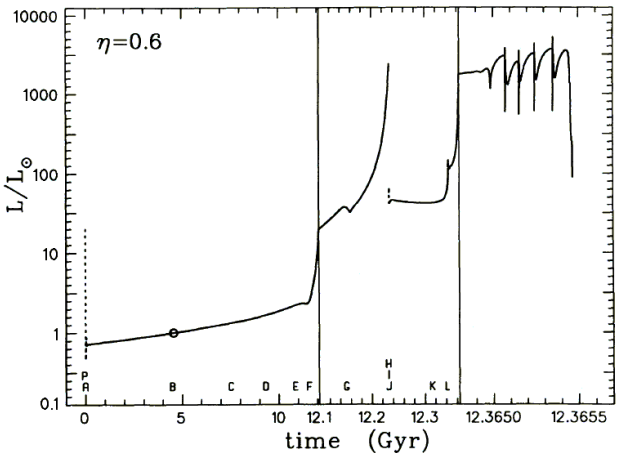
Solar Evolution and The Ultimate Destruction of Life on Earth

The following data are taken from a 1992 article in the *Astrophysical Journal*, in which the authors performed detailed computer models of the history and future evolution of our Sun.

Label	Time	Mass	Luminosity	Temp.	Radius
P	0 Gyr	1 M_{sun}	19.95 L_{sun}	4400 K	7.71 R_{sun}
A	0.048	1	0.7015	5586	0.897
B (now)	4.55	1	1	5779	1
C	7.56	1	1.33	5843	1.13
D	9.37	1	1.67	5819	1.275
E	10.91	1	2.21	6517	1.575
F	11.64	0.9998	2.73	4902	2.3
G	12.15	0.9935	34	4540	6.38
H	12.233	0.7249	2349	3107	165.8
I	12.233	0.7249	57.7	4595	12.0
J	12.234	0.7241	41.0	4724	9.5
K	12.316	0.7133	42.4	4819	9.4
L	12.345	0.708	130	4375	20
M	12.365	0.538	2999	3160	180.3
N	12.365	0.541	5190	3660	177.0
O	12.365	0.541	90	74080	0.058



(Note: Gyr = 1 billion years)

Historical evolution of the Sun

1. Compared to now, was the Sun fainter or brighter at the moment fusion began (point "P")?

2. Had you been on Earth around the time of its formation (a few tens of millions of years after the Sun's), would the Sun then look brighter or fainter than it does today?

The Sun on the Main Sequence

3. Is the Sun currently getting brighter, or fainter?

4. Once temperatures at Earth's surface reach the boiling point (or perhaps somewhat earlier), it is believed that a runaway greenhouse effect will occur, vaporizing the oceans and turning Earth into a sweltering inferno (like Venus). Approximately a 50-100% increase in Solar luminosity should be sufficient for this to happen. How long do we have until life on Earth is destroyed?

The Sun off the Main Sequence

5. About how long from now does the Sun leave the main sequence to turn into a red giant?

6. Earth orbits the Sun at a distance of about 215 R_{sun}. Will our (long-dead) planet be safe, or will it be enveloped by the Sun at some point? What about Mercury (80 R_{sun}) and Venus (155 R_{sun})?

7. Earth's surface temperature is proportional to $L_{Sun}^{1/4}$. Assuming Earth survives, how hot will the surface temperatures get at the time of the Sun's peak luminosity? Earth's current temperature is about 300 K. Compare your answer to the melting point of typical rocks (1000-2000 K).

8. How long does the red-giant phase last? Compare this to the Sun's main-sequence lifetime.

9. How stable (in terms of luminosity, radius, etc.) is the Sun during its red giant phase compared to its main sequence phase?

10. What kind of star is the Sun when it reaches state "O" on the table?

11. The table indicates that the Sun's mass at this final point has been reduced to almost half its initial value. Where did the rest go?

Original worksheet by D. Perley