### Gambling to Win

In the typical state lottery, the "house" has a 65% to 70% advantage, since only 30% to 35% of the money bet is returned as prizes. The house advantage at racetracks is usually around 15%. In casinos, the house advantage is 5.26% for roulette, 1.4% for craps, and 3% to 22% for slot machines.

The house advantage is 5.9% for blackjack, but some professional gamblers can systematically win with a 1% player advantage by using complicated card-counting techniques that require many hours of practice. If a card-counting player were to suddenly change from small bets to large bets, the dealer would recognize the card counting and the player would be ejected. Card counters try to beat this policy by working with a team. When the count is high enough, the player signals an accomplice who enters the game with large bets. A group of MIT students supposedly won millions of dollars by counting cards in blackjack.

**Solution**

**a.** Because the probability of exactly 500 heads in 1000 tosses is 0.0252, that result is *unlikely*. However, we usually get around 500 heads, so this outcome is neither unusually low nor unusually high.

**b.** Without actually finding the exact probability value, it is reasonable to conclude that there is a very low probability of getting 10 heads in 1000 tosses of a fair coin, so this event is unlikely. Also, the outcome of 10 heads is so far below the number of heads we typically expect (around 500), we conclude that this is an unusually low number of heads.

Example 11 considers the result of 500 heads in 1000 tosses and the result of 10 heads in 1000 tosses. Figure 4-3 is a graph of the probabilities for all possible numbers of heads in 1000 tosses. (Such a graph of outcomes and their probabilities is called a *probability histogram,* and it is formally defined in Section 5-2.) From Figure 4-3 we see that every individual number of heads is *unlikely*, because its probability is small (0.0252 or less). The red shaded regions show those outcomes that are *unusually low* or *unusually high*, because they are so far away from the outcomes that we typically expect (around 500). In Chapter 5 we will develop methods for finding the cumulative probabilities corresponding to such unusually low and unusually high numbers of outcomes. For the results shown in Figure 4-3, the probability of getting any number of heads that is unusually low or unusually high is less than 0.05.

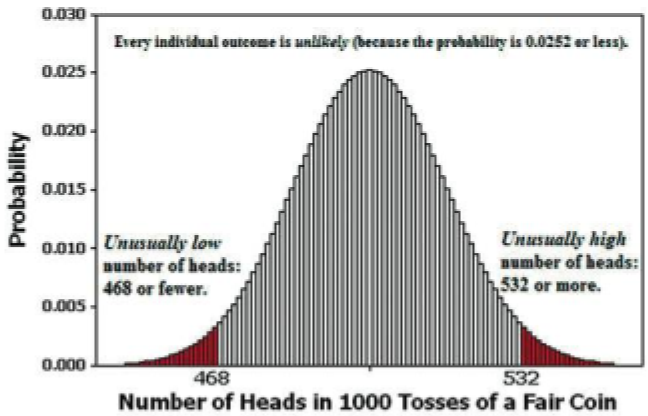


**Figure 4-3** **Graph of Outcomes and Their Probabilities**

Section 4-1 introduced the rare event rule, and that rule is the focus of the next example.

**Example 12** **Rare Event Rule**

In a clinical experiment of the Salk vaccine for polio, 200,745 children were given a placebo and 201,229 other children were treated with the Salk vaccine. There were 115 cases of polio among those in the placebo group and 33 cases of polio in the treatment group. If we assume that the vaccine has no effect, the probability of getting such test results is found to be "less than 0.001." What does that probability imply about the effectiveness of the vaccine?

**Solution**

A probability value less than 0.001 is very small. It indicates that the event will occur fewer than once in a thousand times, so it is very unlikely that the event will