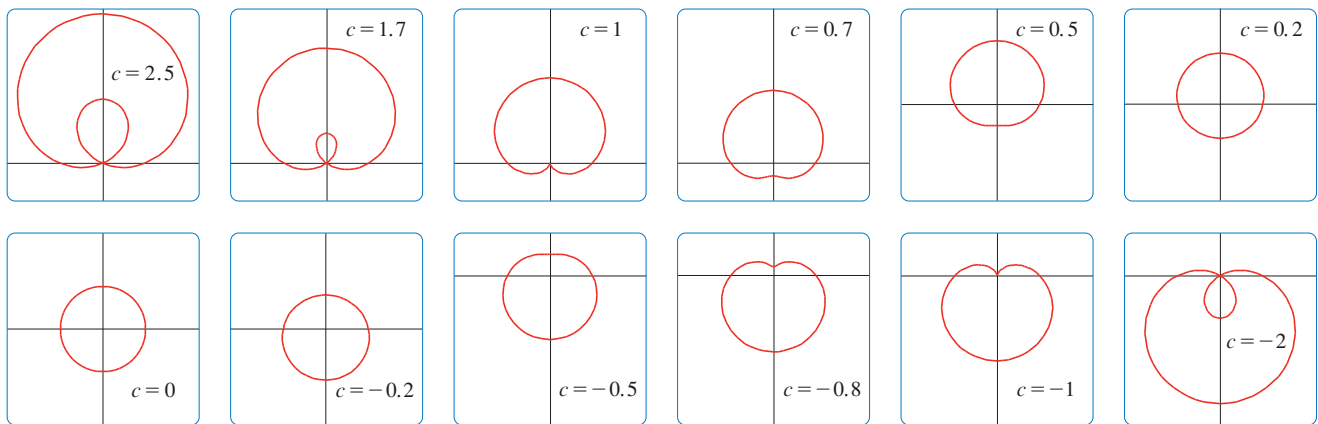


## 9.3 POLAR COORDINATES

**EXAMPLE A** Investigate the family of polar curves given by  $r = 1 + c \sin \theta$ . How does the shape change as  $c$  changes? (These curves are called **limaçons**, after a French word for snail, because of the shape of the curves for certain values of  $c$ .)

**SOLUTION** Figure 1 shows computer-drawn graphs for various values of  $c$ . For  $c > 1$  there is a loop that decreases in size as  $c$  decreases. When  $c = 1$  the loop disappears and the curve becomes the cardioid that we sketched in Example 7. For  $c$  between 1 and  $\frac{1}{2}$  the cardioid's cusp is smoothed out and becomes a "dimple." When  $c$  decreases from  $\frac{1}{2}$  to 0, the limaçon is shaped like an oval. This oval becomes more circular as  $c \rightarrow 0$ , and when  $c = 0$  the curve is just the circle  $r = 1$ .



**FIGURE 1**  
Members of the family of  
limaçons  $r = 1 + c \sin \theta$

The remaining parts of Figure 1 show that as  $c$  becomes negative, the shapes change in reverse order. In fact, these curves are reflections about the horizontal axis of the corresponding curves with positive  $c$ . ■