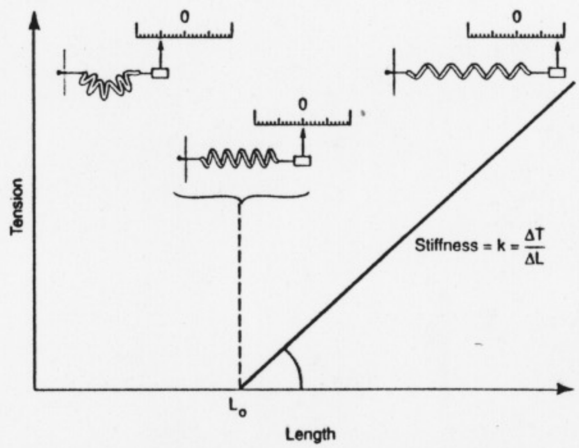
Mechanics of Muscle Contraction

BOX 36–1

A spring is a mechanical device that responds to an increase in length by generating a *restoring force* that is proportional to the change in length. However, this force is developed only when the length exceeds a threshold known as the *set point* or *resting length* (L_0). Until L_0 is exceeded, the spring is slack. Once the length is increased beyond L_0, tension increases linearly.



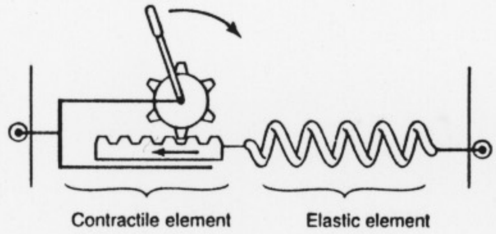
The slope of the line shown in the figure, the incremental force (ΔF) corresponding to a unit change in length (ΔL), represents the spring constant k, also known as the stiffness.

$$k = \Delta F/\Delta L$$

Thus, the tension or force produced by the spring can be described by the simple equation

$$F = k(L - L_0)$$

In muscles the sarcomeres have spring-like properties because they shorten when activated. Thus, muscles can be represented by two elements connected in series: a contractile element (depicted below as a rack and pinion), and an elastic element (depicted by the spring).



The elastic element includes a passive and an active component. The tendon and connective tissue elements through which the sarcomeres exert force on the bone are the passive component. The cross bridges themselves, where external forces can counteract the rotation at the necks of the myosin heads, are the active component. A more complete model of the muscle would include two other components. First, an elastic element, representing elastic proteins between myofibrils and connective tissue between muscle fibers, acts in parallel with the serially connected contractile and elastic elements. Second, a viscous element provides resistance to stretch; this resistance increases with the speed of stretch. For simplicity, these elements are not included here.