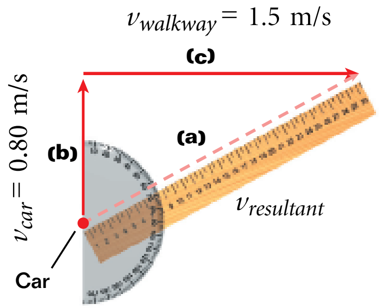

Figure 3
The resultant velocity **(a)** of a toy car moving at a velocity of 0.80 m/s **(b)** across a moving walkway with a velocity of 1.5 m/s **(c)** can be found using a ruler and a protractor.

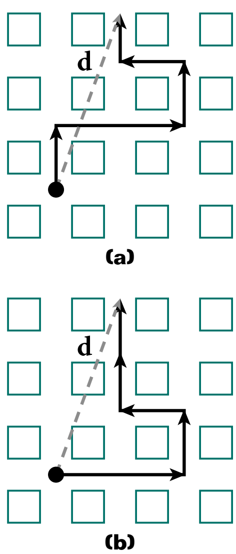

Figure 4
A marathon runner's displacement, **d,** will be the same regardless of whether the runner takes path **(a)** or **(b)** because the vectors can be added in any order.

PROPERTIES OF VECTORS

Now consider a case in which two or more vectors act at the same point. When this occurs, it is possible to find a resultant vector that has the same net effect as the combination of the individual vectors. Imagine looking down from the second level of an airport at a toy car moving at 0.80 m/s across a walkway that moves at 1.5 m/s. How can you determine what the car's resultant velocity will look like from your view point?

Vectors can be moved parallel to themselves in a diagram

Note that the car's resultant velocity while moving from one side of the walkway to the other will be the combination of two independent motions. Thus, the moving car can be thought of as traveling first at 0.80 m/s across the walkway and then at 1.5 m/s down the walkway. In this way, we can draw a given vector anywhere in the diagram as long as the vector is parallel to its previous alignment (so that it still points in the same direction). Thus, you can draw one vector with its tail starting at the tip of the other as long as the size and direction of each vector do not change. This process is illustrated in **Figure 3.** Although both vectors act on the car at the same point, the horizontal vector has been moved up so that its tail begins at the tip of the vertical vector. The resultant vector can then be drawn from the tail of the first vector to the tip of the last vector. This method is known as the *triangle* (or *polygon*) *method of addition.*

Again, the magnitude of the resultant vector can be measured using a ruler, and the angle can be measured with a protractor. In the next section, we will develop a technique for adding vectors that is less time-consuming because it involves a calculator instead of a ruler and protractor.

Vectors can be added in any order

When two or more vectors are added, the sum is independent of the order of the addition. This idea is demonstrated by a runner practicing for a marathon along city streets, as represented in **Figure 4.** The runner executes the same four displacements in each case, but the order is different. Regardless of which path the runner takes, the runner will have the same total displacement, expressed as **d.** Similarly, the vector sum of two or more vectors is the same regardless of the order in which the vectors are added, provided that the magnitude and direction of each vector remain the same.

To subtract a vector, add its opposite

Vector subtraction makes use of the definition of the negative of a vector. The negative of a vector is defined as a vector with the same magnitude as the original vector but opposite in direction. For instance, the negative of the velocity of a car traveling 30 m/s to the west is −30 m/s to the west, or +30 m/s to the east. Thus, adding a vector to its negative vector gives zero.