because the whole star contracts in order to keep the nuclear energy generation going at a sufficient rate. In a certain respect, the evolution during this period resembles the Henyey radiative contraction phase that our own Sun experienced during its final stage of pre–main-sequence evolution.

When the core temperature reaches 12 million kelvins, the center of the star derives the majority of its support from degeneracy pressure, and conductive transport begins to dominate. In this degenerate regime, further contraction does not lead to higher temperatures, and both the overall luminosity of the star and the central temperature begin to decline. The star continues to be driven to higher surface temperatures over the next several billion years as it continues to contract, but eventually the surface temperature also reaches a maximum ($T_* = 5807$ K). After this point, the star "turns the corner" in the Hertzsprung-Russell diagram, i.e., it begins to evolve toward lower luminosity and lower surface temperature.

Interestingly, the shell source is still active at this point, and nuclear reactions are able to provide nearly all of the steadily declining luminosity during a protracted phase of further contraction. Slowly, the shell source is extinguished, and the star ends its life as a cooling, low-mass helium white dwarf with a moderately enriched (15.5%) hydrogen envelope. The envelope composition masks the incredible overall efficiency of the low-mass stars; the overall final hydrogen mass fraction is just more than 1%. It is interesting to point out that similar low-mass helium degenerates actually exist today. They can result from particularly rapacious binary evolution processes in systems containing much more massive stars. Our calculations follow the helium white dwarf along its cooling curve to a luminosity of $\log_{10} [L_*/L_\odot] = -5.287$ and a surface temperature of $T_* = 1651$ K, conditions which prevail 540 billion years after the star first develops its radiative core. The total nuclear burning lifetime of the star is somewhat more than 6 trillion years.

The foregoing life story of a 0.1 $M_\odot$ red dwarf illustrates that the future evolution of low-mass M stars seems quite securely determined (within the model-dependent assumptions). The major uncertainties inherent in red giant mass loss which hamper deterministic calculations for higher mass stars are avoided. The smallest stars will ultimately be very efficient at turning their allotment of hydrogen into helium. Over the long term, they will make much better use of their initial resources than the evolving stars of today.

The future course of evolution for a 0.1 $M_\odot$ star is placed in perspective by Figure 2, which is a Hertzsprung-Russell diagram showing the evolution of stars ranging from 0.06 to 0.25 $M_\odot$. The 0.06 $M_\odot$ object lies beneath the threshold for equilibrium hydrogen burning, and thus rapidly cools and fades away along the hydrogen brown dwarf branch. The figure shows that the general trend of evolution for stars with masses between 0.08 $M_\odot$ and 0.16 $M_\odot$ is quite similar to the 0.10 $M_\odot$ case described above. The models are mainly delineated by increasingly dramatic blueward excursions following the first appearance of a radiative core. Furthermore, as the masses of the stars increase, radiative cores appear at progressively earlier times in the evolution, endowing the final dwarfs with progressively richer concen-

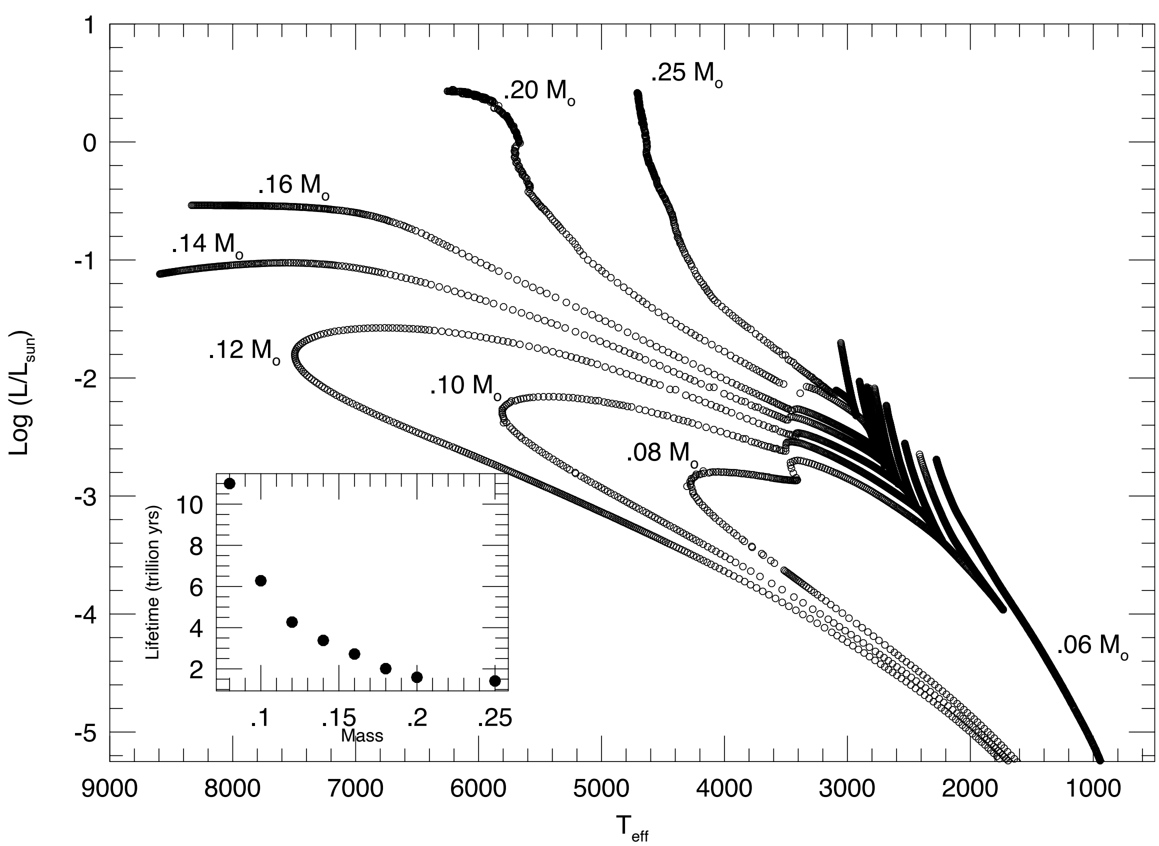

FIG. 2.—Evolution in the Hertzsprung-Russell diagram for stars with masses in the range 0.06 $M_\odot \le M_* \le 0.25$ $M_\odot$. The inset diagram shows the corresponding main-sequence lifetimes as a function of stellar mass.