



FIGURE 13.4 A schematic diagram of the evolution of a low-mass star of $1 M_{\odot}$ from the zero-age main sequence to the formation of a white dwarf star (see Section 16.1). The dotted phase of evolution represents rapid evolution following the helium core flash. The various phases of evolution are labeled as follows: Zero-Age-Main-Sequence (ZAMS), Sub-Giant Branch (SGB), Red Giant Branch (RGB), Early Asymptotic Giant Branch (E-AGB), Thermal Pulse Asymptotic Giant Branch (TP-AGB), Post-Asymptotic Giant Branch (Post-AGB), Planetary Nebula formation (PN formation), and Pre-white dwarf phase leading to white dwarf phase.

and becomes nearly isothermal. At points 4 in Fig. 13.1, the Schönberg–Chandrasekhar limit is reached and the core begins to contract rapidly, causing the evolution to proceed on the much faster Kelvin–Helmholtz timescale. The gravitational energy released by the rapidly contracting core again causes the envelope of the star to expand and the effective temperature cools, resulting in redward evolution on the H–R diagram. This phase of evolution is known as the **subgiant branch** (SGB).

As the core contracts, a nonzero temperature gradient is soon re-established because of the release of gravitational potential energy. At the same time, the temperature and density of the hydrogen-burning shell increase, and, although the shell begins to narrow significantly, the rate at which energy is generated by the shell increases rapidly. Once again the stellar envelope expands, absorbing some of the energy produced by the shell