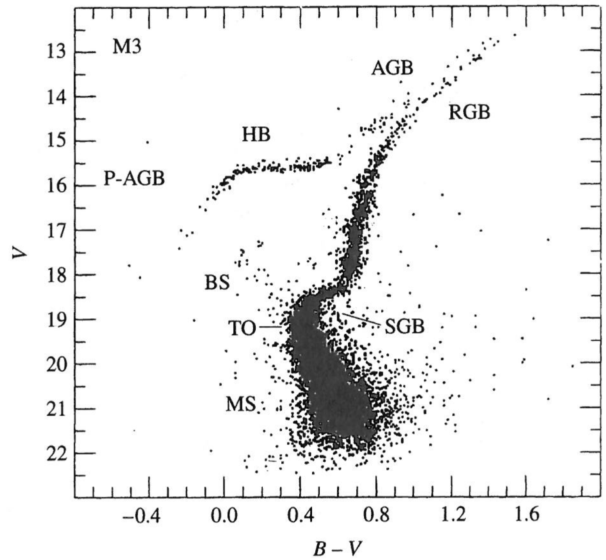

FIGURE 13.17 A color–magnitude diagram for M3, an old globular cluster. The major phases of stellar evolution are indicated: main sequence (MS); blue stragglers (BS); the main-sequence turn-off point (TO); the subgiant branch of hydrogen shell burning (SGB); the red giant branch along the Hayashi track, prior to helium core burning (RGB); the horizontal branch during helium core burning (HB); the asymptotic giant branch during hydrogen and helium shell burning (AGB); post-AGB evolution proceeding to the white dwarf phase (P-AGB). (Figure adapted from Renzini and Fusi Pecci, *Annu. Rev. Astron. Astrophys.*, *26*, 199, 1988. Reproduced with permission from the *Annual Review of Astronomy and Astrophysics*, Volume 26, ©1988 by Annual Reviews Inc.)

Isochrones and Cluster Ages

Clusters, and their associated color–magnitude diagrams, offer nearly ideal tests of many aspects of stellar evolution theory. By computing the evolutionary tracks of stars of various masses, all having the same composition as the cluster, it is possible to plot the position of each evolving model on the H–R diagram when the model reaches the age of the cluster. (The curve connecting these positions is known as an **isochrone**.) The relative number of stars at each location on the isochrone depends on the number of stars in each mass range within the cluster (the initial mass function; see Fig. 12.12), combined with the different rates of evolution during each phase. Therefore, star counts in a color–magnitude diagram can shed light on the timescales involved in stellar evolution.

As the cluster ages, beginning with the initial collapse of the molecular cloud, the most massive and least abundant stars will arrive on the main sequence first, evolving rapidly. Before the lowest-mass stars have even reached the main sequence, the most massive ones have already evolved into the red giant region, perhaps even undergoing supernova explosions. These disparate rates of evolution can be seen by comparing Figs. 12.11 and 13.1 for pre-main-sequence and post-main-sequence evolution, respectively, together with their associated tables.

Since core hydrogen-burning lifetimes are inversely related to mass, continued evolution of the cluster means that the main-sequence **turn-off point**, defined as the point where stars