So occlusions that reduce $R$ to $\frac{R}{2}$ will reduce $Q$ to

$$Q' = \frac{\pi}{8L\eta}\left(\frac{R}{2}\right)^4 p = \left(\frac{1}{2}\right)^4 Q = \frac{1}{16} Q$$

unless the pressure rises.

What change in $R$ causes $p$ to rise by 30%?

$$\frac{p'}{Q'} = 1.3 \frac{p}{Q} \Rightarrow \frac{R'^{-4}}{R^{-4}} = 1.3$$

So

$$\frac{R'}{R} = (1.3)^{-1/4} \approx 0.94.$$

So shrinking $R$ by 6% increases blood pressure by 30%.

Viscous drag at DNA fork:

The torque is

$$\tau = -4\pi\omega\eta R^2 L$$

(by problem 5.9) where $R$ is the radius of the rod and $L$ its length. The rate of work is $-\tau\omega = 4\pi\omega^2\eta R^2 L$,

or

$$W_f = -2\pi\tau = 8\pi^2 \omega\eta R^2 L$$

per turn. Now DNA polymerase makes new DNA in E. coli at $\approx 10^3$ bp per second, and there are 10.5 bp per $2\pi$, so

$$\omega = 2\pi \frac{10^3 \ s^{-1}}{10.5} \approx 600 \, s^{-1}$$

So

$$W_f \approx 8\pi^2 \, 600 s^{-1} \, 10^{-3} \, kg \, m^{-1} s^{-1} (1 \, nm)^2 L$$

$$\approx 4.7 \times 10^{-17} \, J \, m^{-1} \, L$$

since $R_{DNA} \approx 1$ nm. DNA helicase cranks the DNA. Each ATP molecule gives $20kT$ of energy, or $8.2 \times 10^{-20}$ J.

Say 1 ATP does one turn. Then the energy lost to friction is negligible if

$$L < \frac{8.2 \times 10^{-20}\,J}{4.7 \times 10^{-17}\,J\,m^{-1}} \approx 2\,mm.$$

Now 2 mm is much bigger than most cells. Topoisomerases relieve the stress of excessive twisting on much smaller distance scales.