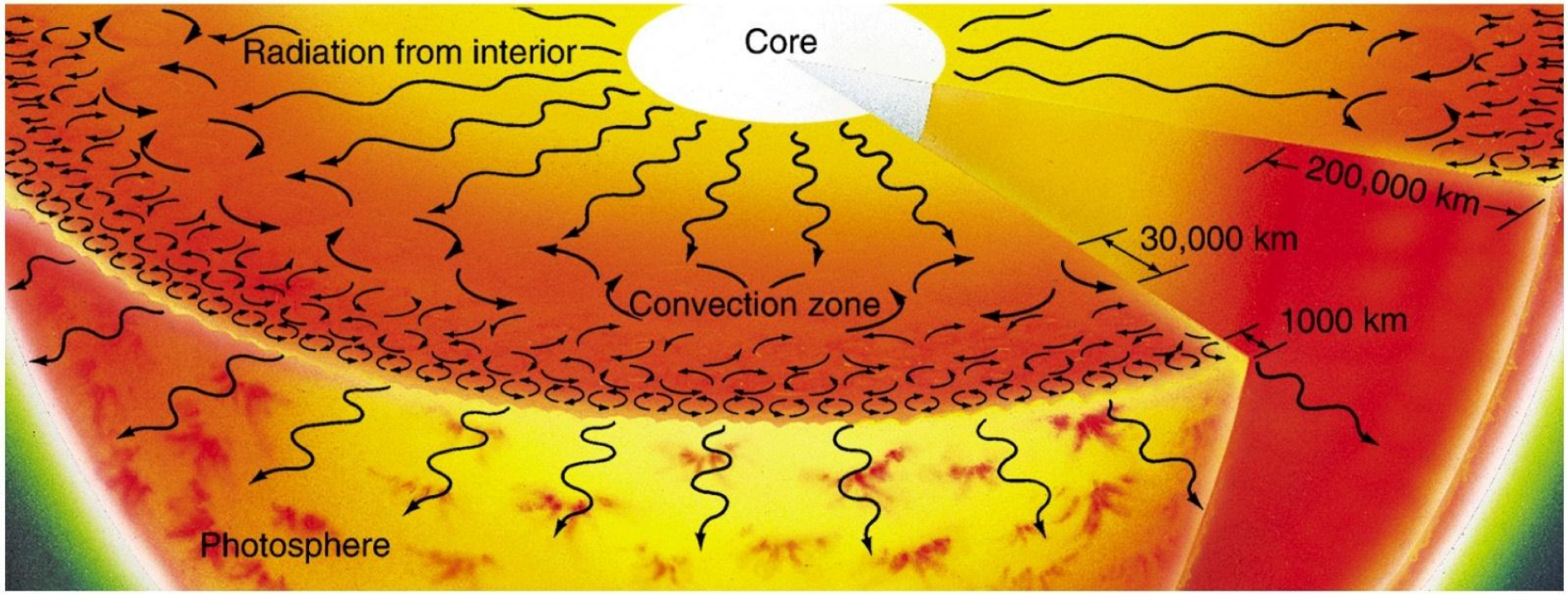
Stellar Structure



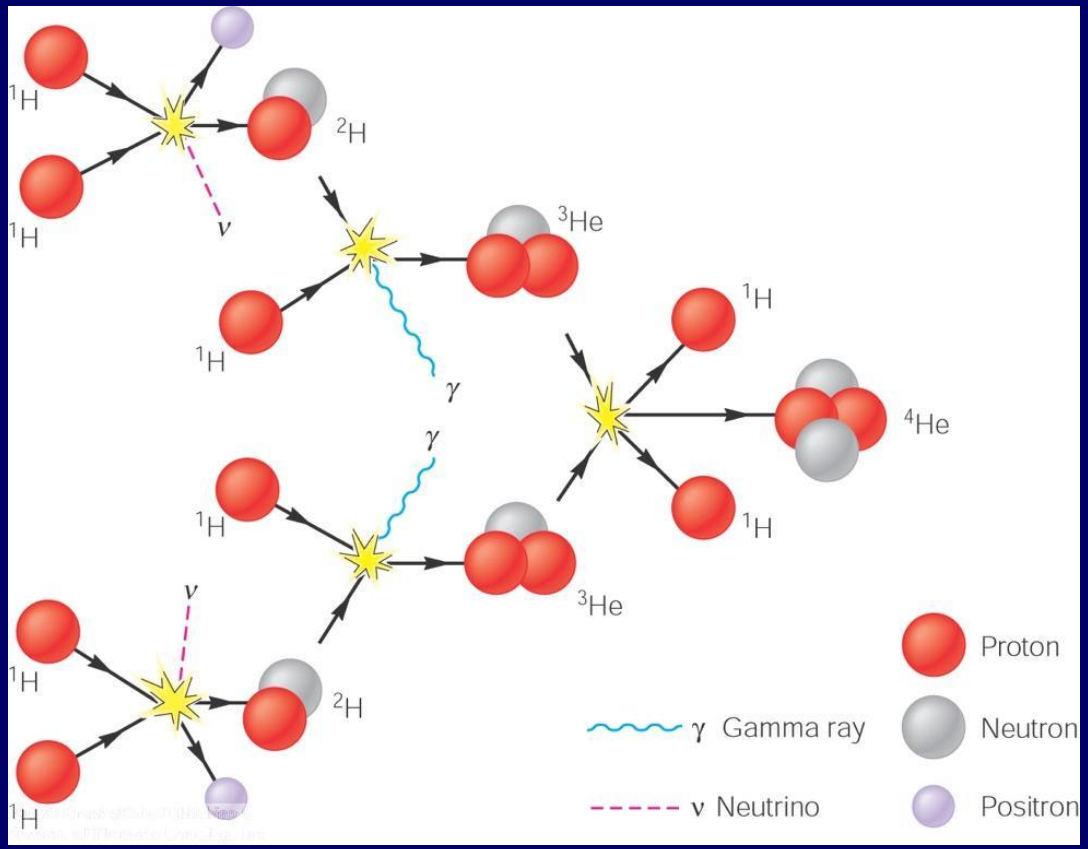
Energy Production
Hydrostatic Equilibrium
Energy Transport
Stellar Models

The Source of Stellar Energy

Recall from our discussion of the Sun:

Stars produce energy by nuclear fusion of hydrogen into helium.

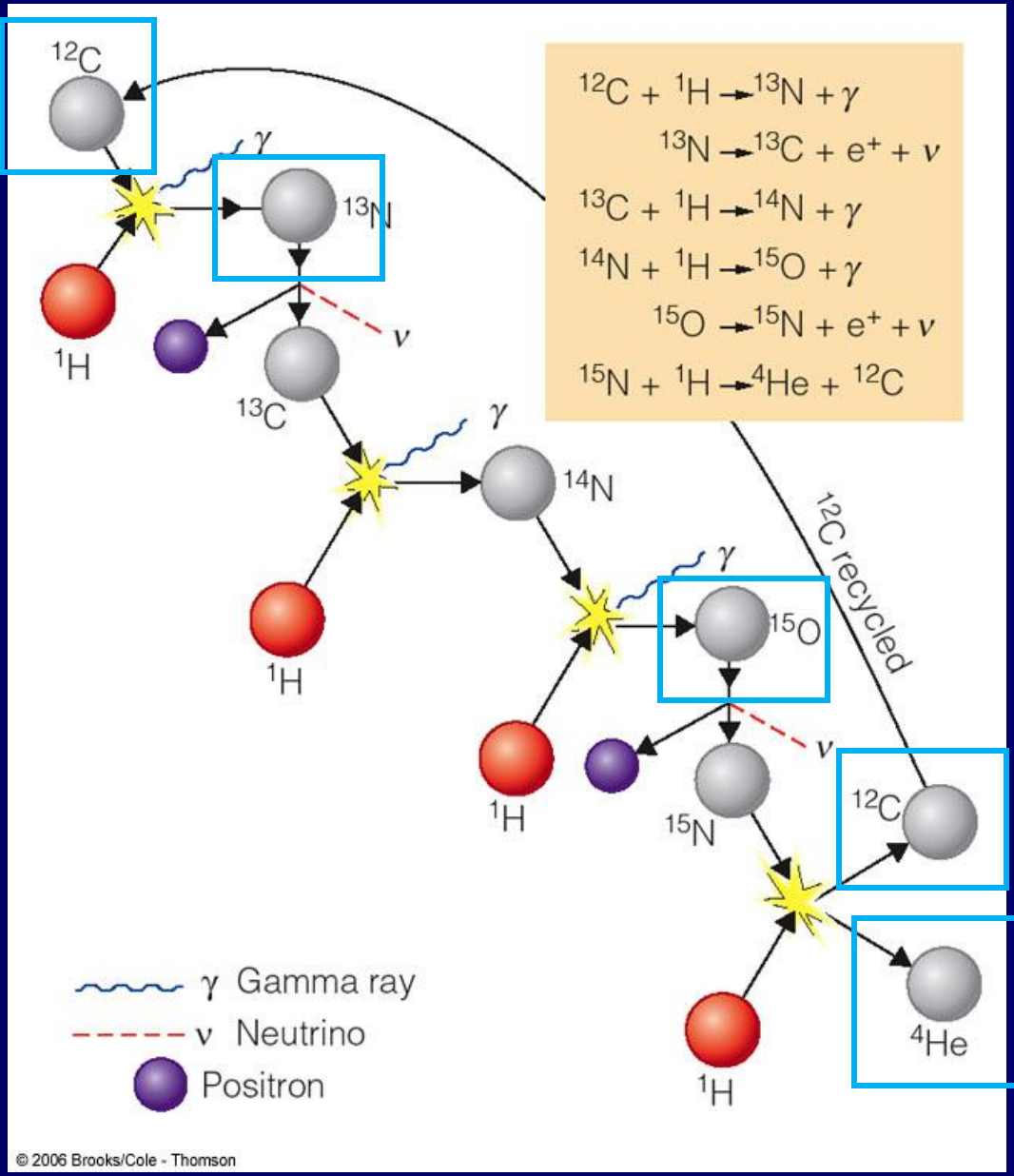
In the Sun, this happens primarily through the proton-proton (PP) chain



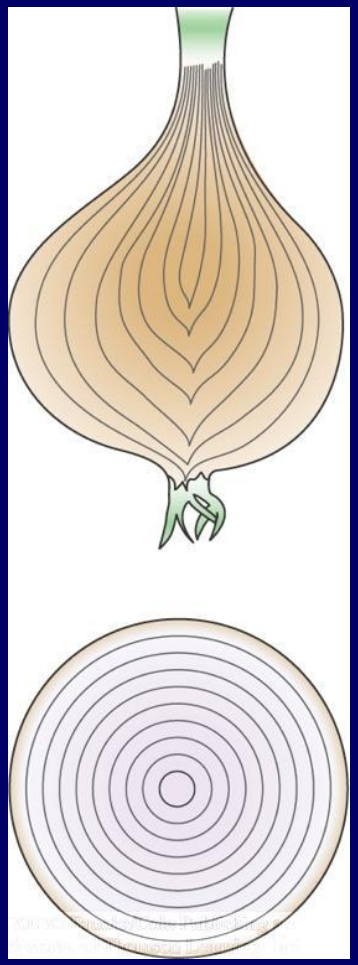
The CNO Cycle

In stars that are slightly more massive than the Sun or larger, another energy generation mechanism dominates over the PP chain:

the CNO cycle.



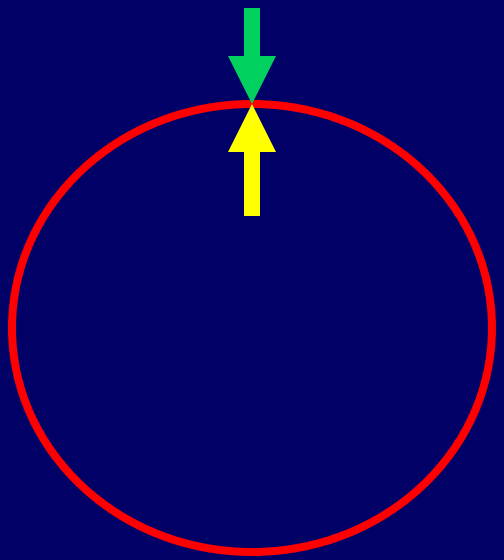
Hydrostatic Equilibrium



Imagine a star's interior composed of individual shells

Within each shell, two forces have to be in equilibrium with each other:

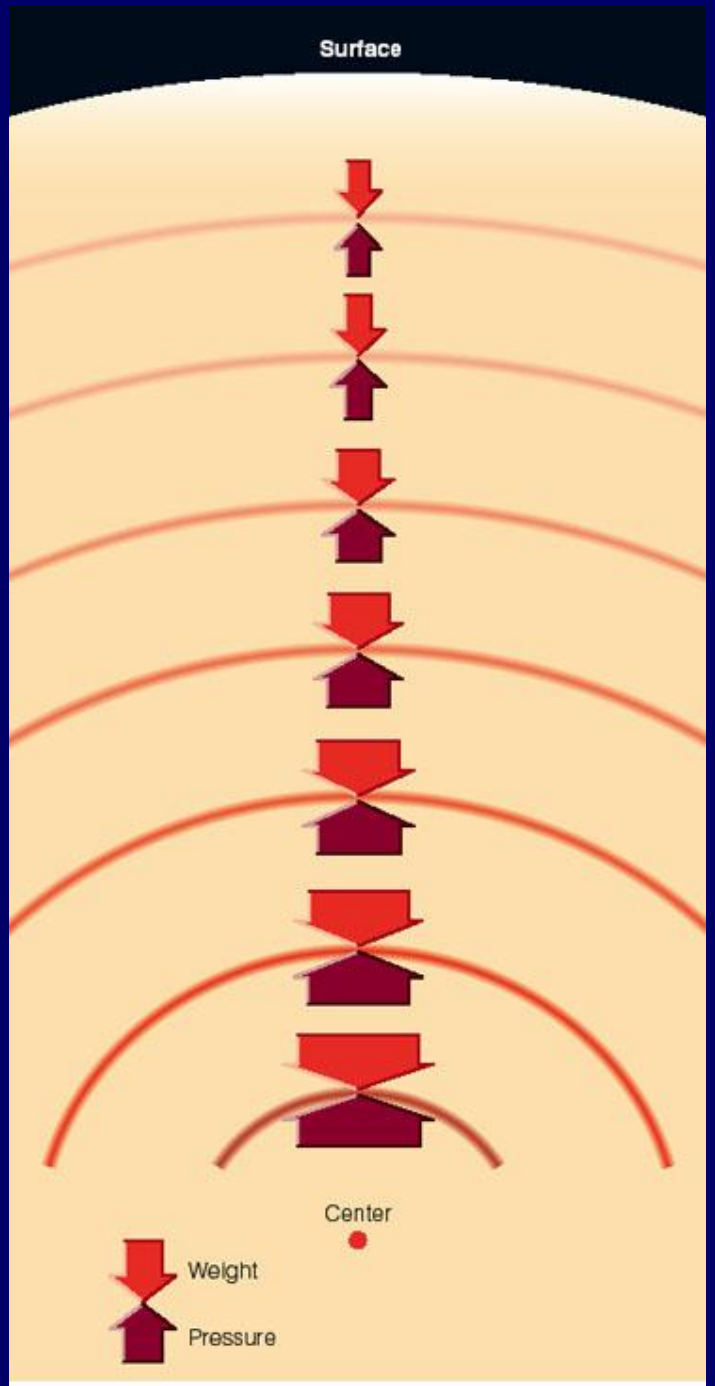
Gravity, *i.e.* the weight from all layers above



Outward pressure from the interior

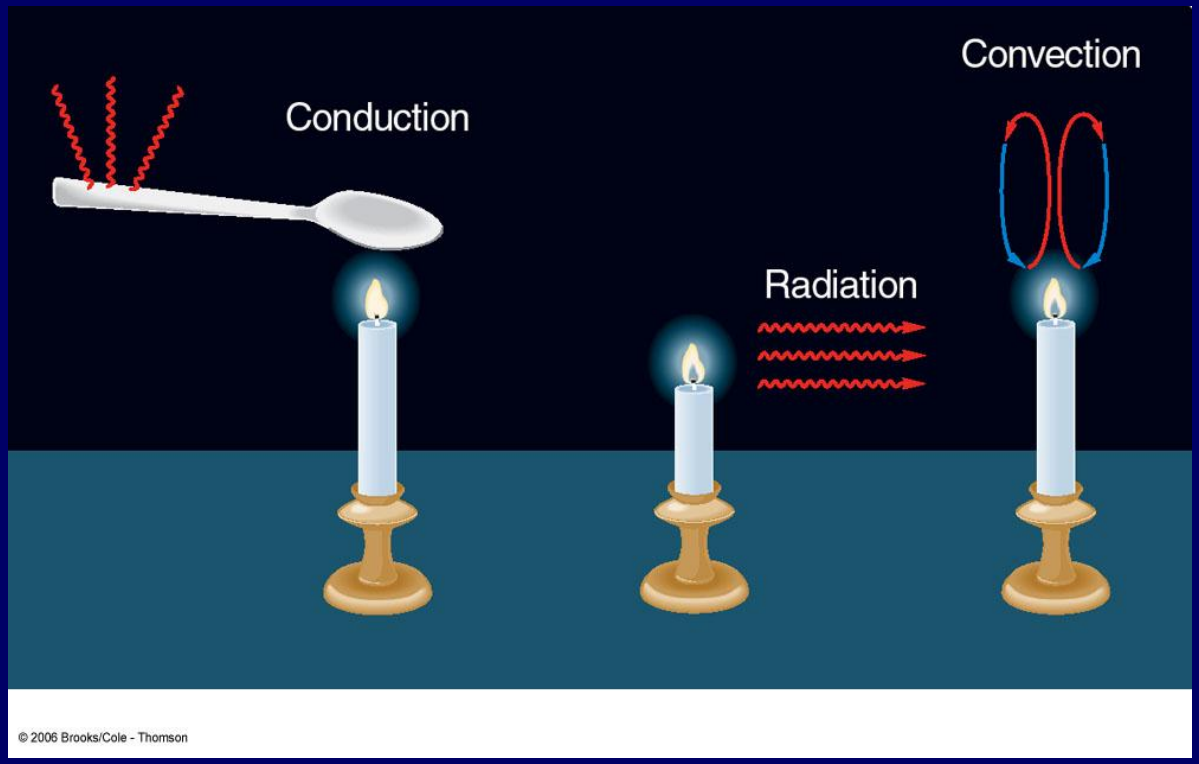
Hydrostatic Equilibrium

- Outward pressure must exactly balance the weight of all layers above everywhere in the star.
- This condition uniquely determines the interior structure of the star.
- This is why we find stable stars on such a narrow strip (main sequence) in the Hertzsprung-Russell diagram.



Energy Transport

Energy generated in the star's center must be transported to the surface.



- **Mechanism for the inner layers of the Sun:**

  Radiative energy transport

- **Mechanism for the outer layers of the Sun (including the photosphere):**

  Convection

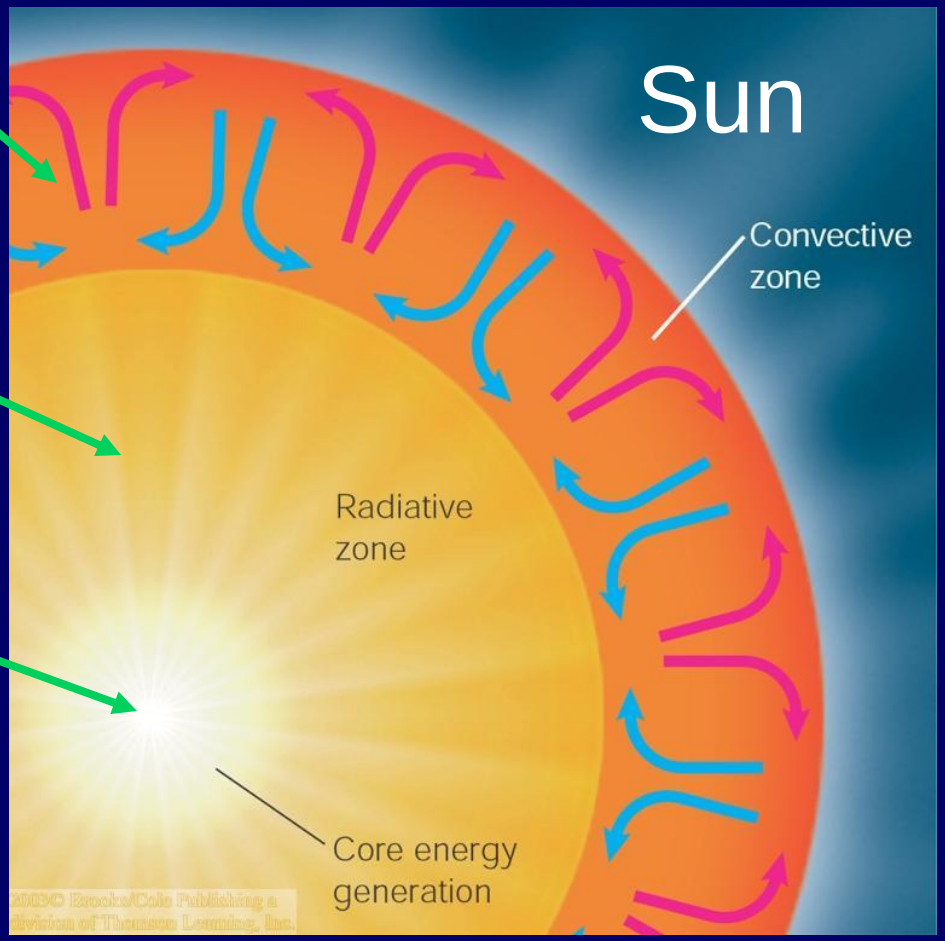
Stellar Structure

Flow of energy

Energy transport via convection

Energy transport via radiation

Energy generation via nuclear fusion



Basically the same structure for all stars with ~1 $m_\odot$ or less.

Temperature, density and pressure decreasing

Stellar Models

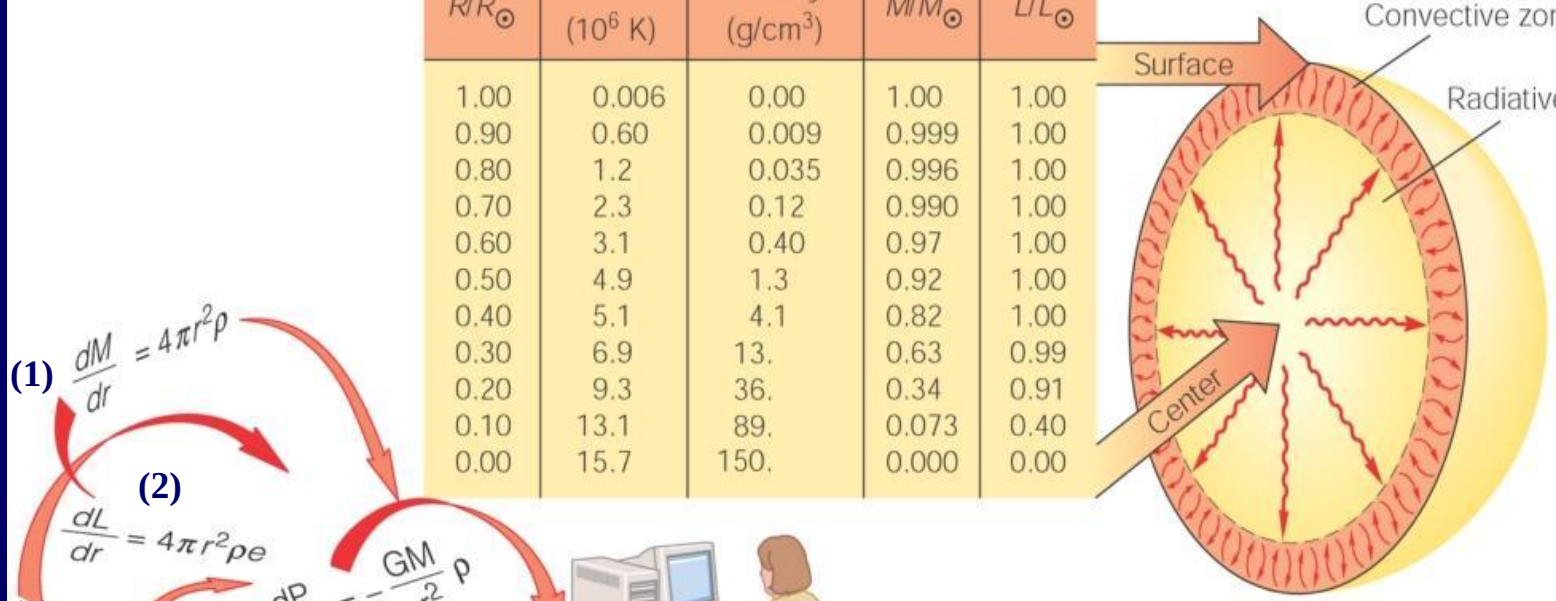
The structure and evolution of a star is determined by the laws of:

1. **Conservation of mass: Total mass equals the sum of shell masses.**
2. **Conservation of energy: Total luminosity equals the sum of energy generated in each shell.**
3. **Hydrostatic equilibrium: The weight on each layer is balanced by the pressure in that layer.**
4. **Energy transport: Energy moves from hot to cool regions by radiation or convection.**

Stellar Models

1. Conservation of mass
2. Conservation of energy
3. Hydrostatic equilibrium
4. Energy transport

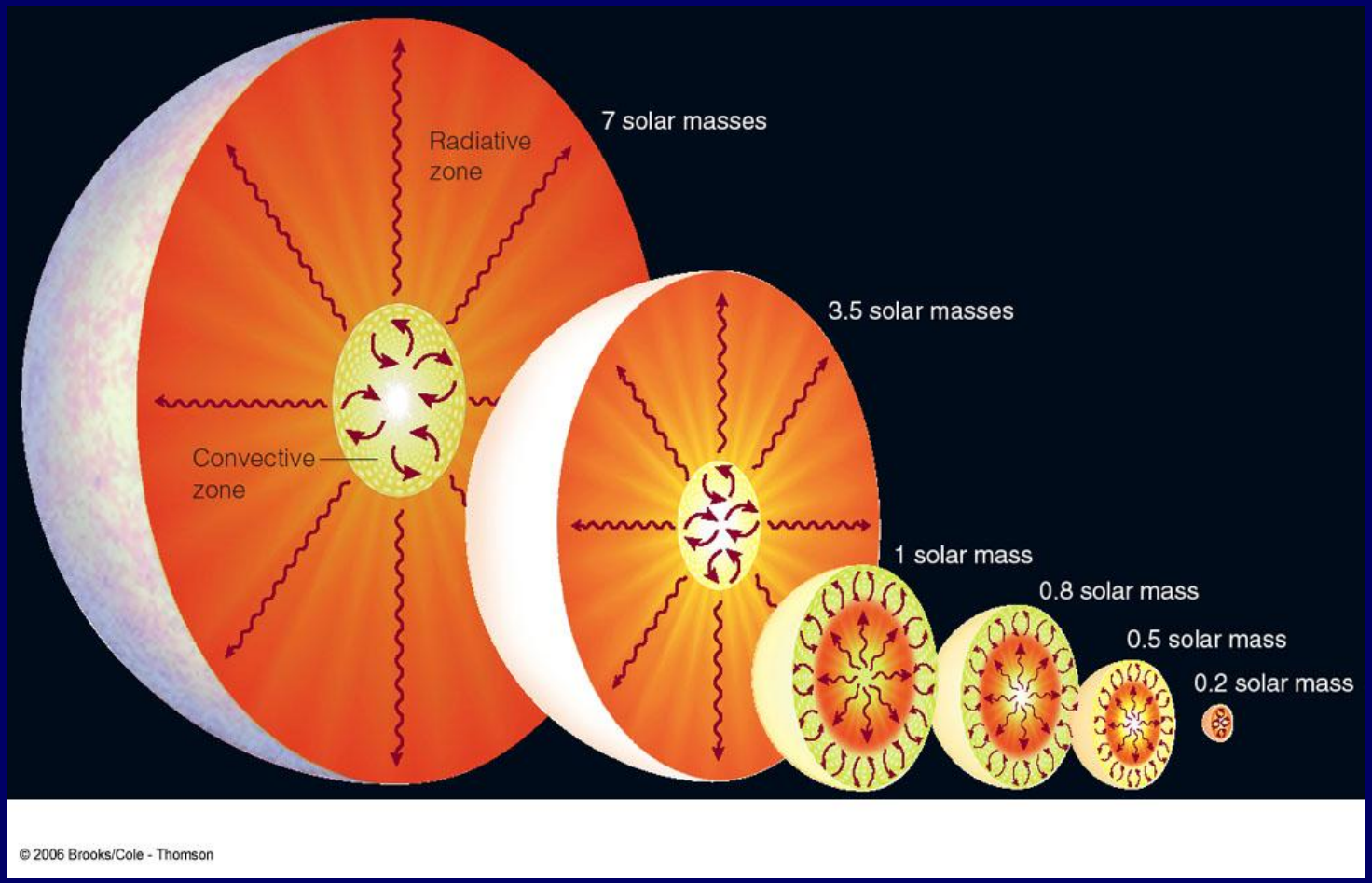
$R/R_\odot$	T (10^6 K)	Density (g/cm^3)	$M/M_\odot$	$L/L_\odot$
1.00	0.006	0.00	1.00	1.00
0.90	0.60	0.009	0.999	1.00
0.80	1.2	0.035	0.996	1.00
0.70	2.3	0.12	0.990	1.00
0.60	3.1	0.40	0.97	1.00
0.50	4.9	1.3	0.92	1.00
0.40	5.1	4.1	0.82	1.00
0.30	6.9	13.	0.63	0.99
0.20	9.3	36.	0.34	0.91
0.10	13.1	89.	0.073	0.40
0.00	15.7	150.	0.000	0.00



Russell-Vogt Theorem:
A star's mass and chemical composition completely determine its properties.

That is why all stars initially line up along the main sequence.

Stellar Models



Computer models show that upper main-sequence stars convect heat in their cores and have radiative heat transport in their envelope, the opposite of lower main-sequence stars.