

Section 6.

End of massive stars

6.1 Dynamical stability of stars

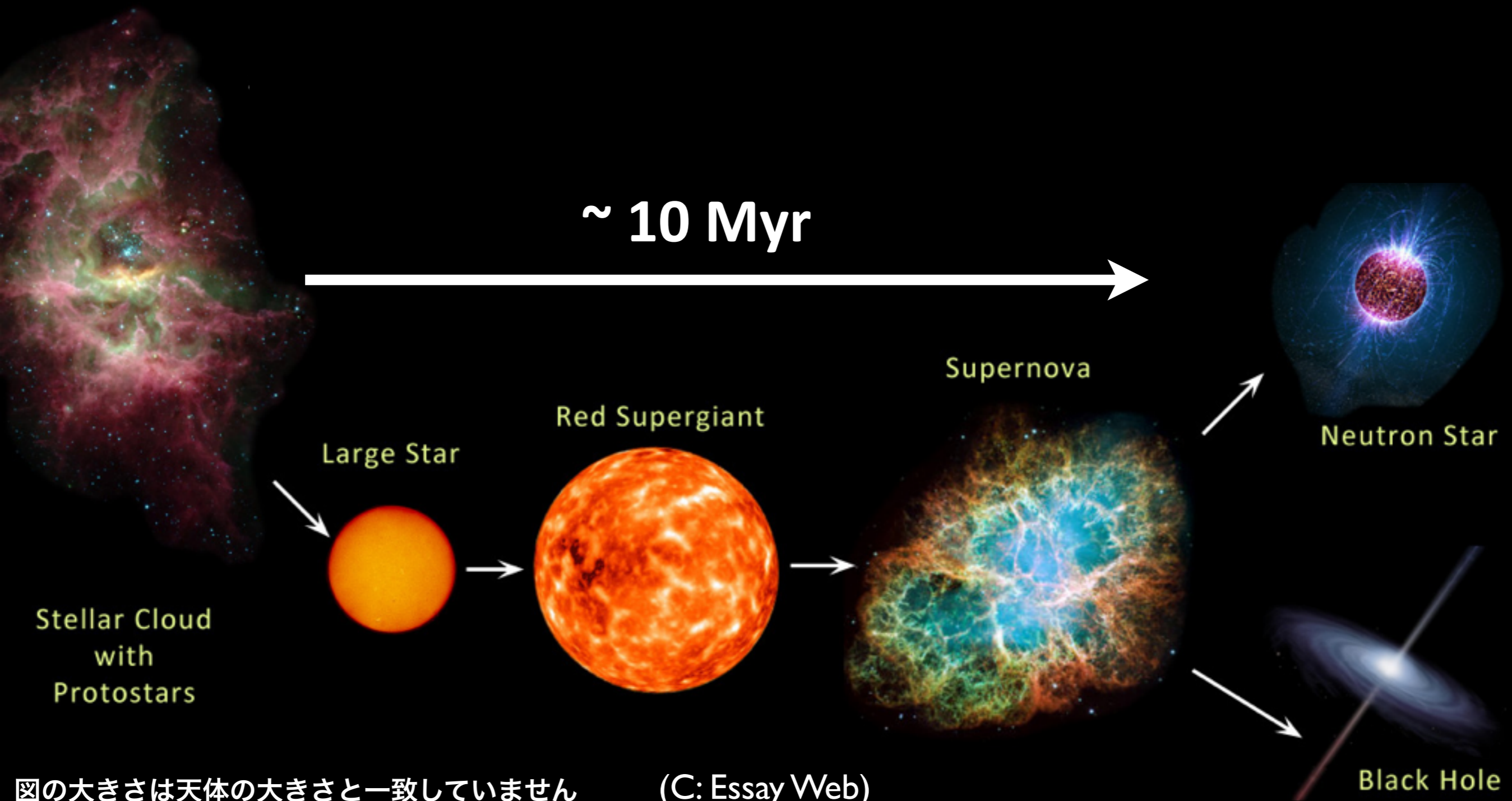
6.2 Core-collapse of massive stars

Let's understand these questions with the words of physics

- Why are stars so luminous?
- Why do stars show $L \sim M^4$?
- Why do stars evolve?
- Why does the destiny of stars depend on the mass?
- Why do some stars explode?
- Why don't normal star explode?
- Why does stellar core collapses?
- Why is the energy of supernova so huge?
- ...

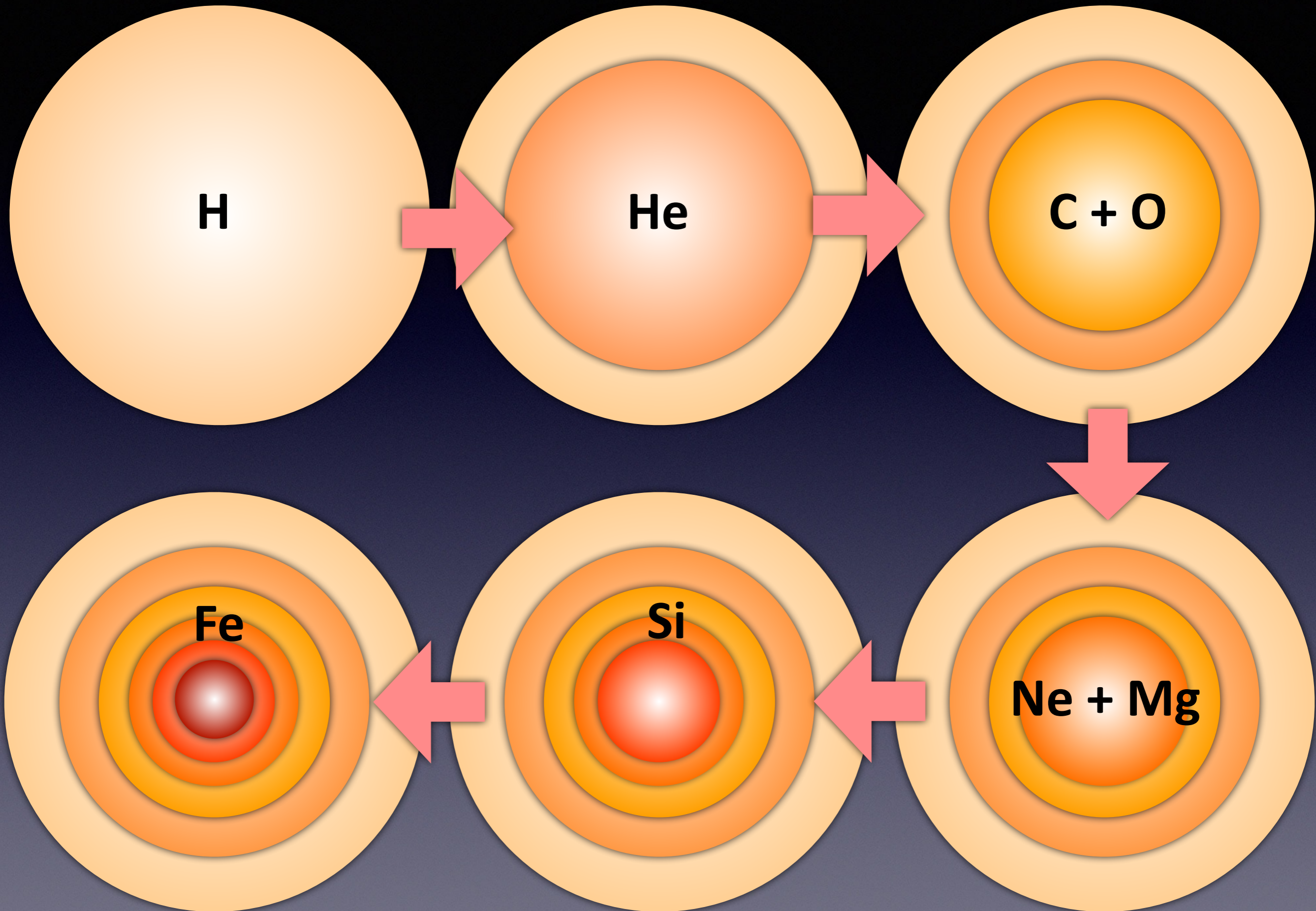
1. Massive stars

$M > 10 M_{\text{sun}}$



図の大きさは天体の大きさと一致していません

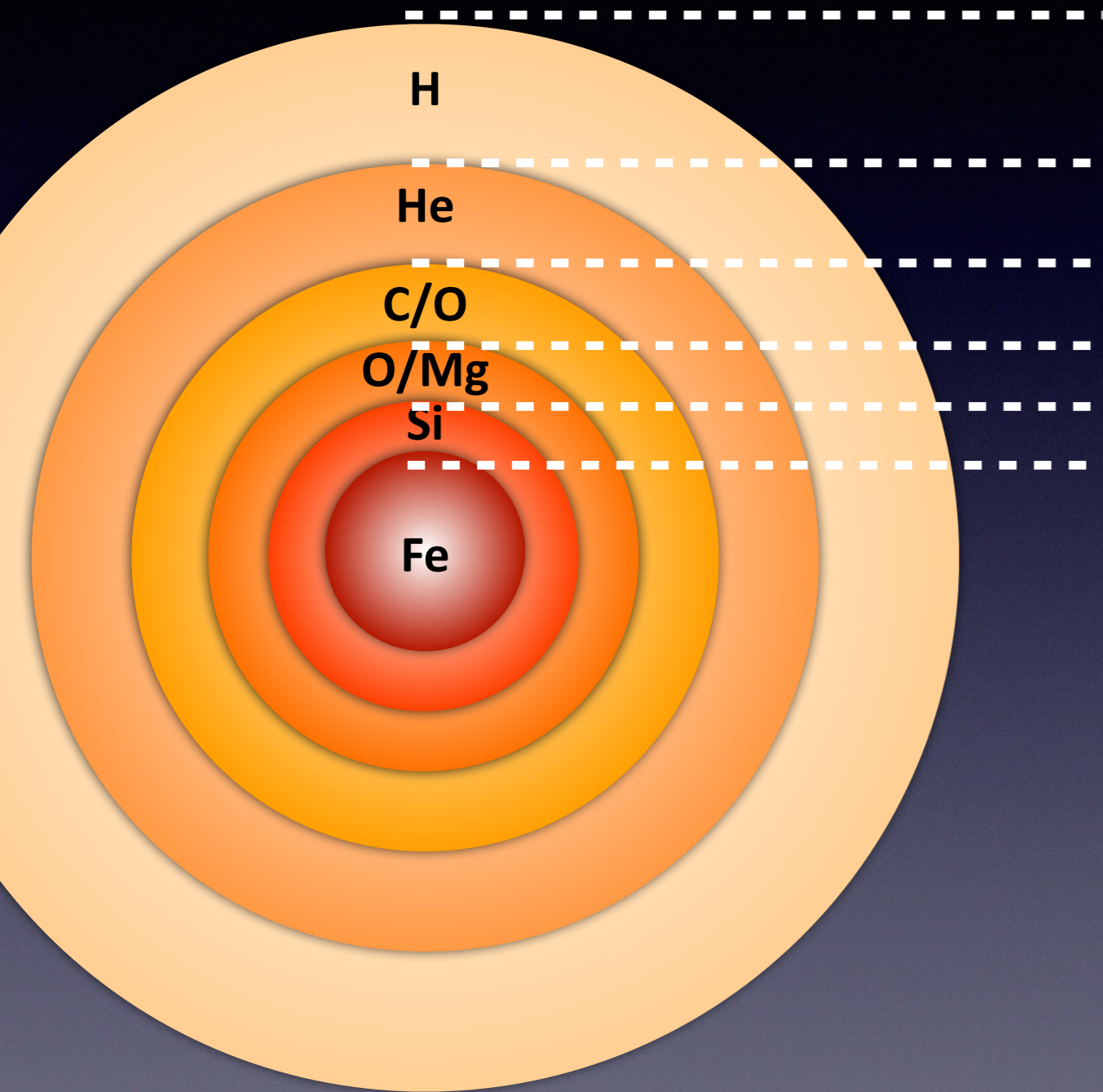
(C: Essay Web)



Images are not to scale

20 Msun star

(~16 Msun before the collapse)



Mass
(Msun)

R
(Rsun)

Free-fall time
(s)

16

1000

3×10^7
(1yr)

6

0.5

300

5

0.2

50

4

0.08

20

2

0.005

1

1.5

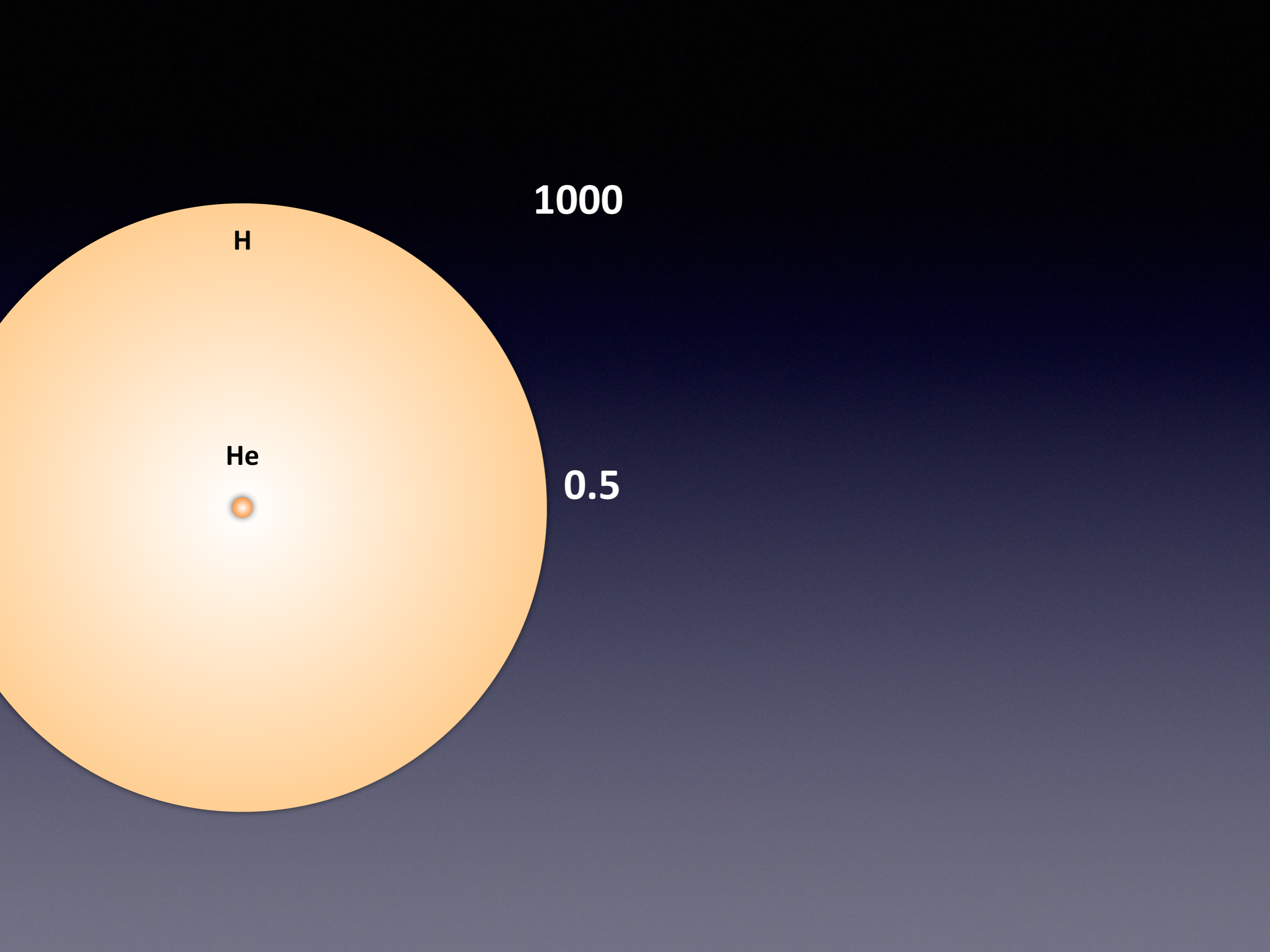
0.003

0.1

$R_{\text{sun}} = 7 \times 10^{10} \text{ cm}$

$R(\text{Fe core}) \sim 0.003 \times 7 \times 10^{10} \text{ cm}$

$\sim 2 \times 10^8 \text{ cm} \sim 2,000 \text{ km}$



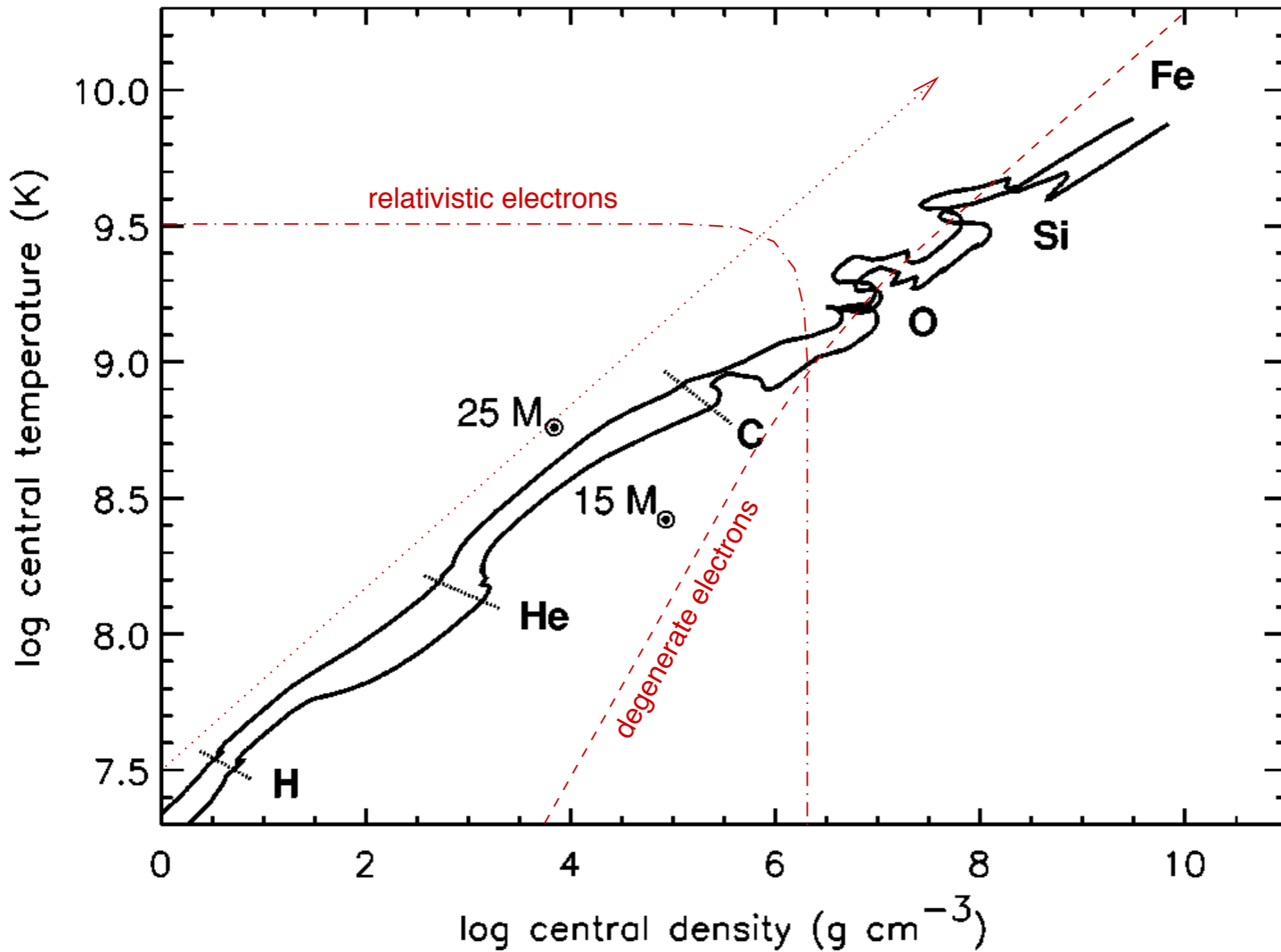
H

1000

He

0.5

Rho-T diagram



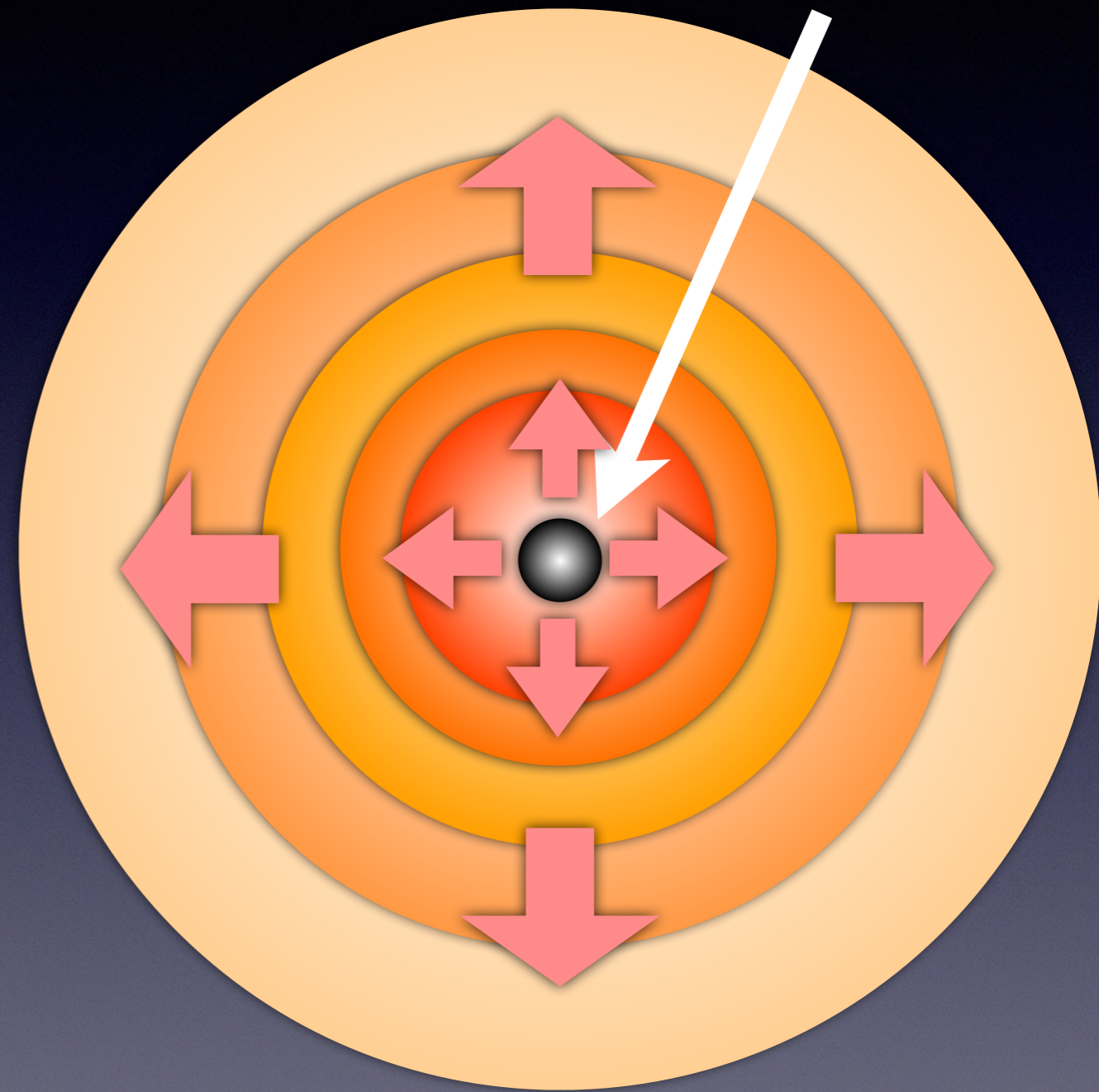
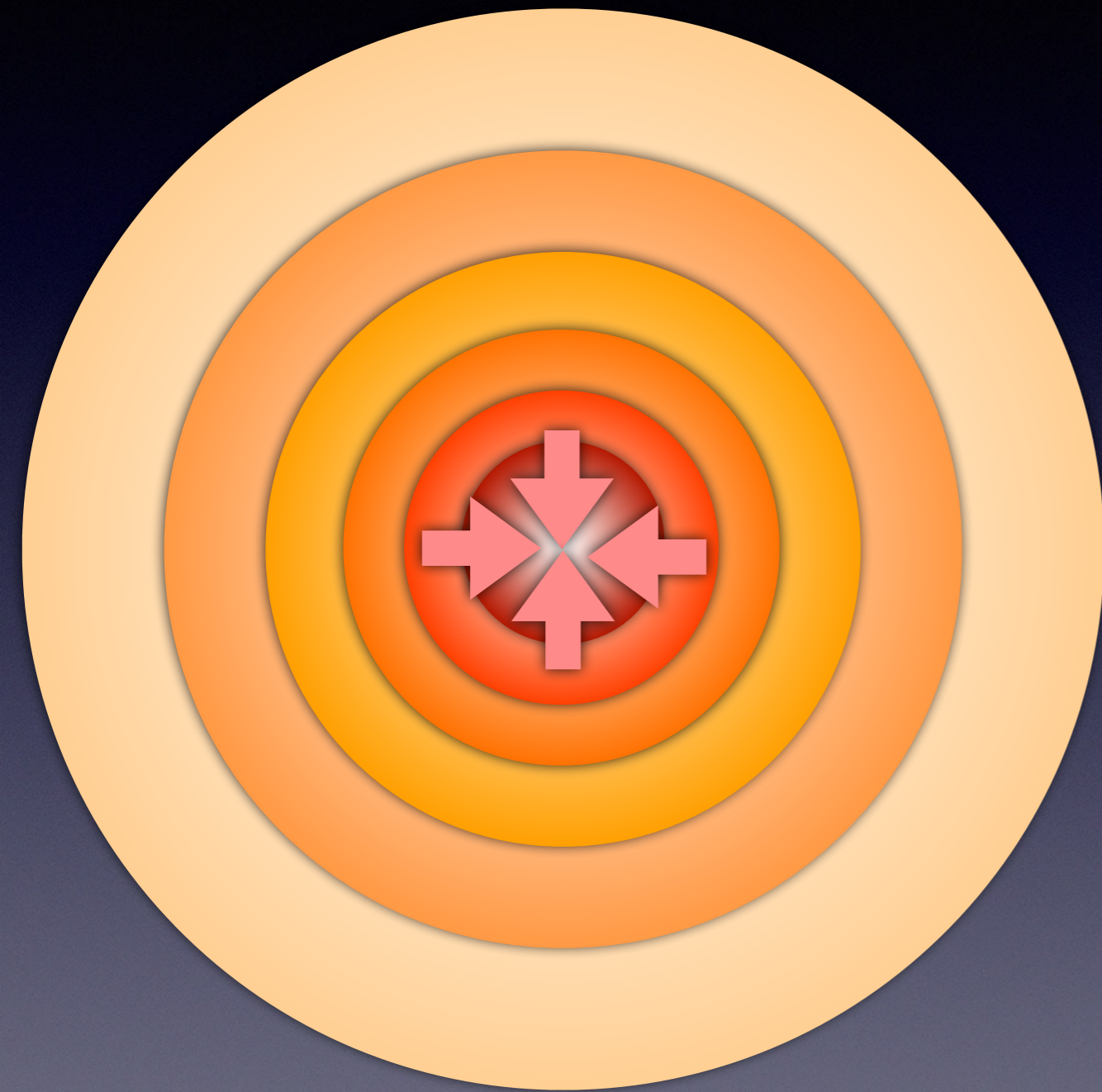
Timescales for nuclear burning stages

Table 12.1. Properties of nuclear burning stages in a $15 M_{\odot}$ star (from Woosley et al. 2002).

burning stage	T (10^9 K)	ρ (g/cm ³)	fuel	main products	timescale
hydrogen	0.035	5.8	H	He	1.1×10^7 yr
helium	0.18	1.4×10^3	He	C, O	2.0×10^6 yr
carbon	0.83	2.4×10^5	C	O, Ne	2.0×10^3 yr
neon	1.6	7.2×10^6	Ne	O, Mg	0.7 yr
oxygen	1.9	6.7×10^6	O, Mg	Si, S	2.6 yr
silicon	3.3	4.3×10^7	Si, S	Fe, Ni	18 d

**Collapse
(< 1 sec)**

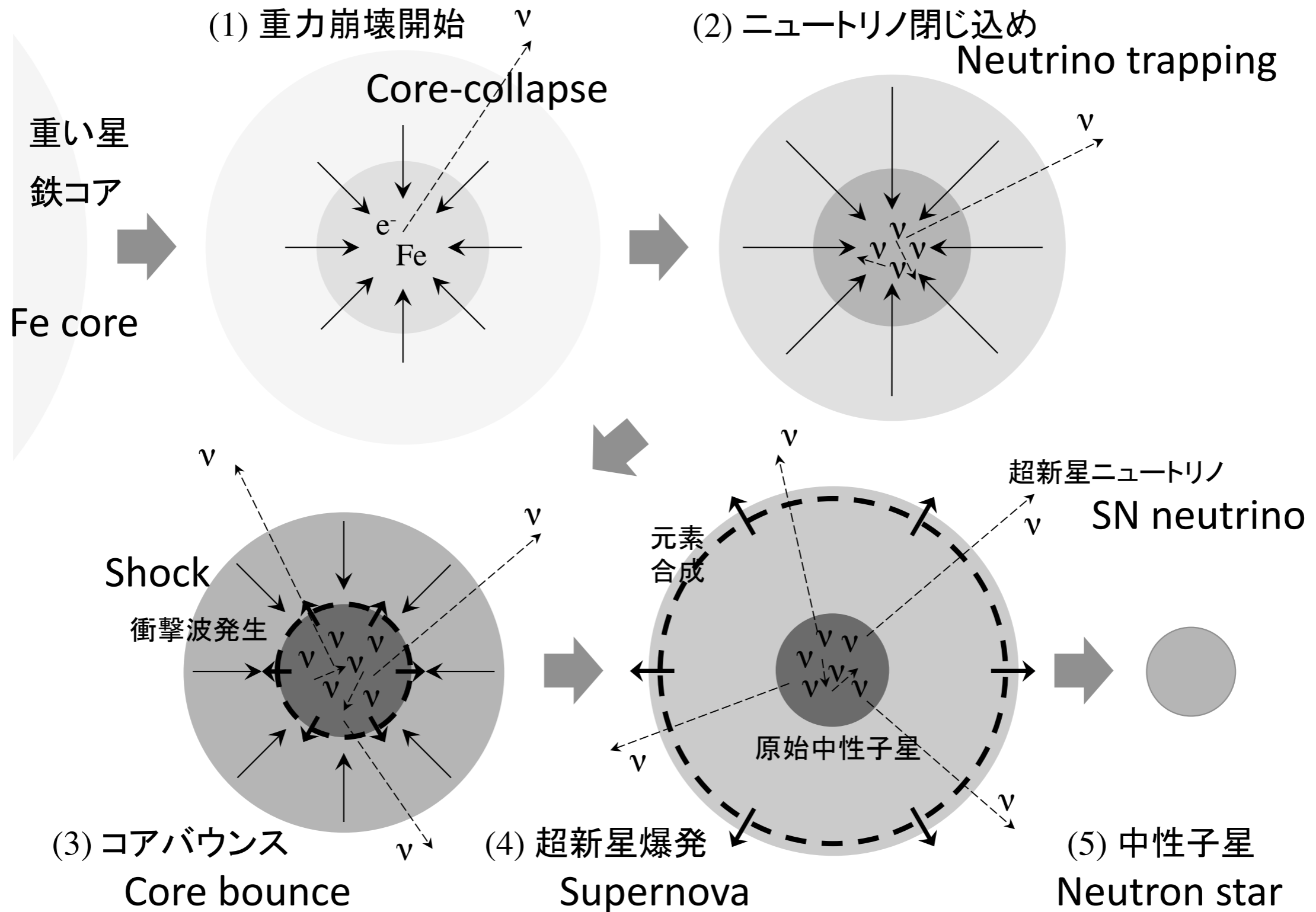
**Neutron star
or
Black hole**



Supernova!



**Why does a core of massive star collapse?
(Why don't normal star collapse or explode?)**



(c) 原子核から読み解く超新星爆発の世界
住吉光介さん著 (Kosuke Sumiyoshi)

Summary: End of massive stars

- **Stability of star**

- Dynamically unstable if adiabatic index $\gamma < 4/3$
- Degenerate Fe core => close to instability

- **What trigger the core-collapse?**

- High density => electron capture
- High temperature => Fe disassociation