Random polymers – DNA and polymer elasticity

Freely jointed chain

Imagine a chain made up of links of size, a

Each link can be oriented randomly

Links do not interact – i.e. there is no self-avoidance
→ all conformations have E = 0

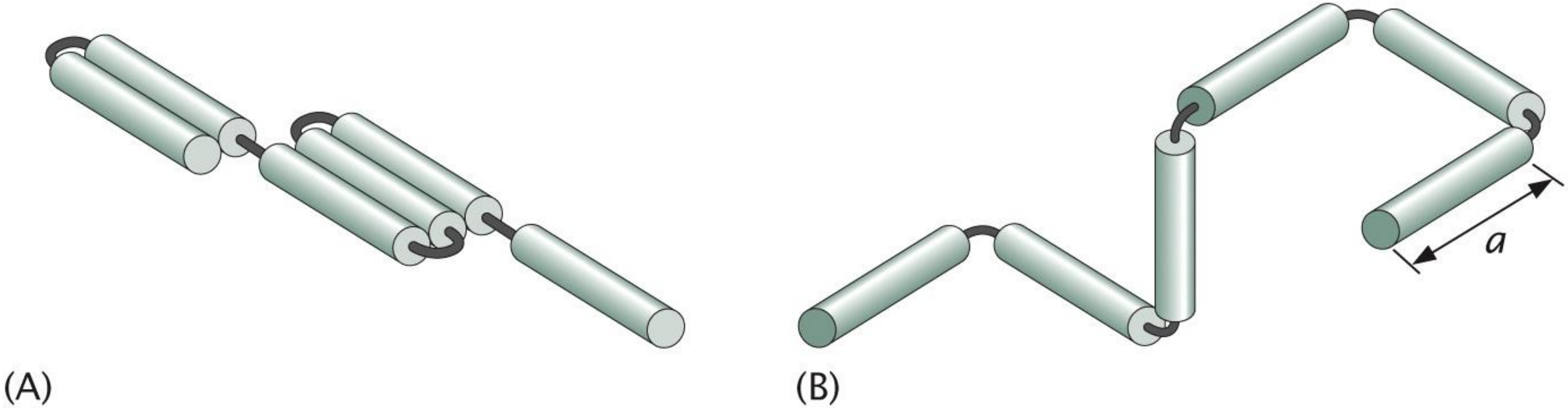


Figure 8.1 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Real biopolymers as freely jointed chains

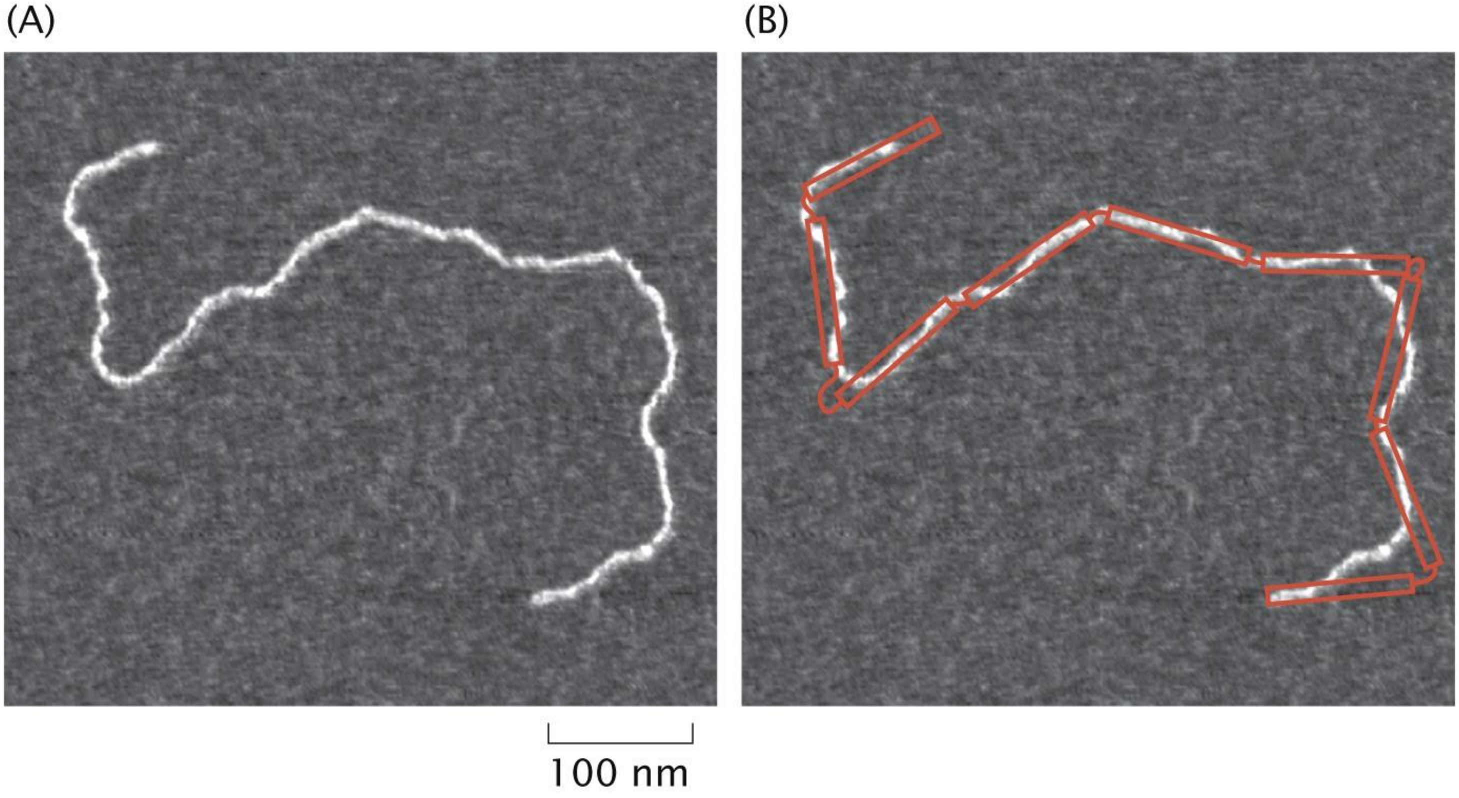


Figure 8.2 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

To discretize a real polymer into links, we consider ‘a’ to be the length over which the polymer is effectively rigid

We’ll see that this can be defined exactly in terms of a measurable quantity called persistence length

Sizes of genomes: Radius of gyration

log-log plot

slope = ½

so chromosomes are like random poly when they are free in solution

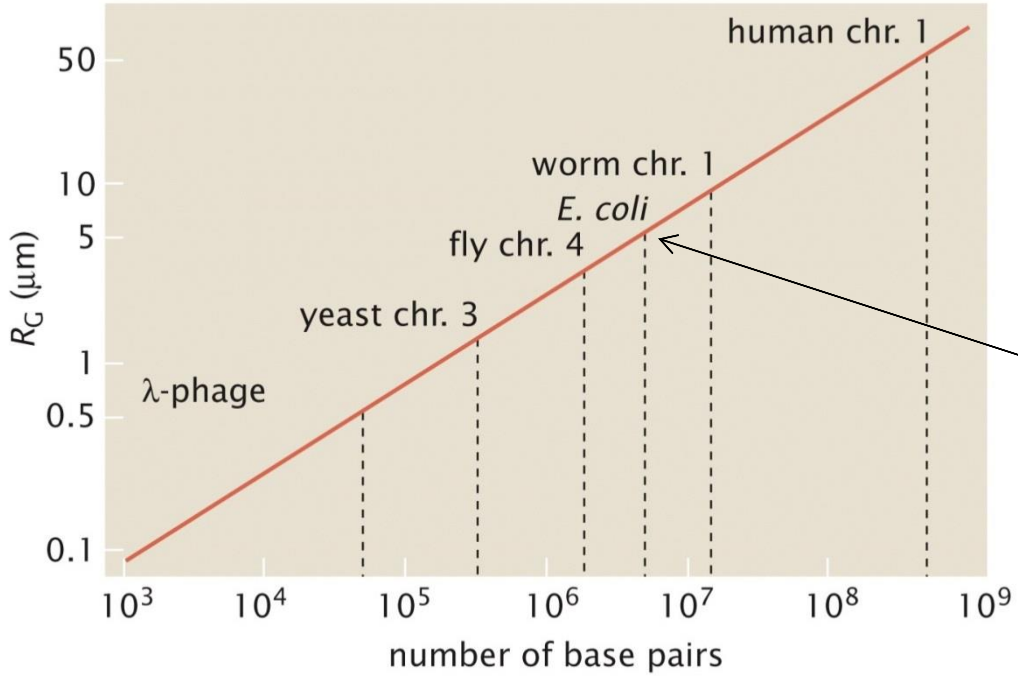


Figure 8.6 Physical Biology of the Cell, 2nd (© Garland Science 2013)

Compare with E.coli size ~ 2 μm

An OK estimate is $\sqrt{\langle R^2 \rangle} = \sqrt{2L\xi_p}$

- Better estimate is radius of gyration

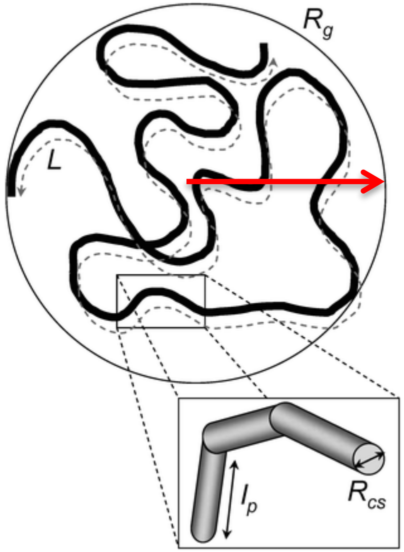
$$\langle R_G^2 \rangle = \frac{1}{N}\sum_{i=1}^{N} \langle (\vec{R}_i - \vec{R}_{CM})^2 \rangle$$

↑ center of mass

can show

$$\sqrt{\langle R_G^2 \rangle} = \sqrt{\frac{L\xi_p}{3}} \approx \frac{1}{3}\sqrt{N_{bp}\,\xi_p} \ \text{nm}$$

# of bp



Distance between fluorescent markers

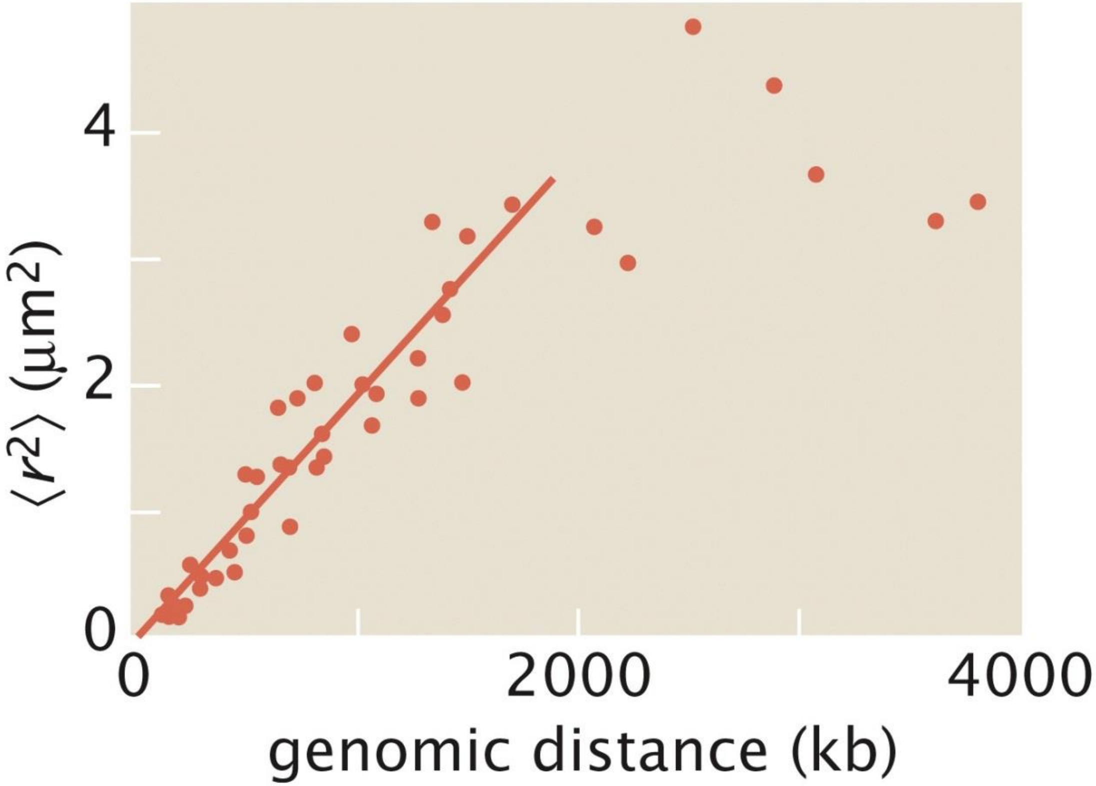


Figure 8.11 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Distance between fluorescent markers goes as random walk

Tethering + Confinement:

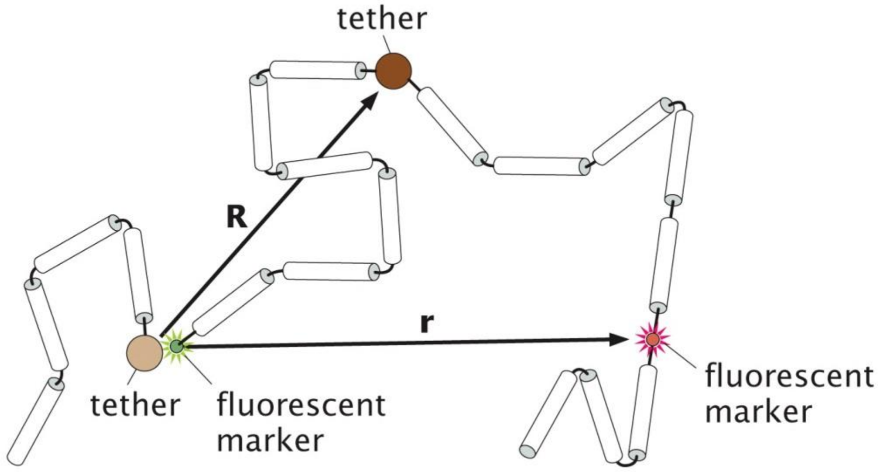


Figure 8.10 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

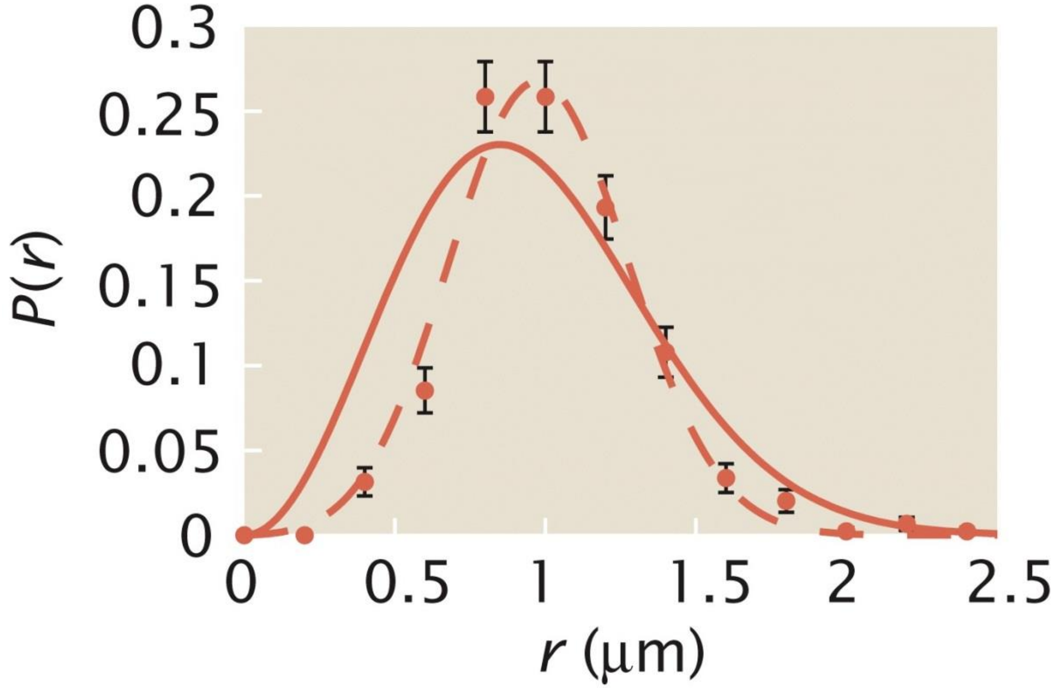


Figure 8.12 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Distribution of distances between 2 fluorescently tagged loci ~ 100 kb apart

Data is consistent with a tether existing between the two

Tethering + Confinement:

Location of Ori shows effects of confinement

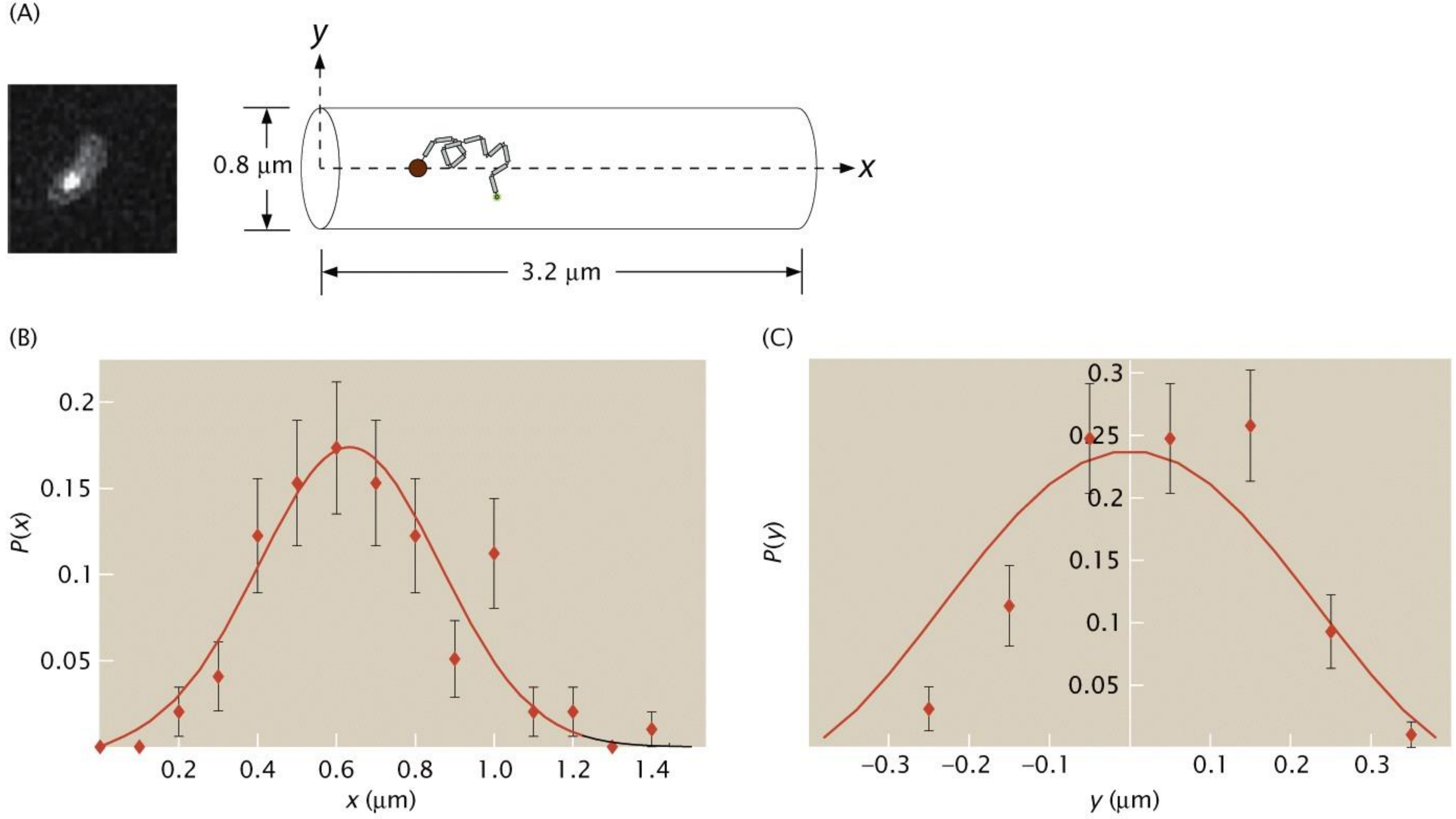


Figure 8.14 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Measuring Looping Frequency

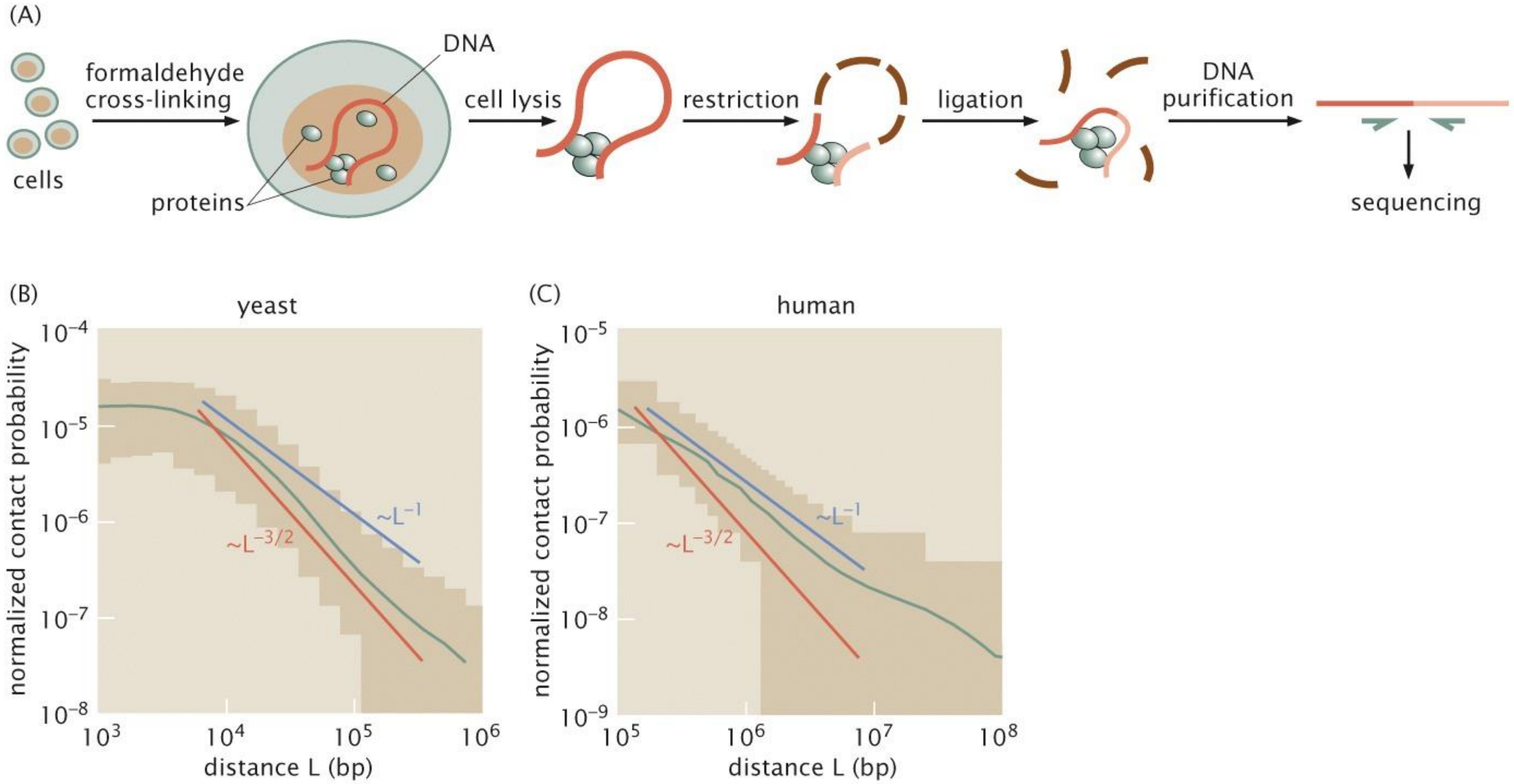


Figure 8.20 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

What is probability of forming a loop in 3D for ideal polymer? $p \sim L^{-3/2}$

Stretching a freely-jointed chain

Optical Trap

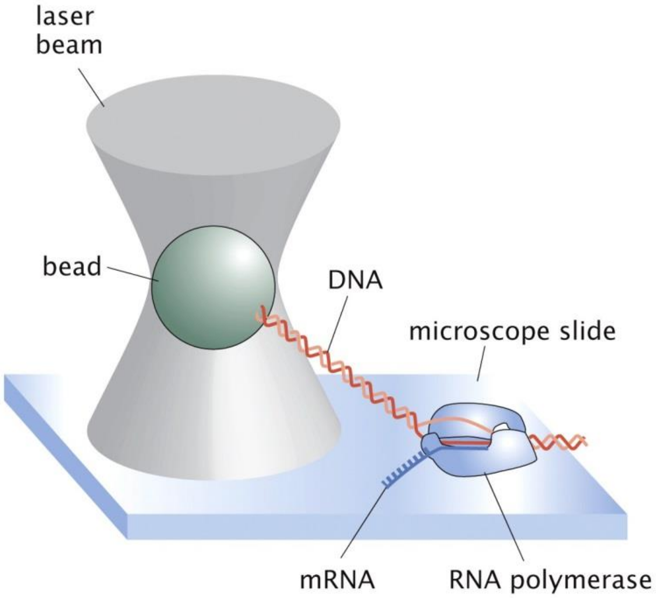


Figure 8.21b Physical Biology of the Cell, 2ed. (© Garland Science 2013)

If we apply a force to a random polymer to stretch it, what will it's force vs extension characteristic look like?

Will it be like Hook's law?

Using an optical trap (or AFM) we can pull on DNA, proteins, RNA to measure how they stretch

These experiments will allow us to determine the persistence length of these polymers directly at the single molecule level

Pulling on a multidomain protein

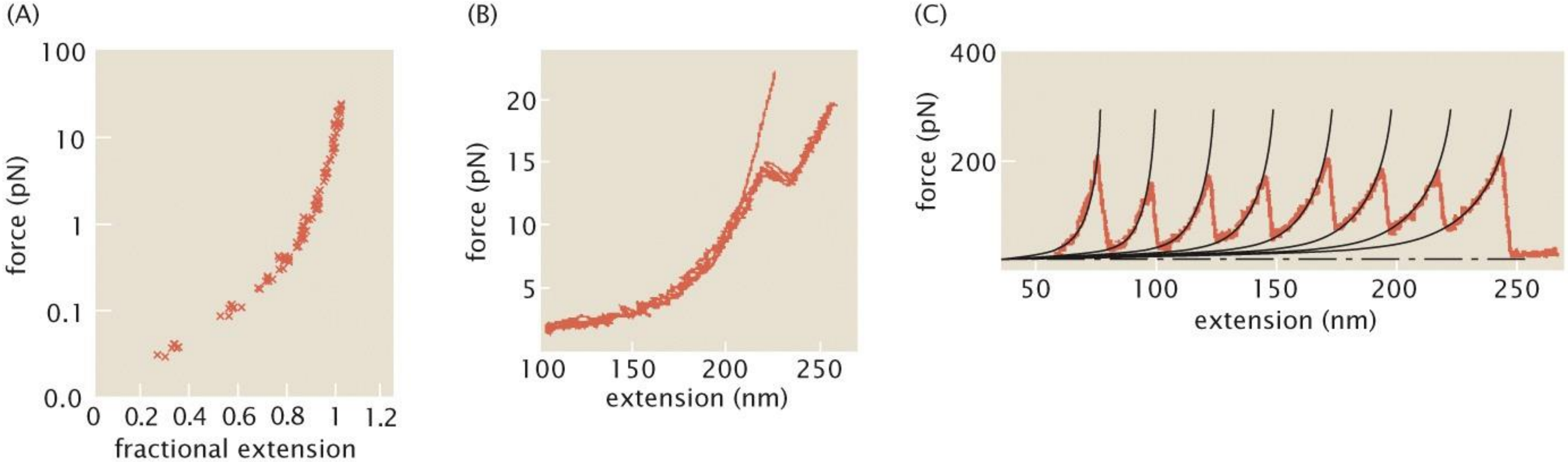
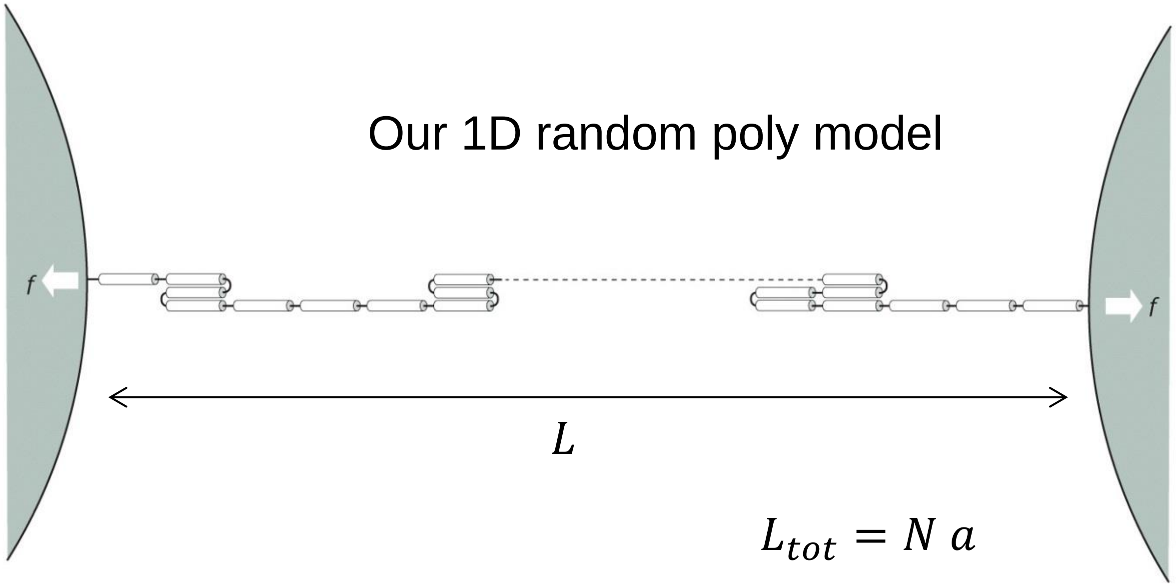


Figure 8.22 Physical Biology of the Cell, 2ed. (© Garland Science 2013)



Our 1D random poly model

L

$L_{tot} = N\, a$

Figure 8.23 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Worm-like chain

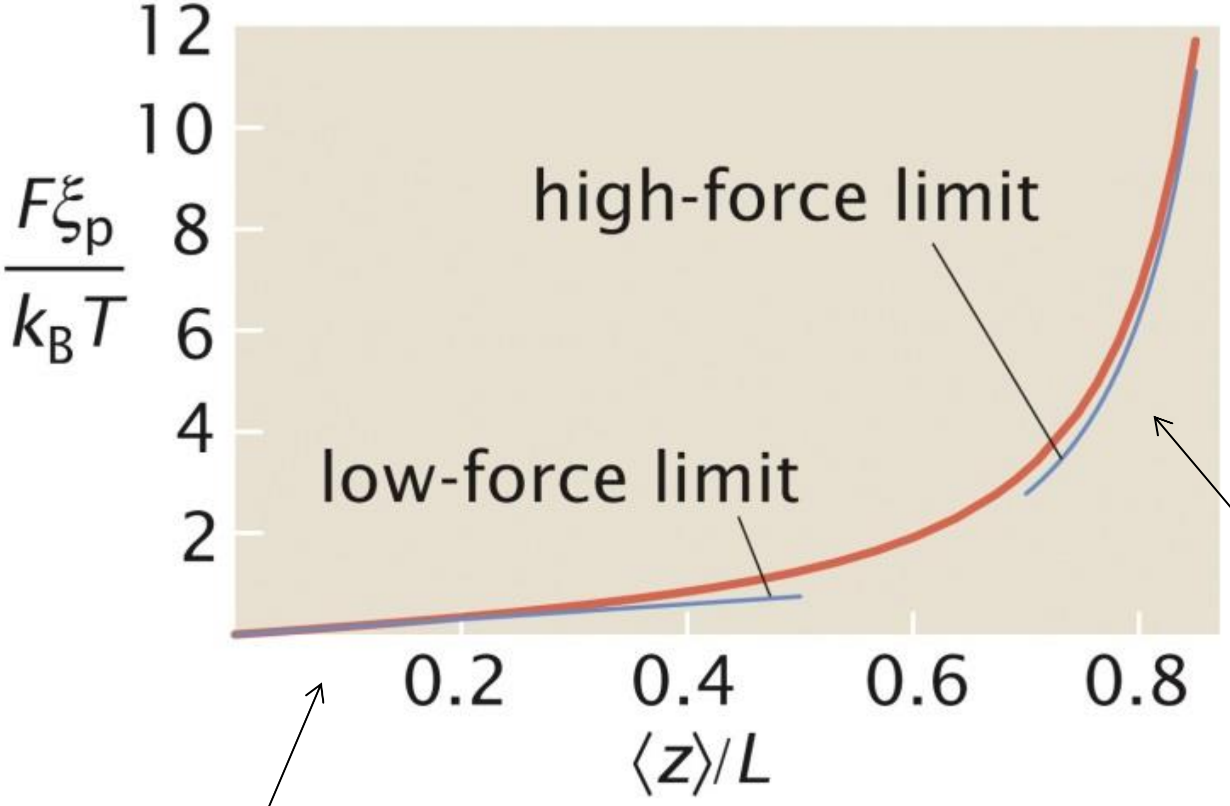


Figure 10.36 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

WLC needed
here

ideal random poly does OK here