Table 1. Membrane tension and mechanical quantities

Force, tension, pressure units, seen in the context of membranes (and apples):

1 Newton is an enormous ***force,*** $\sim 10^{11-12}$-fold greater than needed to pull a membrane tether

1 N ~ = 100 g (. . . ~1 apple in Earth's gravity)

1 Newton/meter is a large ***tension*** that would easily rupture a membrane

1 N/m = 10^3 dyne/cm (. . . ~1 apple dangling from a meterwide banner)

1 Newton/square meter is an unmeasureably small ***pressure*** if applied via a micropipette

1 N/m^2 = 1 Pa = ~0.0001 mmHg (. . . ~1 apple per coffee table)

Membrane tensions*

0.12 mN/m—resting tension, plant protoplast membrane (*see* Kell & Glaser, 1993)

0.003 mN/m—resting tension growth cones of chick neurons (Hochmuth et al., 1996)

0.04, 0.12, 0.02 mN/m—tensions in normal, swollen and reshrunken molluscan neurons (Dai et al., 1998)

~1 mN/m—activation of mechanosensitive channels (*see* Sachs & Morris, 1998)

3–4 1 mN/m—lytic tension of large lecithin bilayer vesicles (Kwok & Evans, 1981)

4 mN/m—lytic tension for plant protoplast (*see* Kell & Glaser, 1993)

5–8 mN/m—lytic tension for mast cells inflated under whole cell clamp (Solsona et al., 1998)

12 mN/m—lytic tension skeletal muscle membrane (Nichol & Hutter, 1996)

*NB—"in-plane" tension (not interfacial surface tension, though the units are the same).

The spring constant (elasticity or stiffness) of Hooke's Law, like tension, has the units of N/m.

Forces* (for references, *see* Dai et al., 1998; Sachs & Morris, 1998)

3 pN . . . force generated by myosin molecule

7 pN . . . force to pull membrane tether from a neuron

10–20 pN . . . calculated force for activation of a "typical" MS channel

20 pN . . . actin-gelsolin bond

50 pN . . . force to pull erythrocyte membrane tethers

30,000 pN . . . carbon-carbon bond

**Sometimes, forces are loosely referred to as "tensions" (the magnitude of a force exerted, say, via a string) but a "tension" that counteracts a force is a force.

Pressure Conversions (*see also,* Table 1 in Sachs & Morris, 1998)

1 N/m^2 = 1 Pa, 1 kPa = 7.5 mmHg, 100 mmHg = 13.3 kPa = 133 mbar, 1 bar = 100 kPa

1 mmHg = 1.36 cm H_2O, 760 mmHg = 1 atmosphere = 101.3 kPa

1 mosmol = 18 mmHg

Laplace's Law: governs the tension of a ideal thin-walled sphere:

Tension = Pressure × radius of curvature × ½

Thus, the more curved a membrane, the less tension experienced for a given transmembrane pressure. (e.g., in an osmotically swelling cell, microvillar bilayer feels less tension than adjacent flat membrane)