Any guess how this is happening?

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Observation of a single-beam gradient force optical trap for dielectric particles

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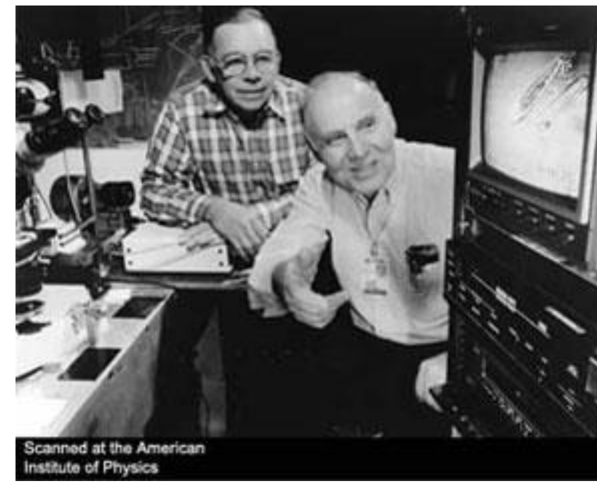
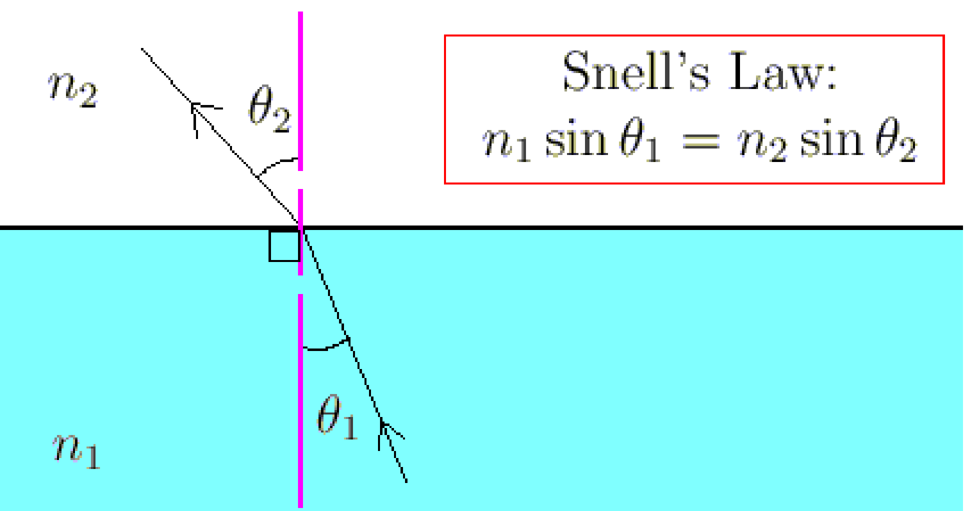
- Trap a dielectric particle in 3D based on the spatial gradient of the light beam, Snell's law, and conservation principles





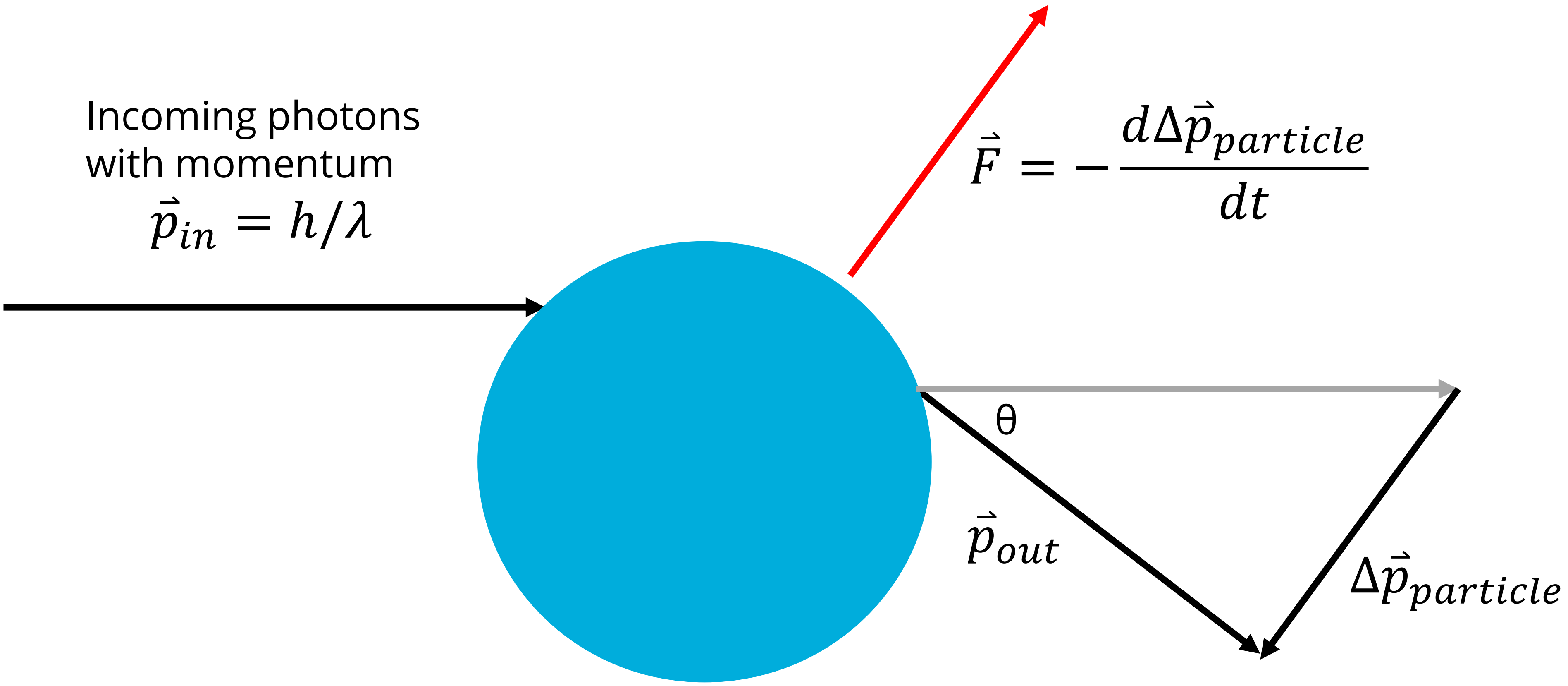
Snell's Law:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

When light hits a surface, some is reflected and some is refracted.

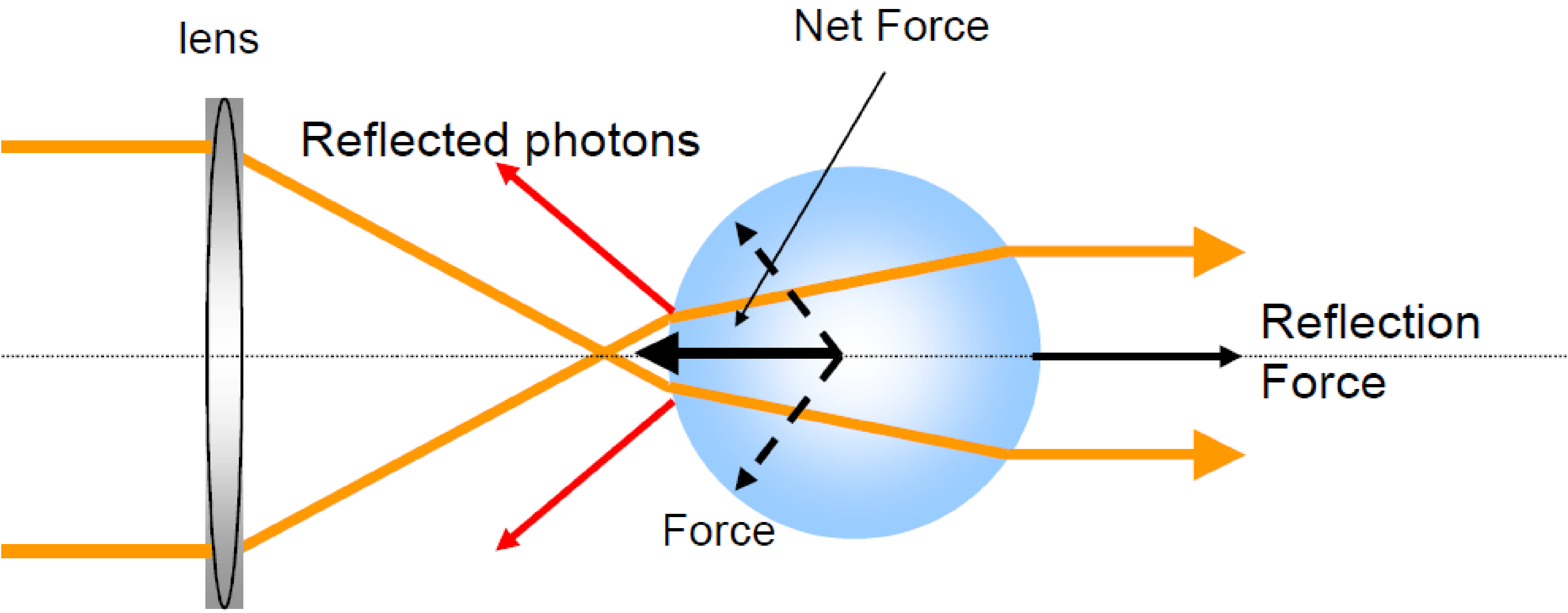
The reflection on a surface describes the scattering force.

A Qualitative Understanding



For every action, there is an equal but opposite reaction.
(Newton's 3rd Law)

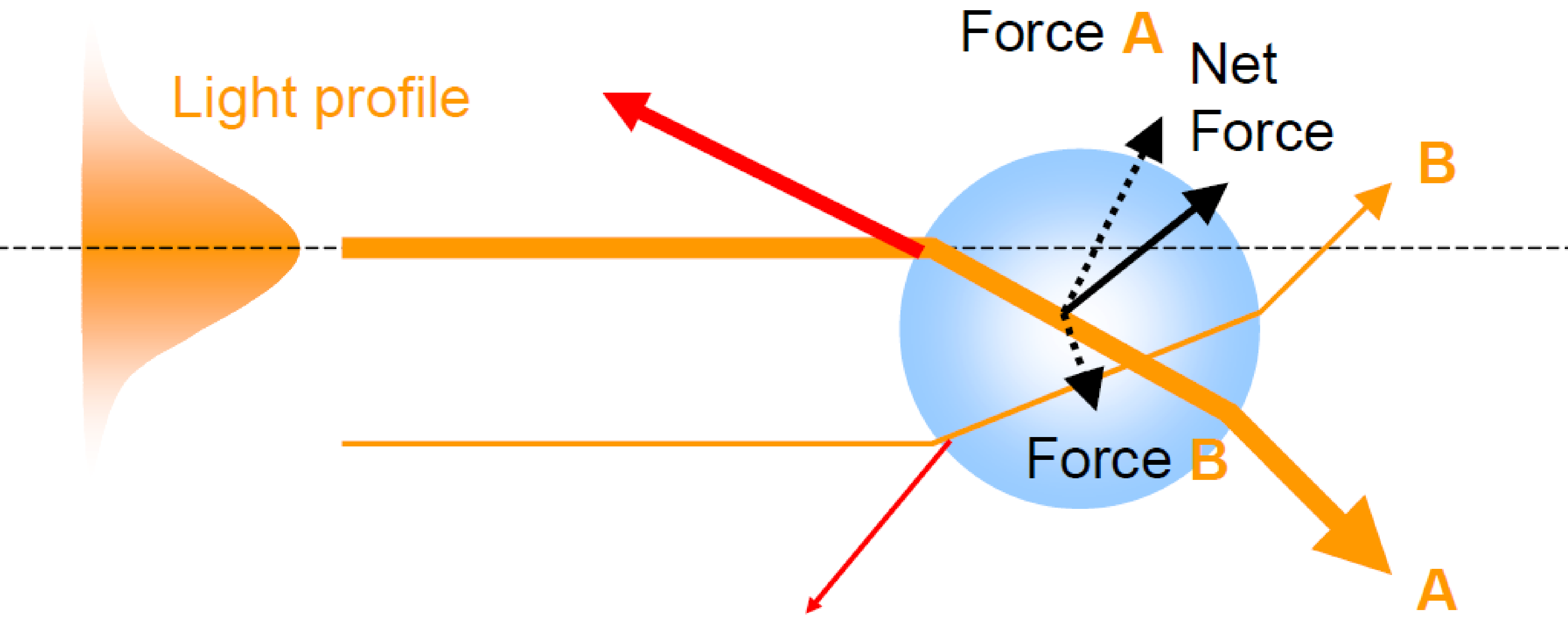
Test Case: Longitudinal



When the bead is in the center of the focused laser beam, forces that push the bead to right and left cancel out each other.

The reflecting or scattering force always pushes objects in the direction of the beam

Test Case: Transverse



If the sphere moves off the trap, the refracted light exerts radial forces to push the sphere back on the axis.

Energy Argument

Recall,

$$\vec{F} = -\nabla U$$

If you think of the trap as a spring, then the potential energy is a parabolic function.

Energy of system is minimum when particle moves to highest field AKA FOCUS.

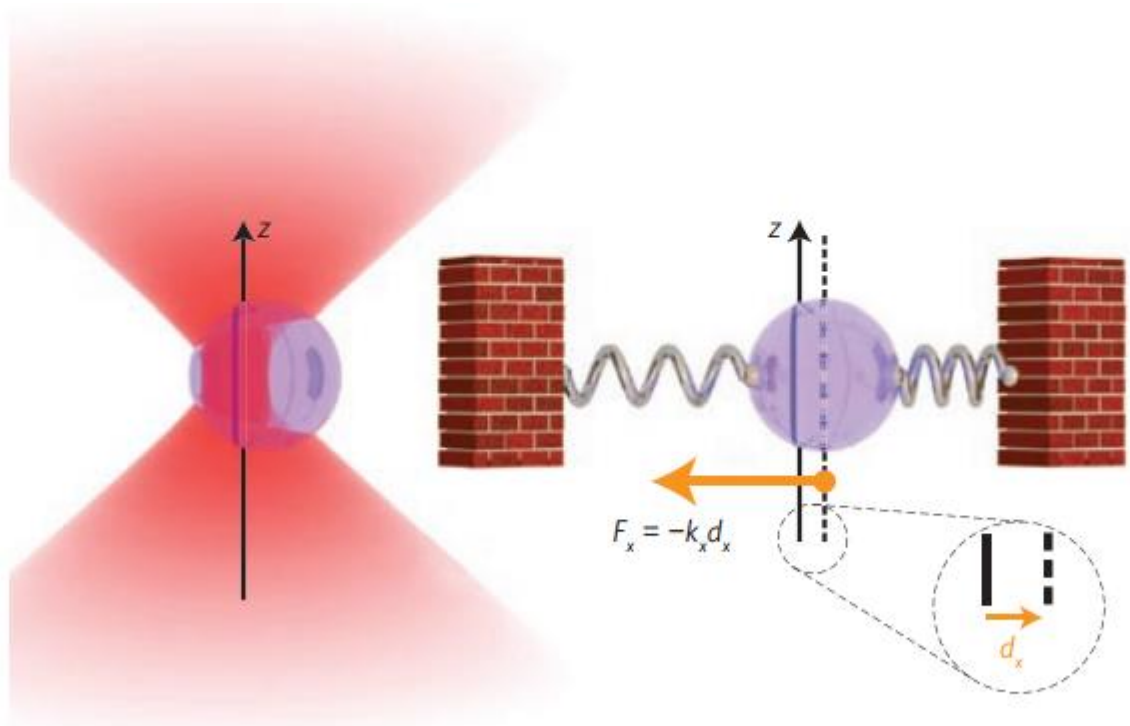


Figure 1 | Optical tweezers are conceptually analogous to a harmonic oscillator. A confined particle within an optical field acts as a harmonic oscillator. The restoring force (F_x) acting on the particle points towards the trap centre with a magnitude that is proportional (through constant k_x, the trap stiffness) to the particle's displacement (d_x) from the equilibrium position. The surrounding aqueous media causes Brownian motion and a high level of motional damping constrains any oscillations of the trapped

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Stretching DNA with Optical Tweezers

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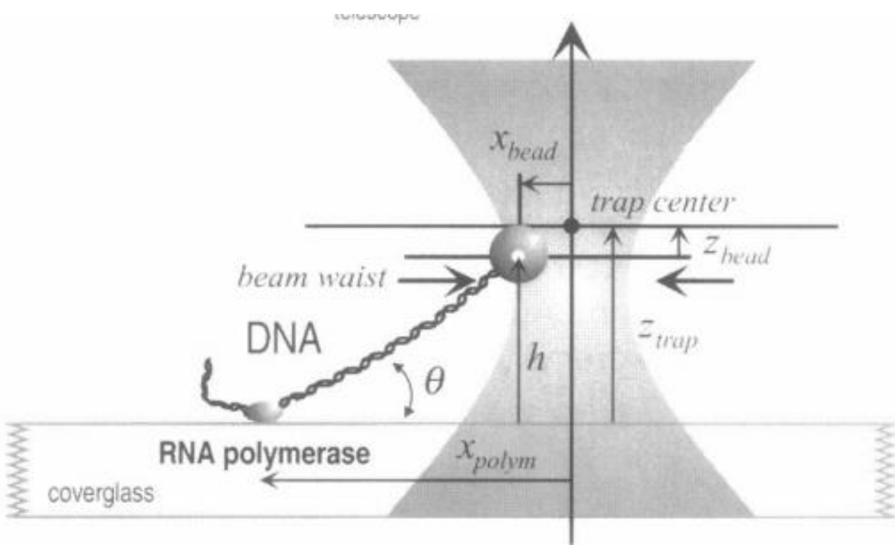


- Single DNA molecule:
  - one end fixed to glass via fixed RNA polymerase complex
  - Other end linked to microscopic bead
- Optical trap captures and holds the bead in place
- DNA stretched by moving coverglass with respect to trap via piezo-driven stage
  - Known distance moved (nm)

Force-Extension Relation for DNA

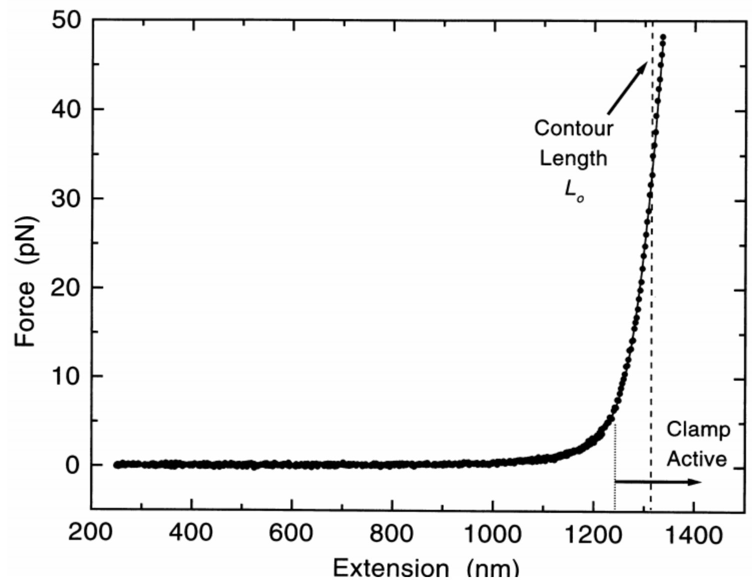
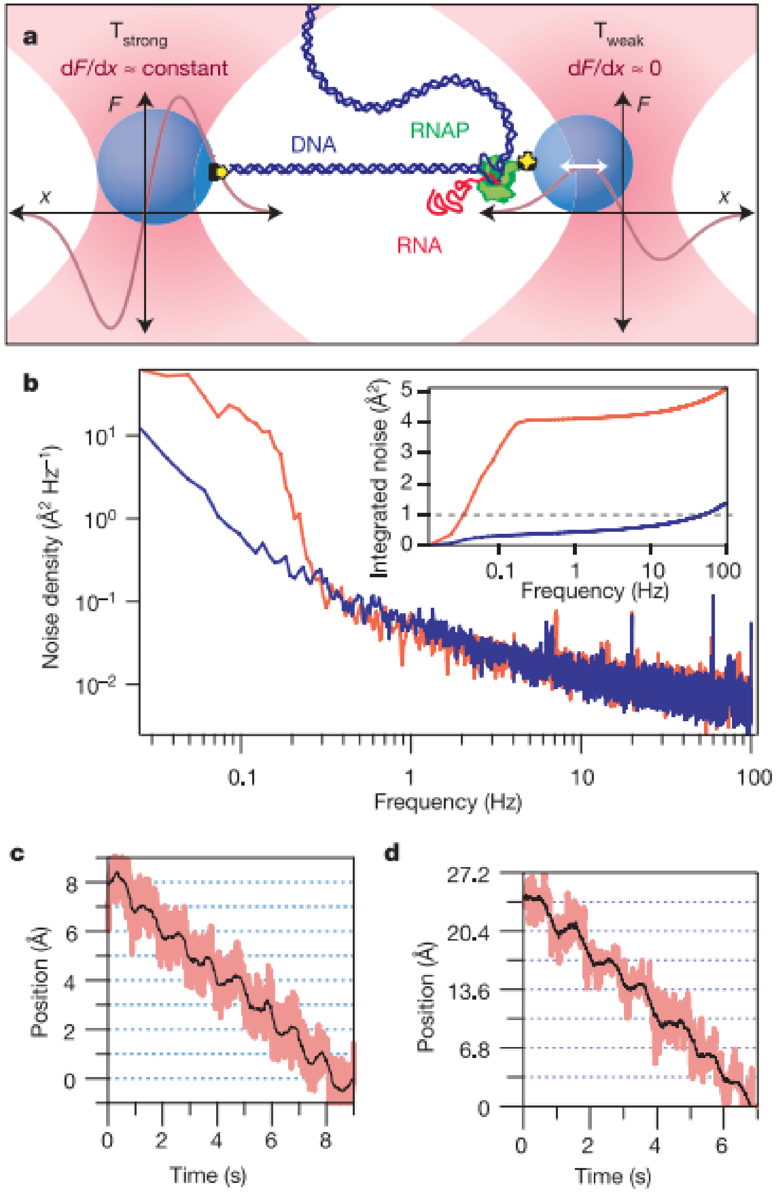


TABLE 1 DNA elasticity models

Model	Formula	Comments
Marko-Siggia (1995) WLC	$F = \left(\frac{k_BT}{L_p}\right)\left[\frac{1}{4(1 - x/L_o)^2} - \frac{1}{4} + \frac{x}{L_o}\right]$	Entropic theory. Interpolation formula of exact solution when [salt] ≥ 10 mM. Applicable when $F \ll \frac{1}{4}(k_BTK_o^2/L_P)^{1/3}$. Differs from exact solution by up to ~10% near $F \approx 0.1$ pN. Approaches exact solution at lower and higher forces.
Odijk (1995) WLC	$x = L_o\left[1 - \frac{1}{2}\left(\frac{k_BT}{FL_P}\right)^{1/2} + \frac{F}{K}\right]$	Entropic/enthalpic theory. Applicable for $\lvert x - L_o\rvert/L_o \ll 1$ (high-force regime).
Smith et al. (1995) FJC	$x = L_o\left[\coth\left(\frac{2FL_P}{k_BT}\right) - \frac{k_BT}{2FL_P}\right]\left(1 + \frac{F}{K_o}\right)$	Entropic/enthalpic theory. Applicable to polymers that approximate a FJC. Note that the Kuhn length = $2L_p$, and Langevin function $L(\alpha) = \coth(\alpha) - 1/\alpha$.
Modified Marko-Siggia WLC	$F = \left(\frac{k_BT}{L_P}\right)\left[\frac{1}{4(1 - x/L_o + F/K_o)^2} - \frac{1}{4} + \frac{x}{L_o} - \frac{F}{K_o}\right]$	Entropic/enthalpic theory. Modification of Marko-siggia formula to incorporate enthalpic stretching. Has limitations similar to Marko-Siggia near $F \approx 0.1$ pN.

WLC, Wormlike chain; FJC, freely jointed chain; F, force; x, extension (end-to-end distance); L_P, persistence length; L_o, contour length; K_o, elastic modulus; k_BT, Boltzmann's constant times absolute temperature.

[Direct observation of base-pair stepping by RNA polymerase]



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Bead movement by single kinesin molecules studied with optical tweezers

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Kinesin 1 – Straight Movement
https://www.youtube.com/watch?v=GLTHM5lBOV4

Kinesin 2 – Lane Change
https://www.youtube.com/watch?v=o6bHxxFC-os

Tying a molecular knot with optical tweezers

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