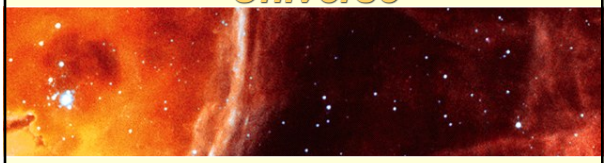
Discovering the Essential Universe



Neil F. Comins

CHAPTER 11
The Lives of Stars from Birth Through Middle Age

1

Chapter 12 Opener
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2

TABLE 12-1 Composition of the Interstellar Medium

	Particle number (%)	Mass (%)
Hydrogen (atoms and molecules)	90	74
Helium	9	25
Metals*	1	1

*Metals are all elements except hydrogen and helium.

Table 12-1
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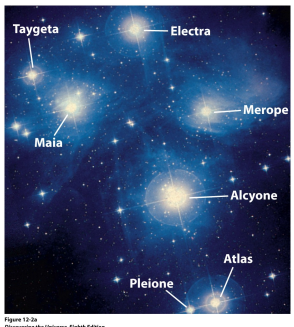

Figure 12-2a
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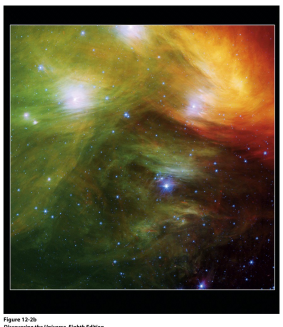

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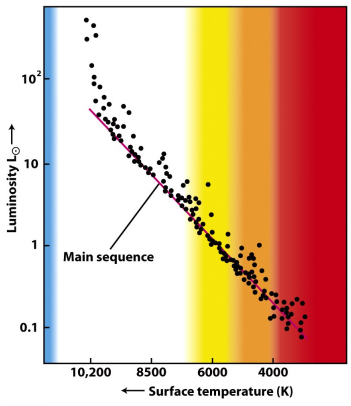

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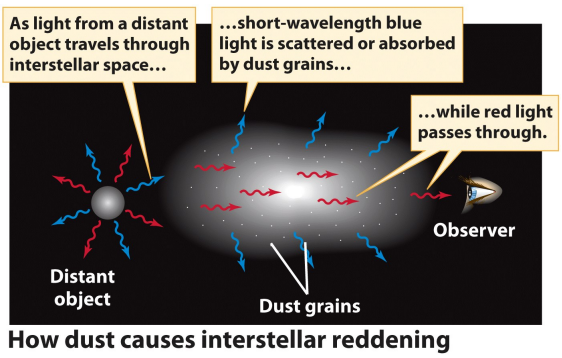

How dust causes interstellar reddening

Figure 12-4a
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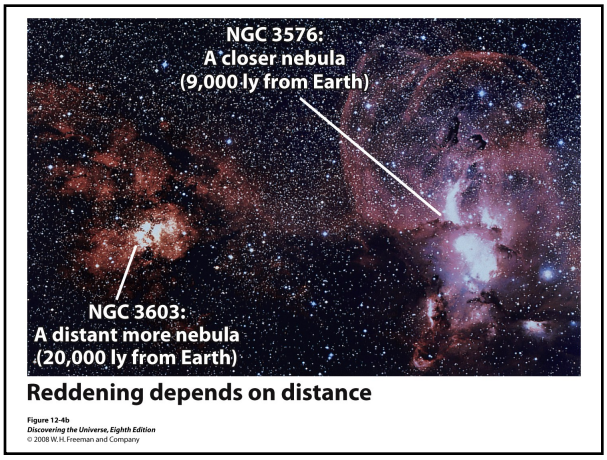
NGC 3576:
A closer nebula
(9,000 ly from Earth)
NGC 3603:
A distant more nebula
(20,000 ly from Earth)
Reddening depends on distance
Figure 12-4b
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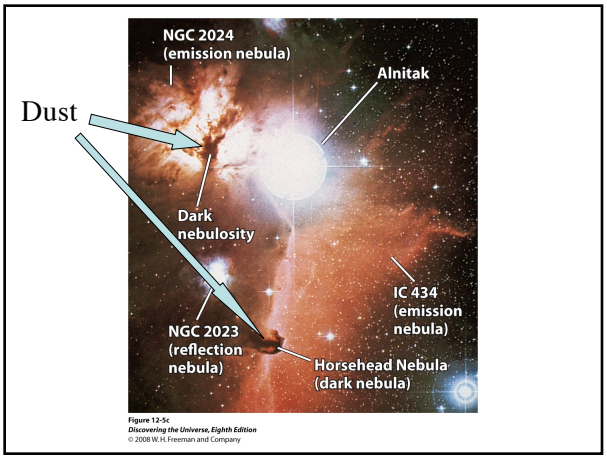
NGC 2024
(emission nebula)
Alnitak
Dust
Dark
nebulosity
IC 434
(emission
nebula)
NGC 2023
(reflection
nebula)
Horsehead Nebula
(dark nebula)
Figure 12-5c
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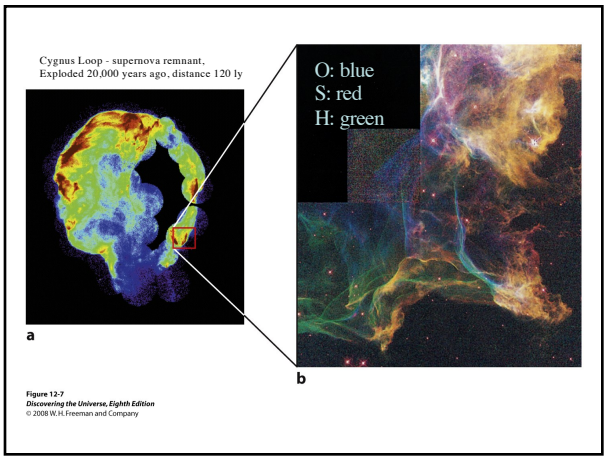
Cygnus Loop - supernova remnant,
Exploded 20,000 years ago, distance 120 ly
O: blue
S: red
H: green
a
b
Figure 12-7
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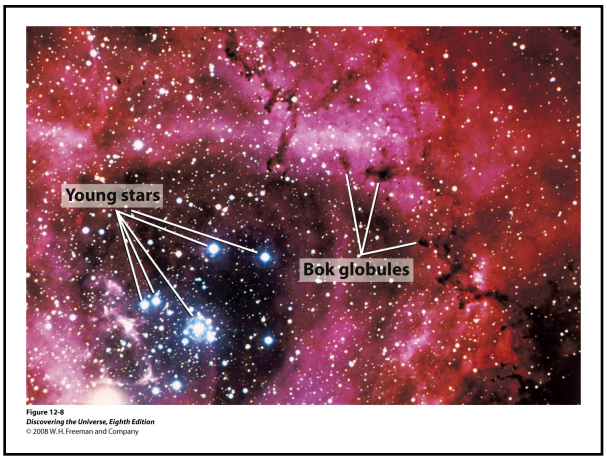
Young stars
Bok globules
Figure 12-8
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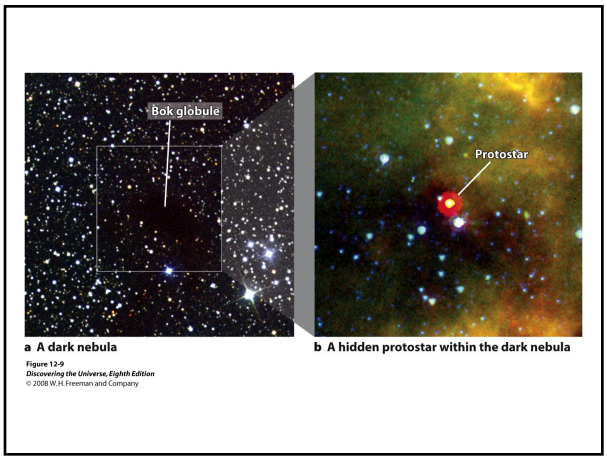
Bok globule
Protostar
a A dark nebula
b A hidden protostar within the dark nebula
Figure 12-9
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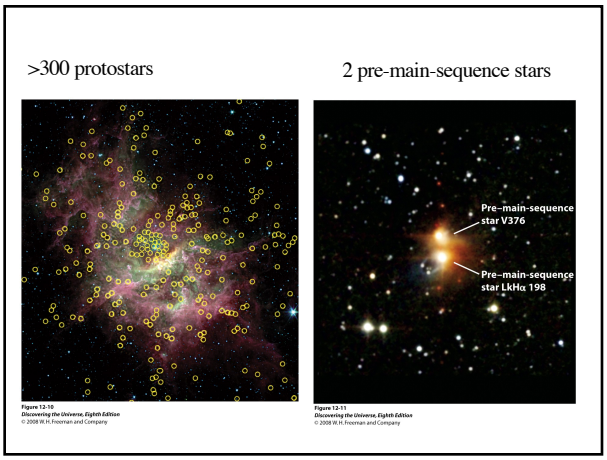
>300 protostars
2 pre-main-sequence stars
Pre-main-sequence
star V376
Pre-main-sequence
star LkHα 198
Figure 12-10
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Figure 12-11
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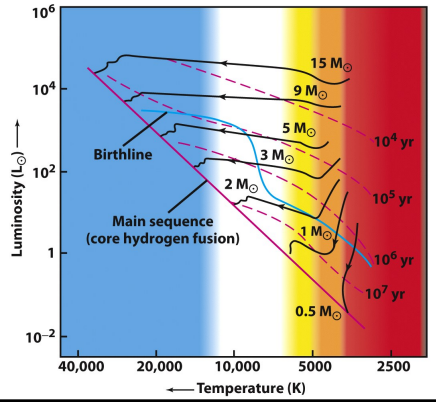
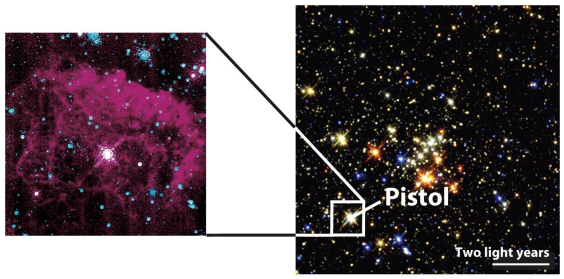
Pre-main sequence evolutionary tracks



13

Supermassive star, originally M~100 to 200 M_{sol}



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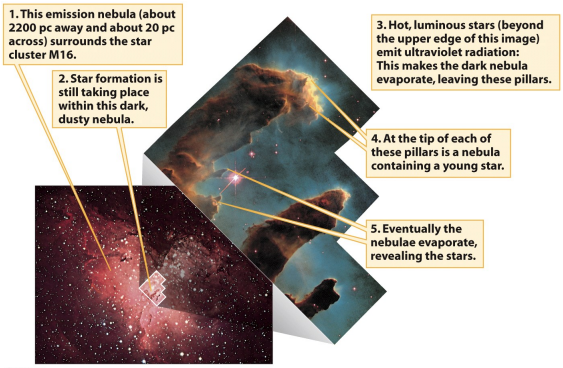

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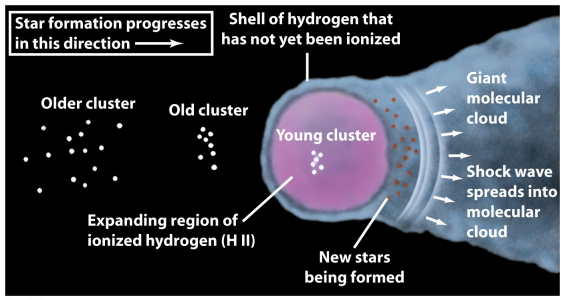

Figure 12-17a
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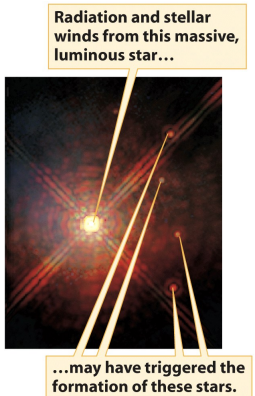

Figure 12-17b
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Stars about to burn H

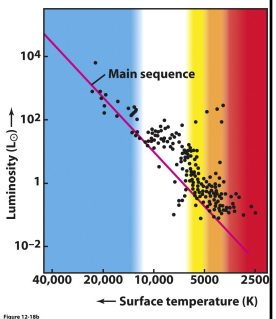

Figure 12-18a
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Figure 12-18b
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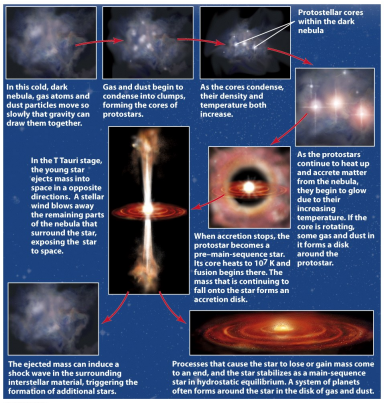

Figure 12-19
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TABLE 12-2 Main-Sequence Lifetimes

Mass ($M_\odot$)	Surface temperature (K)	Luminosity ($L_\odot$)	Time on main sequence (10^6 years)	Spectral class
25	35,000	80,000	3	O
15	30,000	10,000	15	B
3	11,000	60	500	A
1.5	7000	5	3000	F
1.0 (Sun)	6000	1	10,000	G
0.75	5000	0.5	15,000	K
0.50	4000	0.03	200,000	M

Table 12-2
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$Lt = fMc^2$

$t \alpha Mc^2/L \qquad L \alpha M^{3.5}$

$\Rightarrow \quad t \alpha M^{-2.5}$

20

Evolution of low-mass stars

Red dwarfs

85% of all stars

0.08 M_{sol}
to
0.4 M_{sol}

Burn all H to He, then cool and move down the main sequence

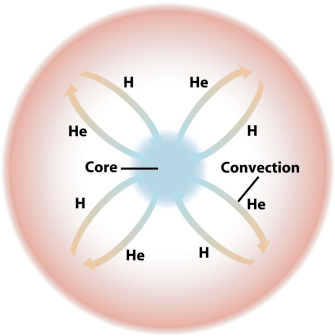

Figure 12-20
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Early and middle evolution of stars with more than 0.4 M_{sol}

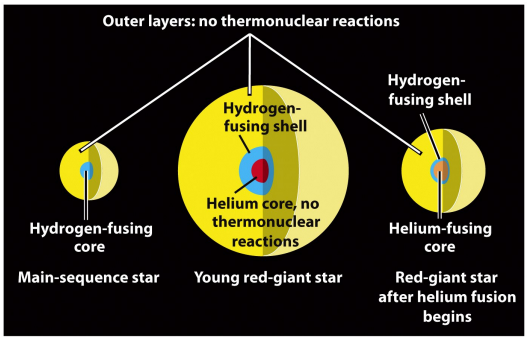

Figure 12-21
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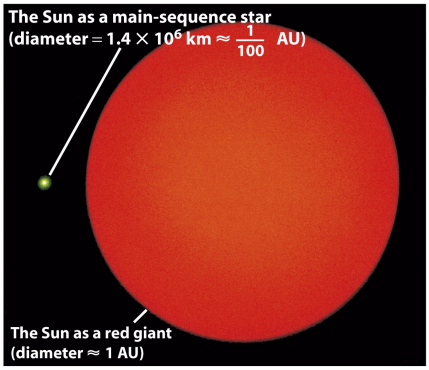

The Sun today and as a red giant

Figure 12-23a
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Post main-sequence evolution

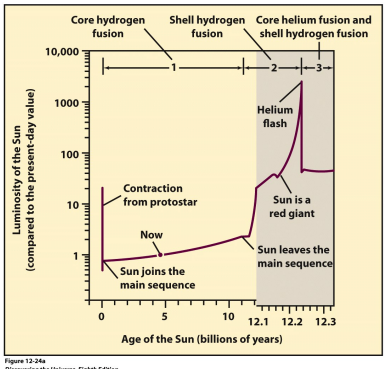

Figure 12-24a
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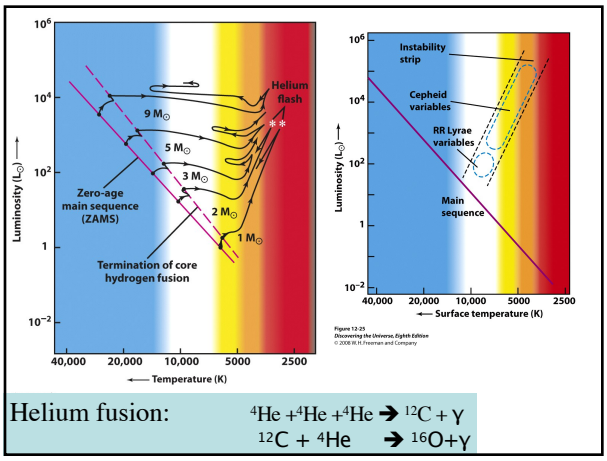
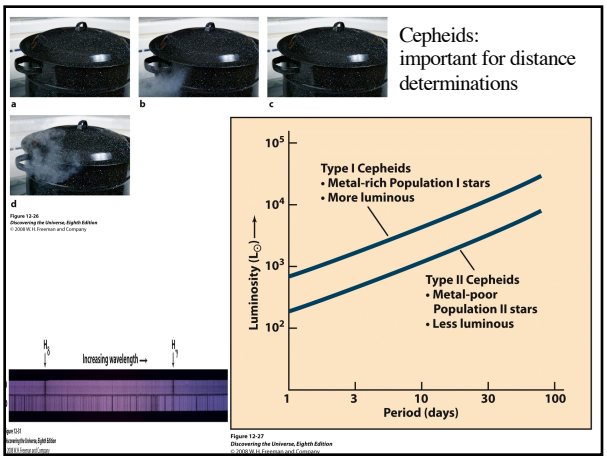


Helium fusion: $^4He + {}^4He + {}^4He \rightarrow {}^{12}C + \gamma$

$^{12}C + {}^4He \rightarrow {}^{16}O + \gamma$

25



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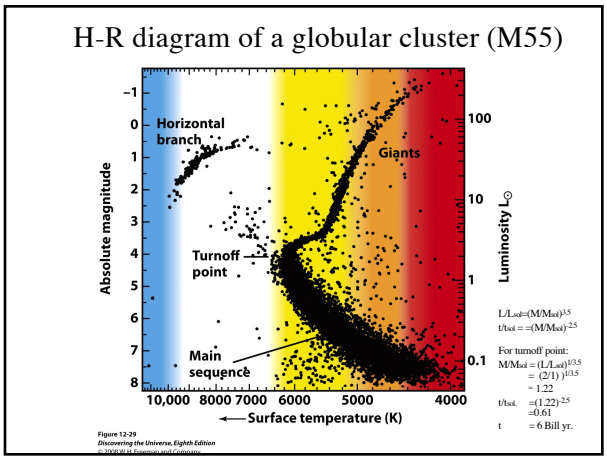
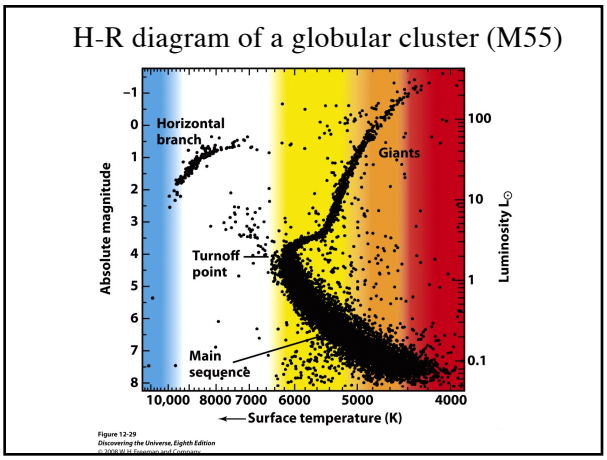


27



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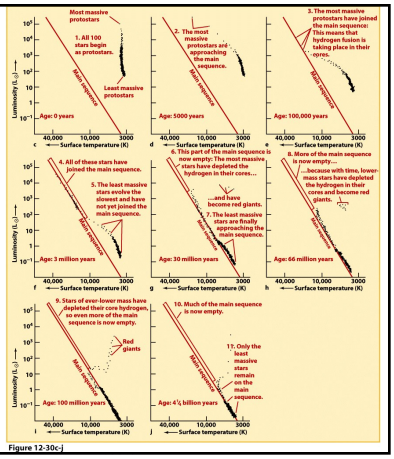
Simulation of the evolution of a cluster from 0 to 4.5 billion years



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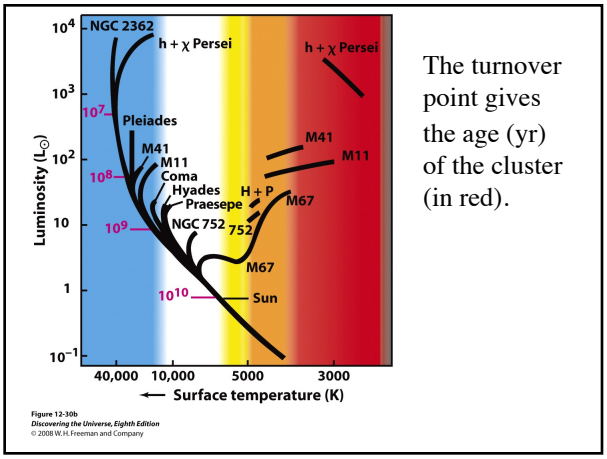

The turnover point gives the age (yr) of the cluster (in red).

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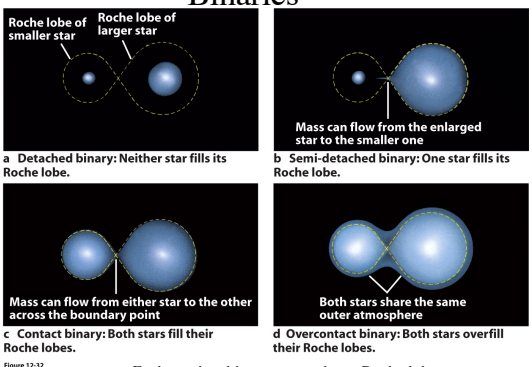
Binaries



a Detached binary: Neither star fills its Roche lobe.
b Semi-detached binary: One star fills its Roche lobe.
c Contact binary: Both stars fill their Roche lobes.
d Overcontact binary: Both stars overfill their Roche lobes.

Figure 12-32
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Each star in a binary system has a Roche lobe.
Within a Roche lobe, orbital material is bound to the star.

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A companion star can influence the evolution

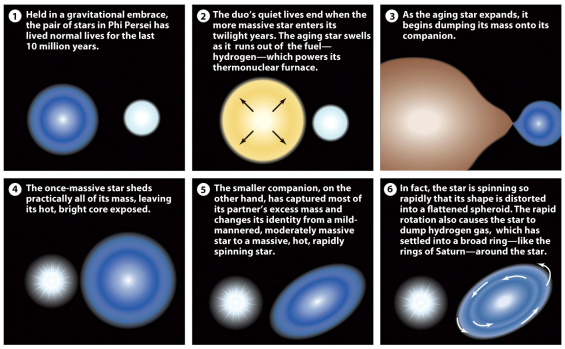

Figure 12-34
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