When the Sun Dies—12 Oct

- Sun will use up the hydrogen in the center in 5 Byr
- Center of sun must shrink to get hotter to balance gravity
  - Sun will become a red giant. Surface expands.
- Sun will become a planetary nebula
- Sun will become a white dwarf

Sun as a main-sequence star

- H? He in the core
- T=15MK
- Fuel will last another 5 Byr.

Composition of the sun

- In center, hydrogen is half used up.

Sun as a subgiant

- H is gone in the core
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure (PV=nRT) would fall and gravity would win.
  - Core shrinks, gets hotter
  - H? He in the a shell surrounding inert core
  - Balance restored.
Sun as a giant

- H is gone in the core
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure (PV=nRT) would fall and gravity would win.
  - Core shrinks, gets hotter
  - H? He in a shell surrounding inert core
  - Balance restored.
- Inert He core expands

Sun Burns Helium

- H is gone in the core & shell is exhausted
- The never-ending battle between gravity and pressure. How does the sun adjust?
  - Without burning fuel to keep temperature up, pressure (PV=nRT) would fall and gravity would win.
  - Core shrinks, gets hotter
  - T=200MK
  - 3He? C in the core (triple alpha process)
  - Balance restored.

Other fusion reactions?

- Sun has one more trick after He is exhausted in core.
  - Burn He in a shell
- Sun is not massive enough to shrink further and get hotter
  - Core is supported by pressure of degenerate electrons.
  - Temperature does not rise to burn anything else.
- End of the road: planetary nebula & white dwarf core

<table>
<thead>
<tr>
<th>Reaction</th>
<th>( T_{\text{min}} ) (MK)</th>
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</thead>
<tbody>
<tr>
<td>( 4 , ^1\text{H} \rightarrow ^3\text{He} )</td>
<td>10 MK</td>
</tr>
<tr>
<td>( 3 , ^3\text{He} \rightarrow ^4\text{C} )</td>
<td>200 MK</td>
</tr>
<tr>
<td>( ^3\text{He} + ^3\text{He} \rightarrow ^4\text{O}, \text{Ne}, \text{Na}, \text{Mg} )</td>
<td>800 MK</td>
</tr>
<tr>
<td>Ne ( \rightarrow ^{12}\text{C} )</td>
<td>1500MK</td>
</tr>
<tr>
<td>O ( \rightarrow ^{16}\text{O}, \text{Si} )</td>
<td>2000MK</td>
</tr>
<tr>
<td>Si ( \rightarrow \text{Fe peak} )</td>
<td>3000MK</td>
</tr>
</tbody>
</table>
Summarizing question

- At what point will the earth die?