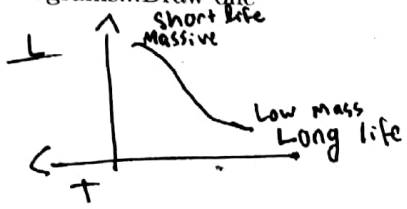
Stars cont'd[1]

1. HR diagrams...Draw one [2]



   (a) Draw the main sequence (MS) on your HR diagram $L \propto M^4$ -> large L <-> large M

   (b) Label where the most massive stars on the MS lie.

   (c) *Explain* why the main-sequence lifetime scales as $\frac{1}{M^3}$. *Hint:* think about how mass scales with luminosity.

$$t_{MS} \propto \frac{\text{amount of fuel}}{\text{how fast you use fuel}} \propto \frac{M}{M^4} = \frac{1}{M^3}$$

amount of fuel $\propto M$

how fast use $\propto L \propto M^4$

   (d) Label where the ~~longest~~ Shortest lived stars on the MS lie.

2. **Bonus:** Humans have been on Earth for about 200,000 years. By what factor would you have to increase the mass of the Sun for its MS lifetime to be comparable to the existence of humanity?

$t_{MS,now} \simeq 10\ \text{Gyr} = 10^{10}\text{yrs}$

$t'_{MS} = 10^5\ \text{yr}$

$$\frac{t'_{MS}}{t_{MS,now}} = \frac{10^5}{10^{10}} = \frac{\left(\frac{1}{M'}\right)^3}{\left(\frac{1}{M_{now}}\right)^3} = \frac{M_{now}^3}{(M')^3} = \left(\frac{M_{now}}{M'}\right)^3$$

$\rightarrow M' = \left(M_{now}^3\, 10^5\right)^{\frac{1}{3}}$

Star Wars

3. **Episode I: The Post MS-Attack:** *Star Ben has just finished ~10 billion years of hard-working, main-sequence fusion. Suddenly, Ben is under attack by a mysterious and vicious force known as gravity.*

   (a) What is Ben's core now made out of?

Helium

   (b) Why does fusion in Ben's core stop?

Not hot enough to do He fusion

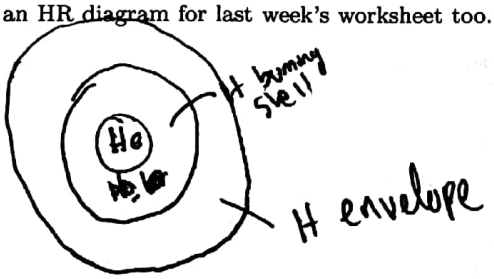
   (c) Who's winning right now, pressure or gravity?

Gravity

   (d) What happens to Ben's core?

Contracts

   (e) Sketch the star at this point, labeling which parts are composed of what elements. *Hint:* There are 3 main sections of the star to consider.



[1] Finally!

[2] yes, I had you draw an HR diagram for last week's worksheet too. thankfully, there's no such thing as drawing too many HR diagrams.

4. **Episode II: Retreat and Regroup:** *Gravity's attempt to crush Ben hasn't gone quite as planned. Pressure valiantly flights back.*

   (a) As Ben's core shrinks, it releases energy. Why? Where does the energy go? *Hint: it gets split half and half*

   Shrinking releases gravitational potential energy
   ½ energy goes to heat up core
   ½ energy goes to heating up H burning shell

5. **Episode III: A Cooler Compromise:**

   (a) What colour is Star Ben now? Why?

   Red ; H envelope pushed outward by fusion from H burning shell
   expanding gas cools → cold = Red

   (b) Star Ben has increased in radius by a factor of 100 at this point. If Ben's temperature holds constant, what happens to his luminosity? [3]

   $$\frac{L_2}{L_1} = \frac{4\pi R_2^2 \sigma T_2^4}{4\pi R_1^2 \sigma T_1^4} = \left(\frac{R_2}{R_1}\right)^2 = (100)^2 = 10^4$$

   Note $T_2 = T_1$

6. **Episode IV: Return fire!**

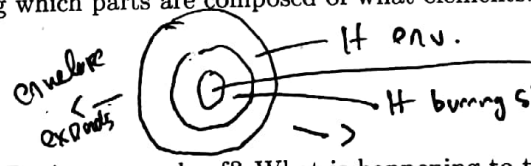
   (a) Eventually, Ben's core is able to ignite fusion again. What elements are fusing in the star now, and where?

   He → Carbon in Core
   H → He @ burning shell

   (b) Is the star contracting, expanding, or stable now?

   expanding still ; H envelope pushed farther out
   (AGB star)

   (c) Sketch the star at this point, labeling which parts are composed of what elements.



7. **Episode V: What now?**

   (a) Some ≈1 million years later, what is Ben's core made of? What is happening to the core?

   Carbon core. Shrinking again b/c no fusion

   (b) Sketch what Ben looks like now, labeling all component regions.

   (c) Is Ben's size decreasing, staying constant, or increasing? Why?

   (?) Expanding, outer layers pushed away by lots of shell burning → planetary nebula

8. **Episode VI: All hope is not lost**[4]

   (a) Eventually, gravity hits a roadblock even it cannot overcome. What is it?

   e^- degen. pressure
   Carbon core stops shrinking.
   Live happily ever after as WD.

[3] Who ever said Ben isn't bright?
[4] I hope it is clear that Episodes III-VI were *far* superior to the original trilogy.