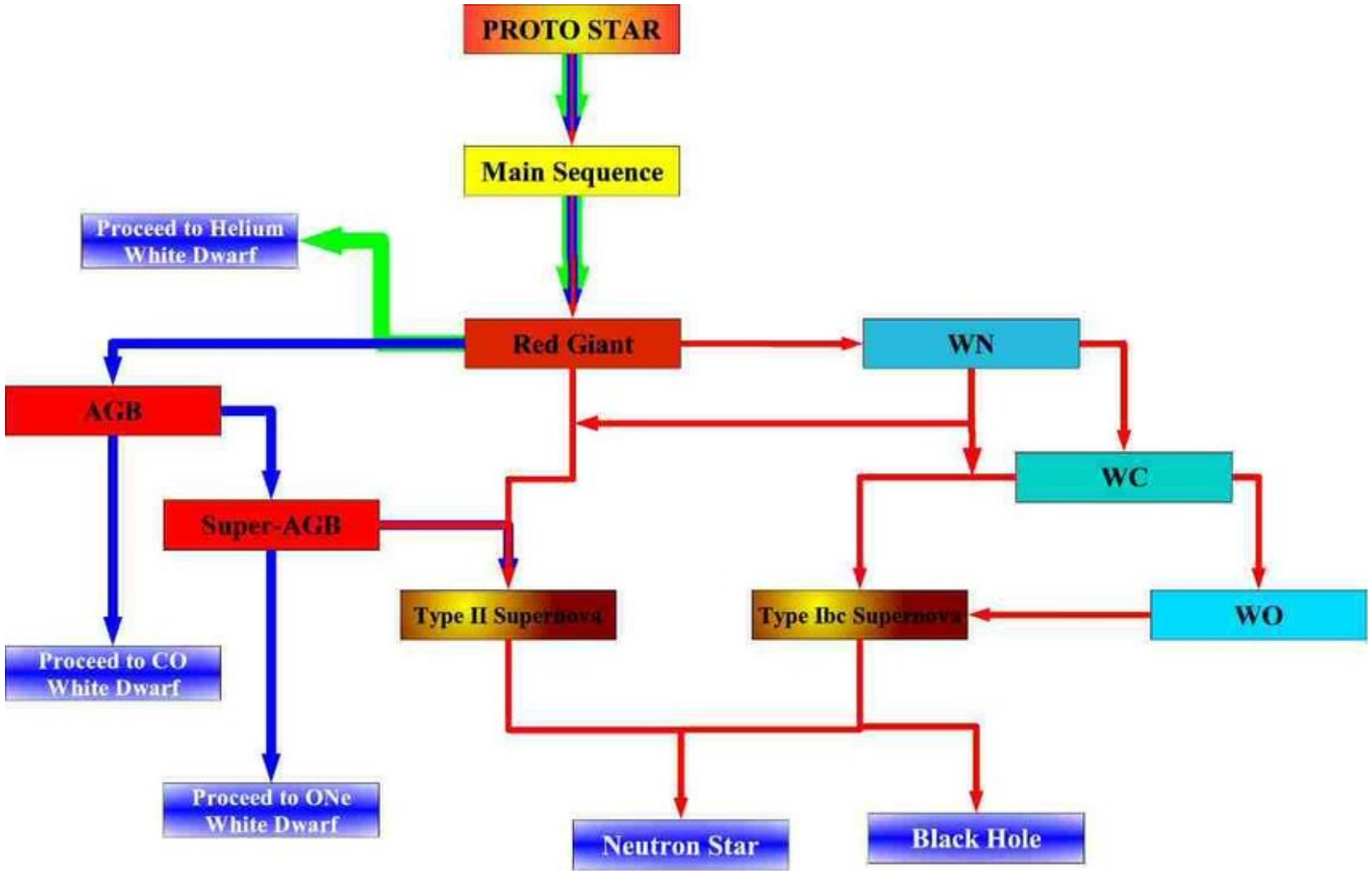
STELLAR EVOLUTION OF HIGH MASS STARS

CLAYTON HANSEN

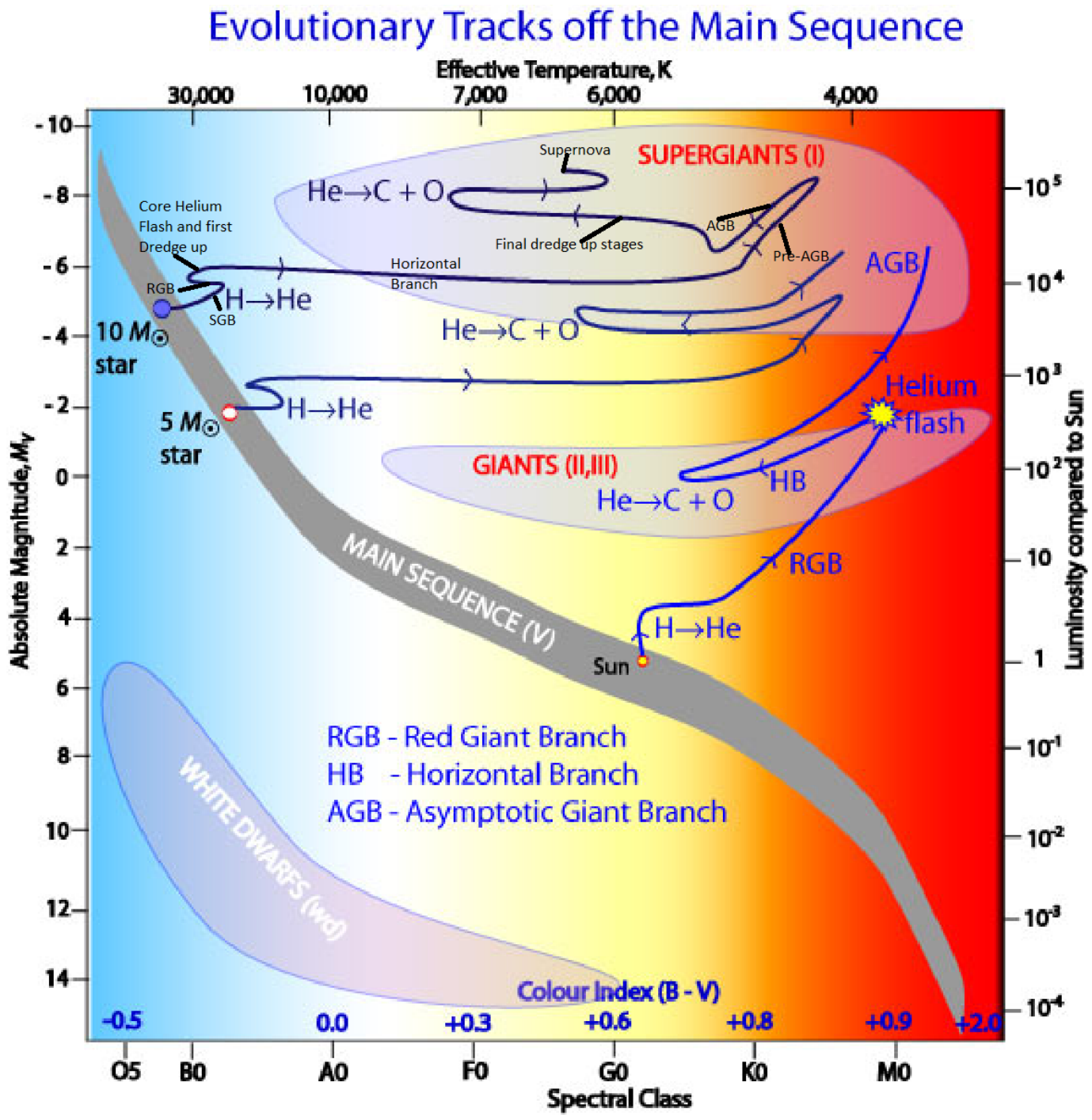
PHYS 5500

- Red lines indicates High Mass Star (HMS) paths
  - >8M
- Blue lines indicate Medium Mass Star (MMS) paths
  - 0.8M to 8M
- Green lines indicate Low Mass Star (LMS) paths
  - <0.8M
- W stands for Wolf-Rayet, a star near the supernova stage
- WN is mostly Nitrogen
- WC is mostly Carbon
- WO is mostly Oxygen



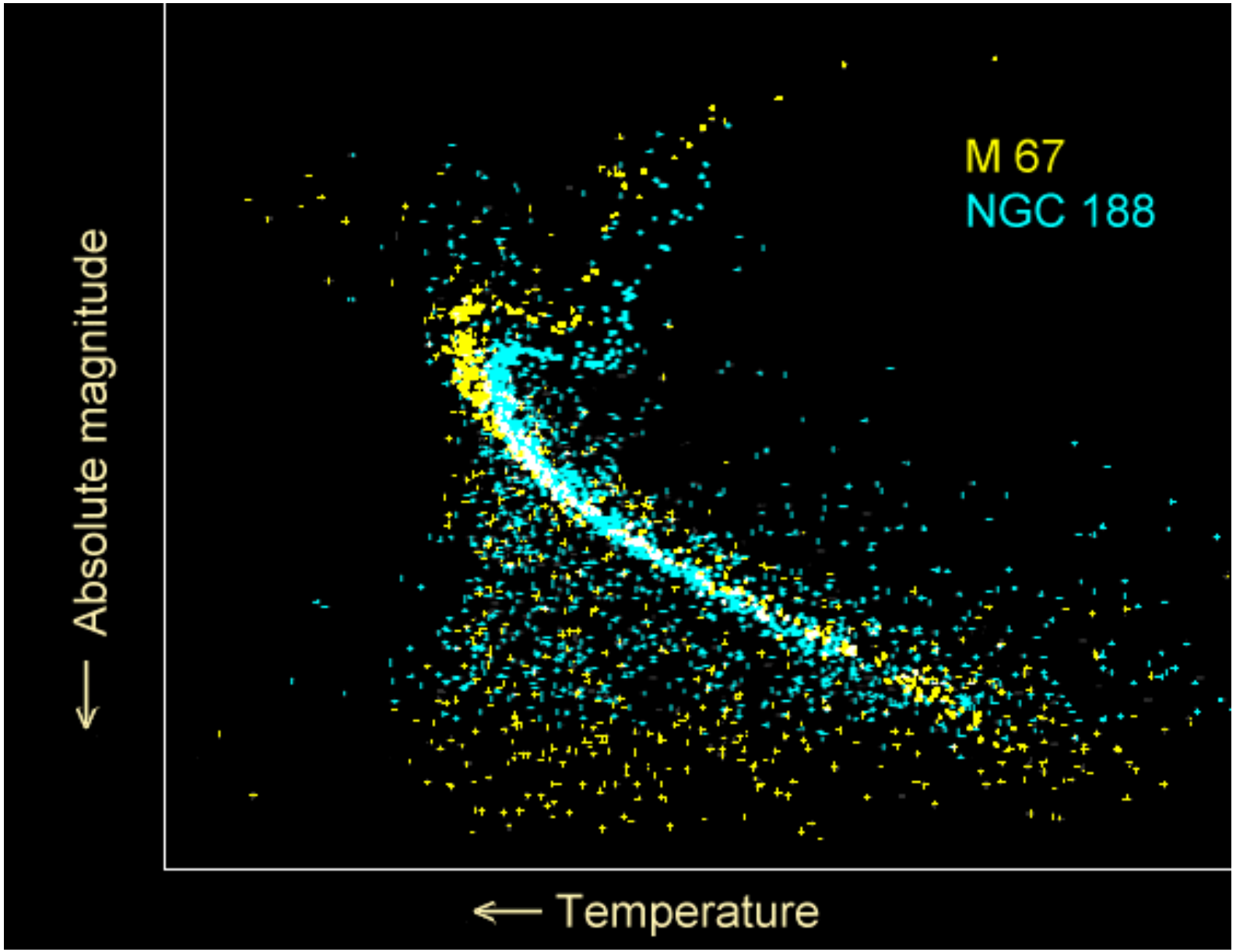
MASSIVE STAR LIFE CYCLE

Subgiant Branch (SGB)	• Burns Hydrogen Shell, outer layers grows in size
Red Giant Branch (RGB)	• Helium Core Compresses, Increased hydrogen shell burning
Core helium Flash	• Pressure causes Helium to ignite
First Dredge up	• Expanded atmosphere cools, convection moves elements around
Horizontal Branch	• Helium core burning, Hydrogen Shell Burning
Pre-Asymptotic Giant Branch (AGB)	• Outer layer expands, cools down and hydrogen shell stops burning
AGB	• Hydrogen shell reignites
Several dredge up stages	• Nucleosynthesis of lighter elements into heavier elements
Supernova	• Turns into Black Hole or Neutron Star


Evolutionary Tracks off the Main Sequence
Effective Temperature, K
30,000
10,000
7,000
6,000
4,000
Absolute Magnitude, M_V
Luminosity compared to Sun
Supernova
SUPERGIANTS (I)
He→C + O
Core Helium
Flash and first
Dredge up
Final dredge up stages
AGB
Pre-AGB
Horizontal
Branch
RGB
H→He
SGB
10 $M_\odot$
star
He→C + O
AGB
Helium
flash
5 $M_\odot$
star
H→He
GIANTS (II,III)
HB
He→C + O
MAIN SEQUENCE (V)
RGB
H→He
Sun
RGB - Red Giant Branch
HB - Horizontal Branch
AGB - Asymptotic Giant Branch
WHITE DWARFS (WD)
Colour Index (B - V)
-0.5
0.0
+0.3
+0.6
+0.8
+0.9
+2.0
O5
B0
A0
F0
G0
K0
M0
Spectral Class

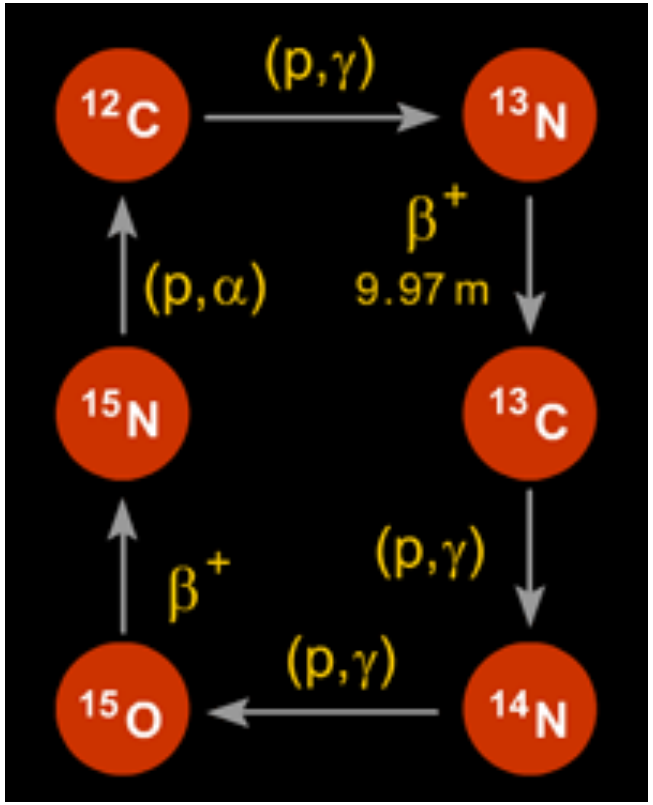
SGB

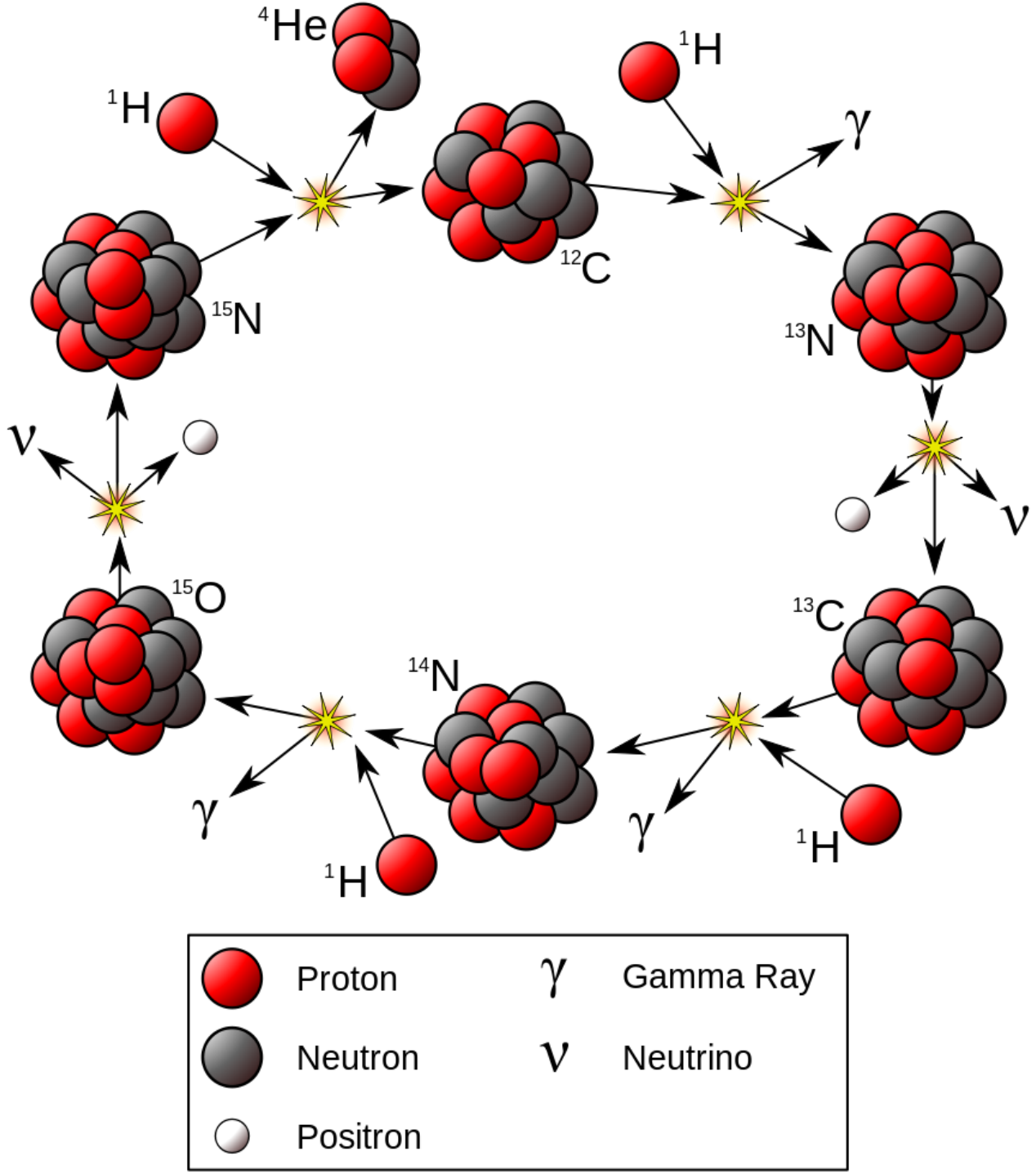
- Immediately follows the turnoff from main sequence star
- More massive star means shorter SGB
- Core helium fusion begins at end of SGB
- More massive stars can finish SGB before core becomes helium
- Star expands in size
- May have convection cells that lead to core from the CNO cycle
- Theta^2 Orionis A is an example of a massive star currently in the SGB



CNO CYCLE

- Stands For Carbon, Nitrogen, Oxygen cycle
- Fuses hydrogen into helium
- Carbon acts as the catalyst while Oxygen and Nitrogen absorb protons to create helium
- Occurs as the temperature and pressure at core for a HMS is much greater than a LMS (Low Mass Star)




^{4}He
^{1}H
^{12}C
^{1}H
γ
^{15}N
^{13}N
ν
ν
^{15}O
^{13}C
^{14}N
γ
γ
^{1}H
^{1}H
Proton
Neutron
Positron
γ
Gamma Ray
ν
Neutrino

RED GIANT BRANCH

- Hydrogen core fuses into helium core
- Helium core + Convection push remaining hydrogen in core out to the hydrogen shell
- Continually increasing mass, temperature, and luminosity
- Starts to cool down
- Brings convection to core to create the first dredge up

CORE HELIUM FLASH

- Enough pressure in the core allows the ash helium core to ignite
- Sends out massive amounts of neutrinos
- A star over 2.2M or under 0.8M does not have a core helium flash
- Instead of ‘flashing’ the helium core away in minutes, the helium core and shell takes an extremely long time to burn

FIRST DREDGE UP

- Expands the atmosphere
- Pushes elements like Hydrogen, helium nitrogen, carbon, out of core
- Core begins to become more massive elements like silicon and iron
- Star begins to cool down again

HORIZONTAL BRANCH

- Larger hydrogen shells lead to a cooler star
- Temperature rang stays roughly the same throughout the entire branch
- Hotter stars typically have lower luminosity during this stage
- Temperature variation is much more noticeable at lower metallicity, older star clusters have much more pronounced horizontal branches as well as LMS

PRE-AGB AND AGB

Pre-AGB

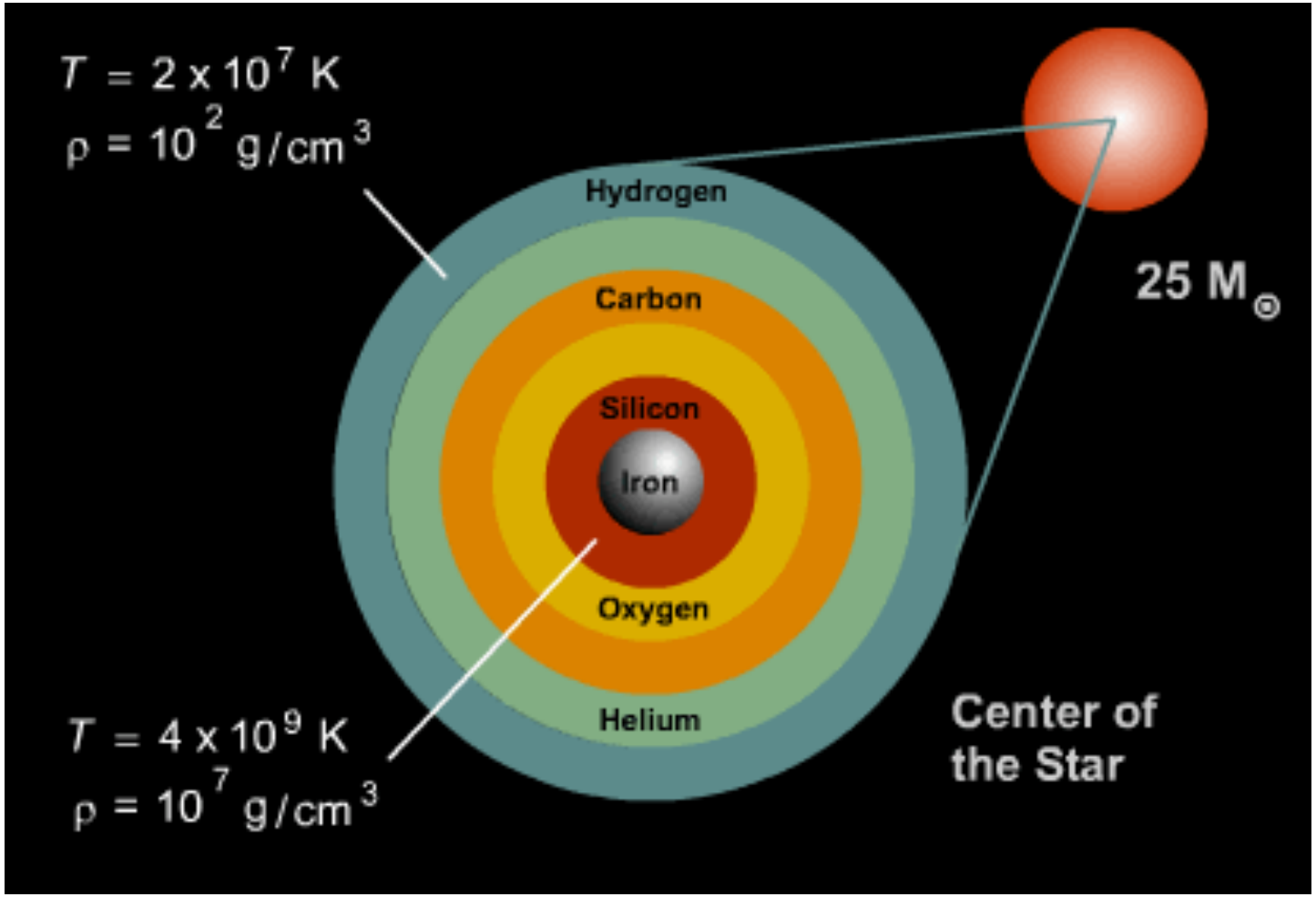
- Outer layer of star cools down and massively expands
- Hydrogen shell stops burning from the cooldown
- Inner helium shell continue to burn due to pressure
- Stops once helium shell is burned up

AGB

- Thermal pulses last a few hundred years
- Thermal pulses create multiple dredge ups creating more lighter element shells around the heavier Silicon or Iron core
- Begins to fuse hydrogen shell into another helium shell
- The star may lose 50% to more than 70% of its mass during this stage

FINAL DREDGE UP STAGES

- In the final stages of dredging up nucleosynthesis causes the core of the star to change from Helium to Carbon, Carbon to Neon, Neon to Oxygen, Oxygen to Silicon, then Silicon to Iron.
- Gravitational pressure in the core causes temperatures to raise allowing the star to burn its core all the way until it reaches iron. Upon reaching iron the star goes supernova and turns into a Black hole or Neutron star
- In a 25M star, Hydrogen takes 7E6 years to fuse, Helium takes 7E5 years, Carbon takes 600 years, Neon takes 1 year, oxygen takes 6 months, and silicon burns in a day.



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