Answer to Essential Question 10.8: The expression for the rotational inertia of the ring has no factor less than 1 in front of the MR^2 because every bit of mass in the ring is a distance R from the center of the ring. In all the other cases shown in Figure 10.23, most of the mass of the given object is at a distance less than R (or less than L) from the axis in question.

10-9 Newton's Laws for Rotation

In Chapter 3 we considered Newton's three laws of motion. The first two of these laws have analogous statements for rotational motion.

Newton's First Law for Rotation: an object at rest tends to remain at rest, and an object that is spinning tends to spin with a constant angular velocity, unless it is acted on by a nonzero net torque ***or there is a change in the way the object's mass is distributed***.

Recall that the net torque is the sum of all the forces acting on an object. Always remember to add torques as vectors. The net torque can be symbolized by $\sum \vec{\tau}$.

The first part of the statement of Newton's first law for rotation parallels Newton's first law for straight-line motion, but the phrase about how spinning motion can be affected by a change in mass distribution is something that only applies to rotation.

Newton's second law for rotation, on the other hand, is completely analogous to Newton's second law for straight-line motion, $\sum \vec{F} = m \, \vec{a}$. Replacing force by torque, mass by rotational inertia, and acceleration by angular acceleration, we get:

$\sum \vec{\tau} = I \vec{\alpha}$. 　　　　　　　　(Equation 10.12: **Newton's Second Law for Rotation**)

We'll spend the rest of this chapter, and a good part of the next chapter, looking at how to apply Newton's second law in various situations. In Chapter 11, we will deal with rotational dynamics, involving motion and acceleration. For the remainder of this chapter, however, we will focus on situations involving static equilibrium.

Conditions for static equilibrium

An object is in static equilibrium when it remains at rest. Two conditions apply to objects in static equilibrium. These are:

$$\sum \vec{F} = 0 \qquad \text{and} \qquad \sum \vec{\tau} = 0 \, .$$

Expressed in words, an object in static equilibrium experiences no net force and no net torque. Using these conditions, we will be able to analyze a variety of situations. Many excellent examples of static equilibrium involve the human body, such as when you hold your arm out; when you bend over; and when you stand on your toes. In each case, forces associated with muscles, bones, and tendons maintain the equilibrium situation.

Essential Question 10.9: Newton's first law for rotation includes a phrase that says spinning motion can be affected by a change in the way an object's mass is distributed. Can you think of a real-life example of this?