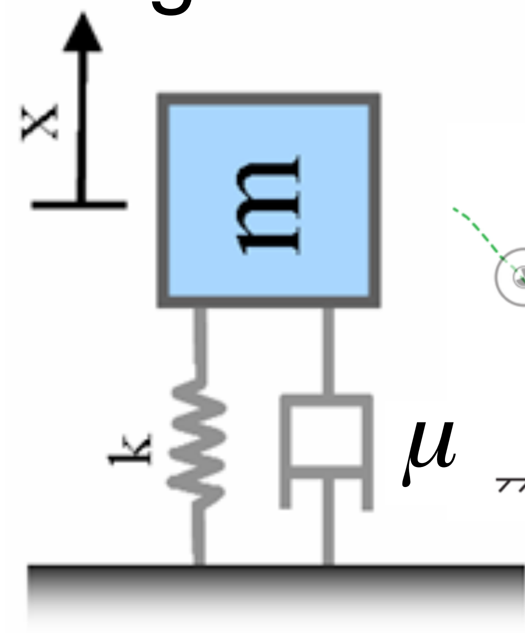
Biology 427 Biomechanics

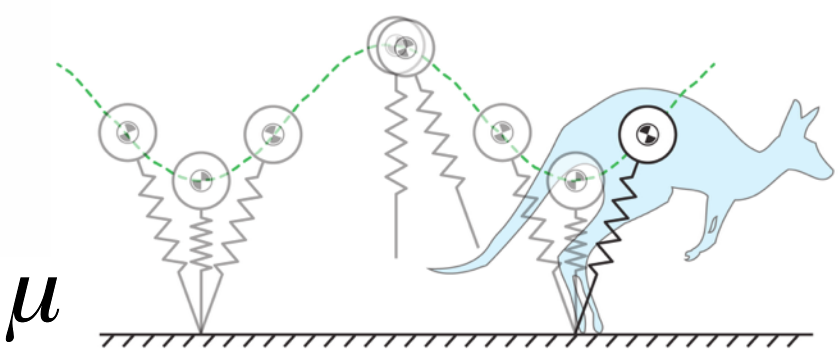
Lecture 12. Molecular motors

- Recap vibrations
- Motility at the cellular and sub-cellular level
- Diversity of molecular motors
- The fundamental problem of converting chemical energy into mechanical energy.
- Converting mechanical energy into motion
- Myosin — the basis of movement with muscle.

If you know x, what is F for our Kangaroo model?

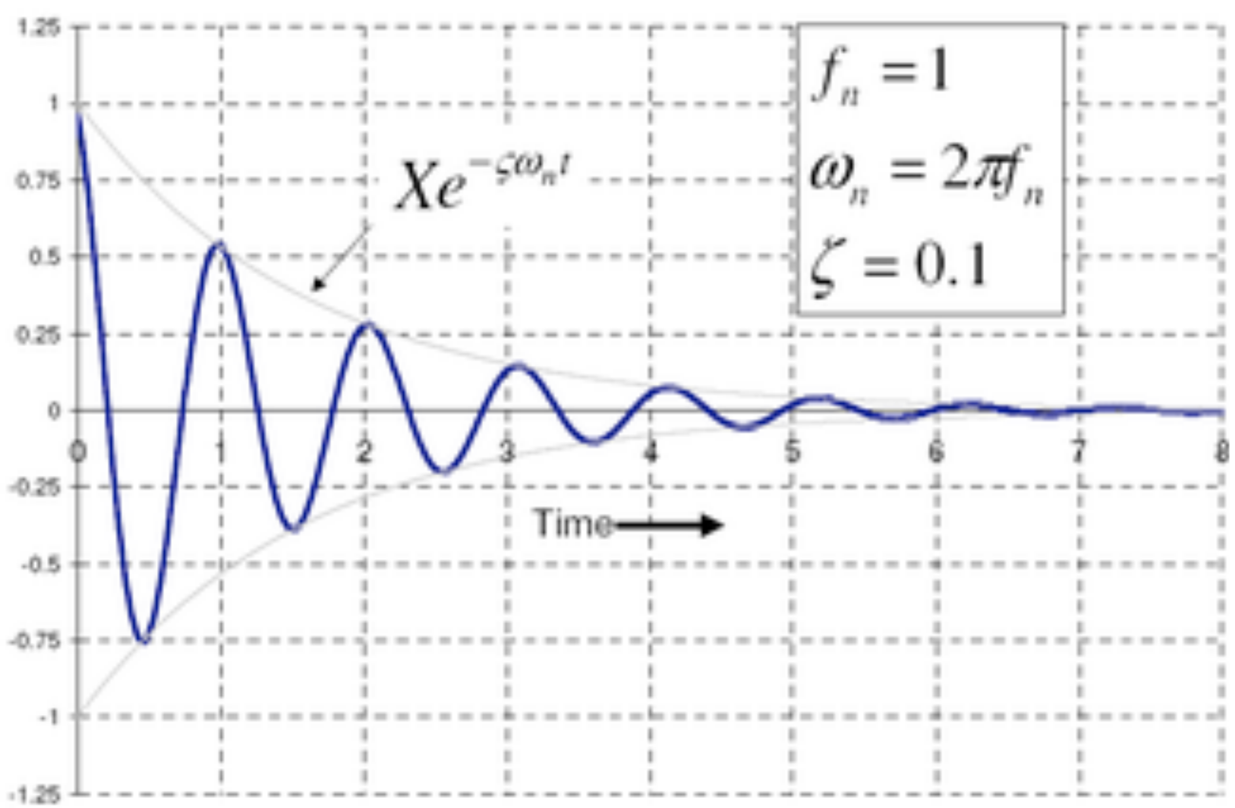
$$x = \sin(2\pi f t) \quad = \sin(\omega t)$$

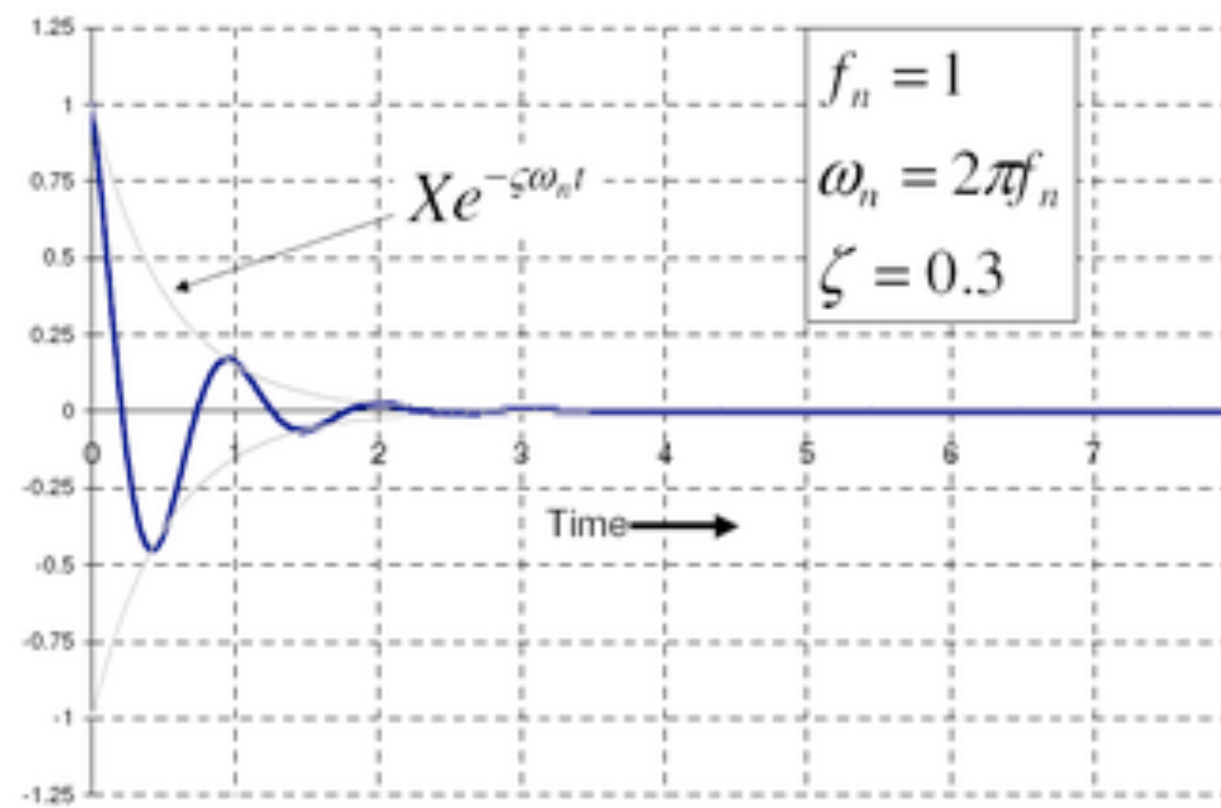




$$F = kx + \mu \frac{dx}{dt} + m \frac{d^2 x}{dt^2}$$

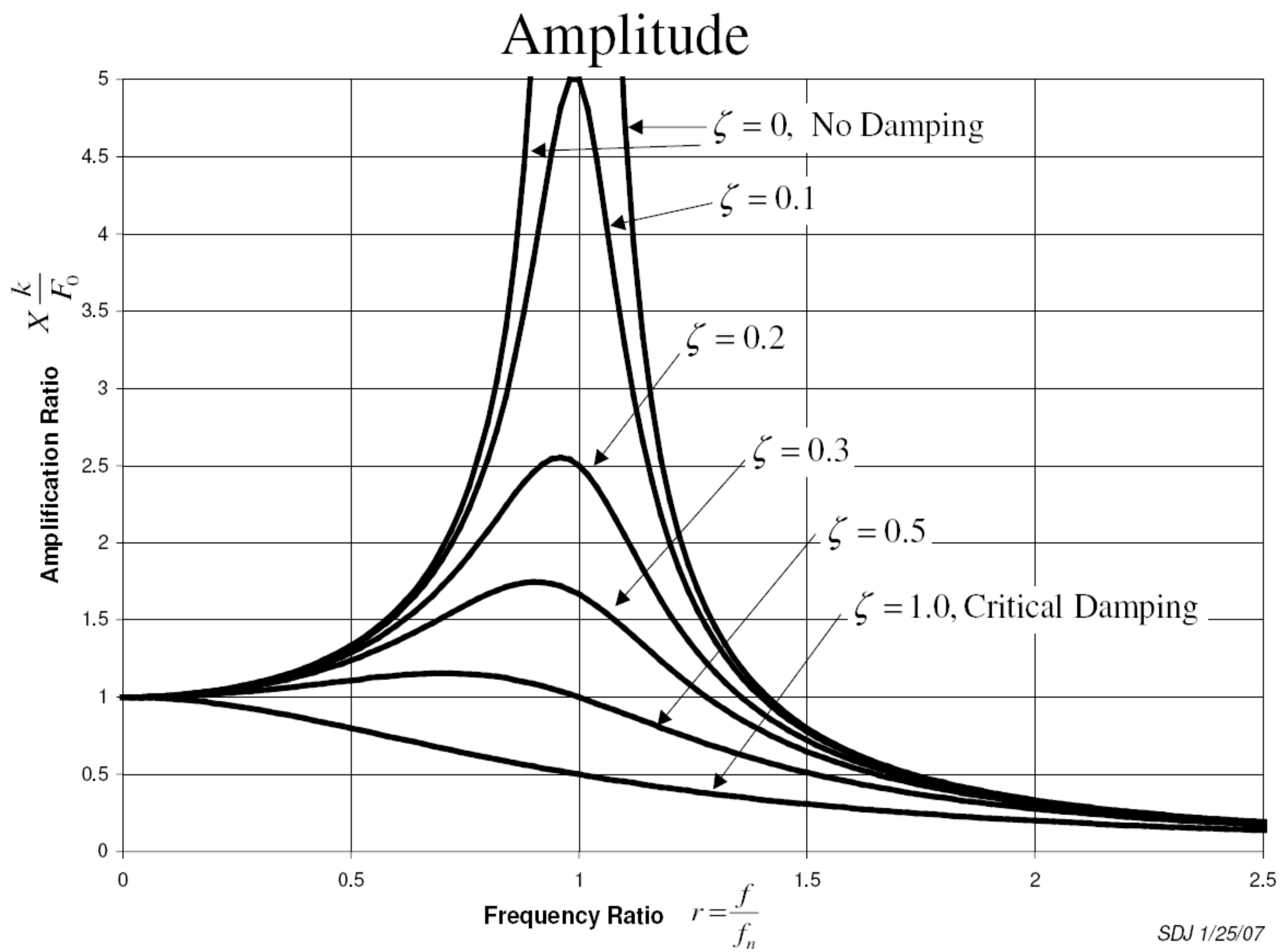
$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$



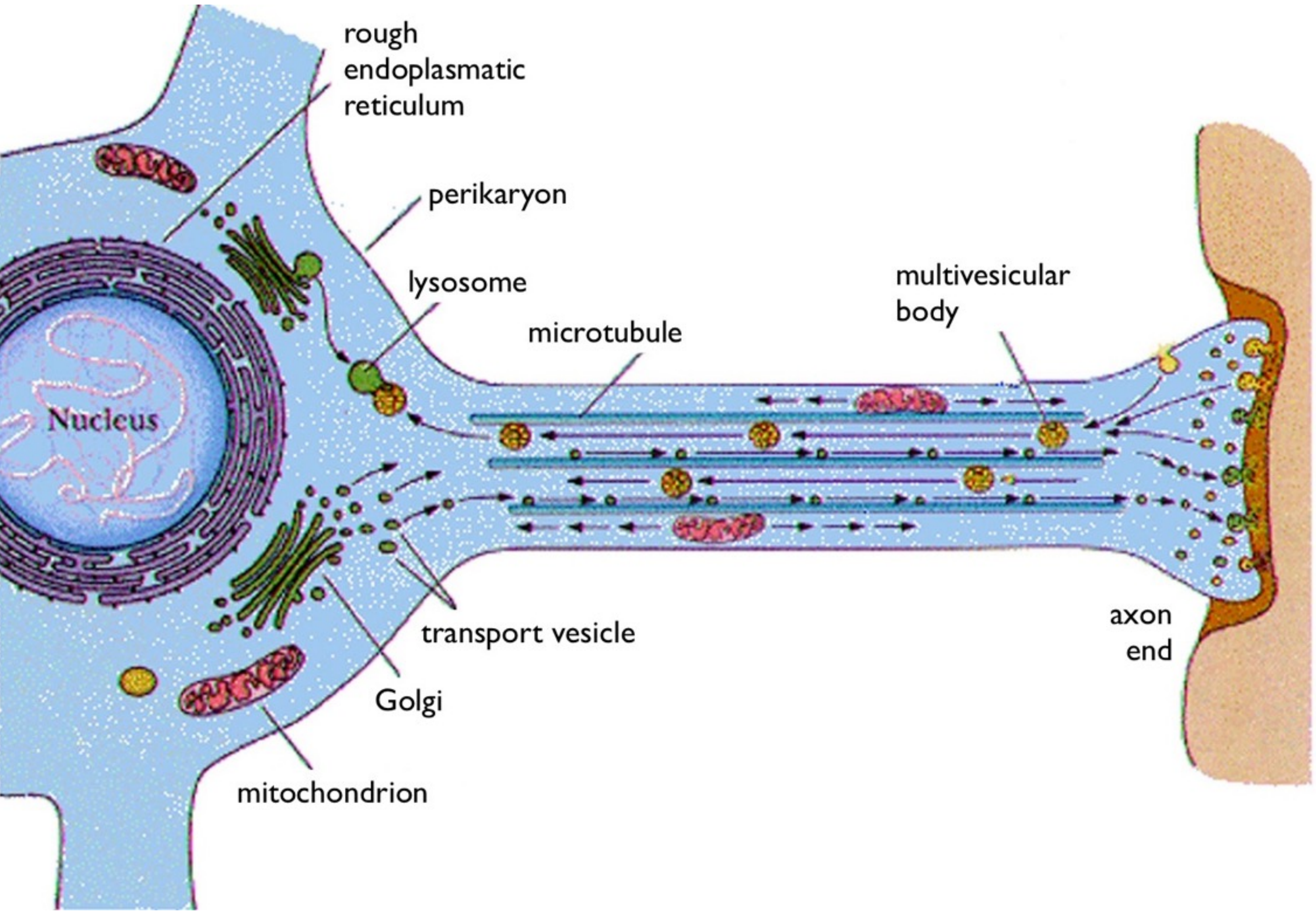


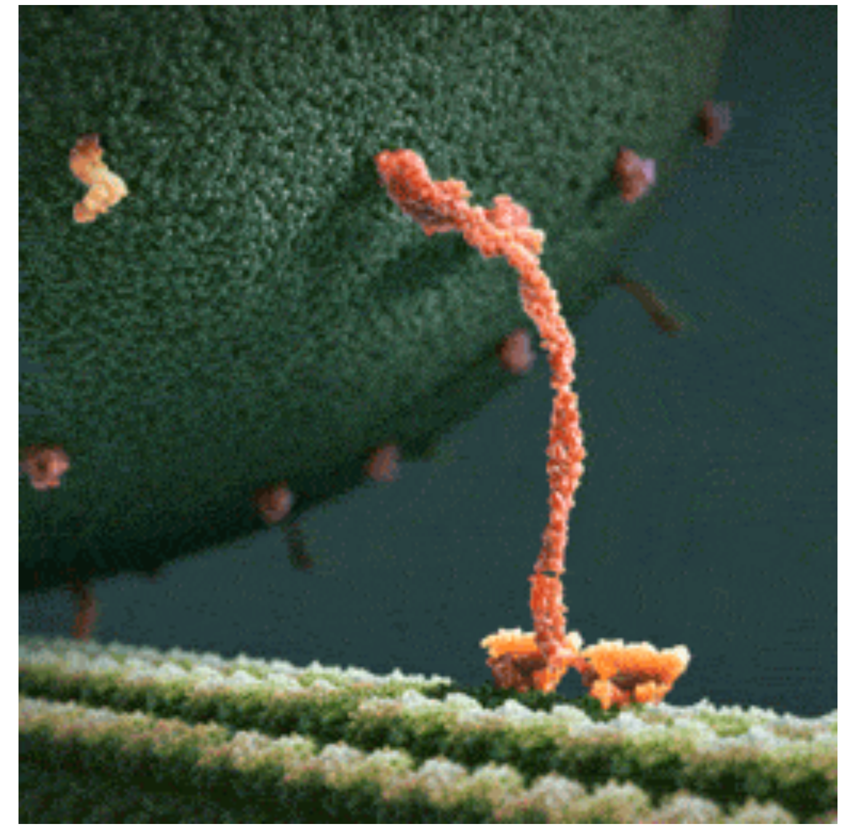
How does the motion (x) change as we input a force near resonance?

A sample demonstration in Mathematica.

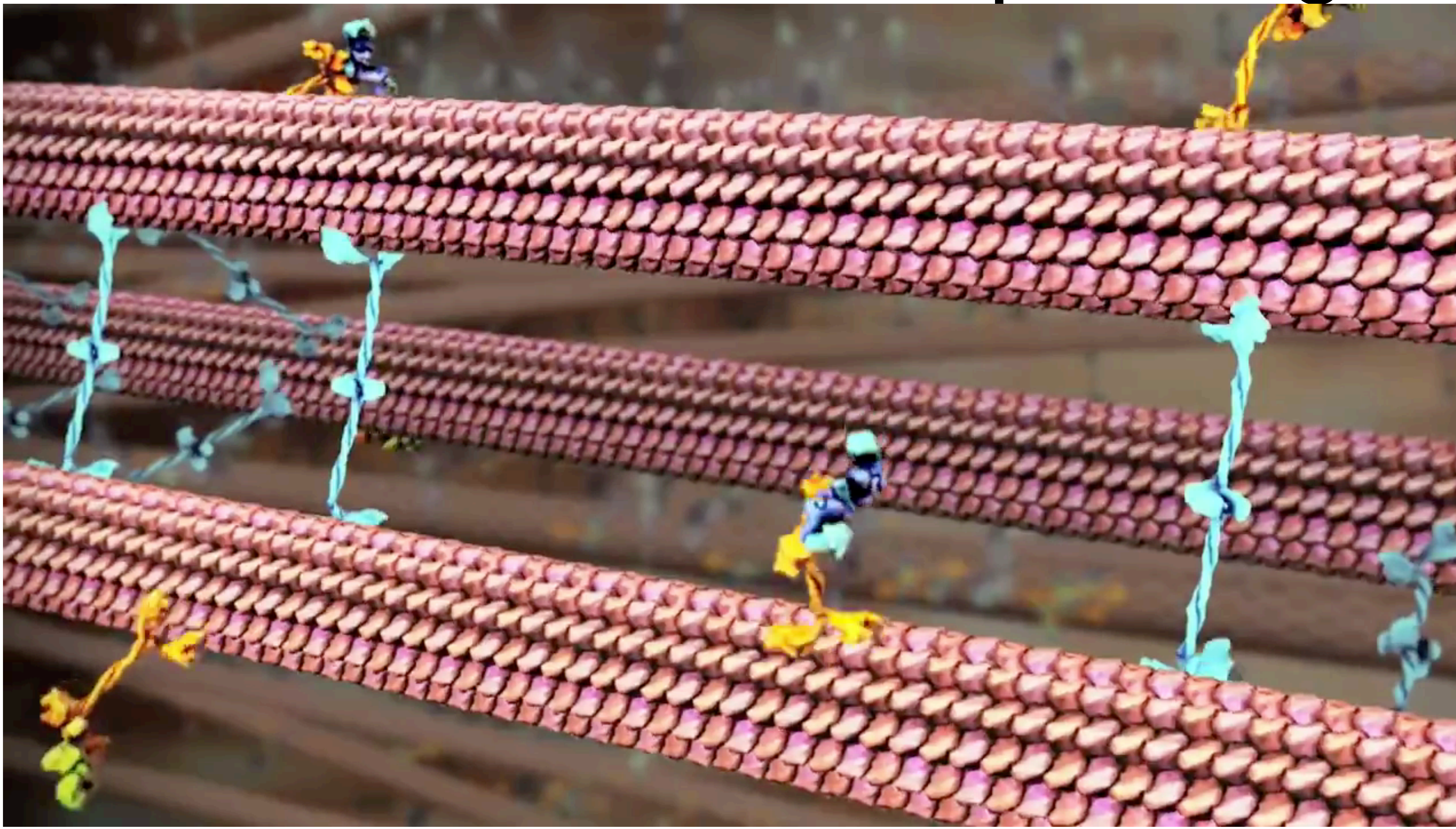


Motility at the cellular and sub cellular level: axonal transport



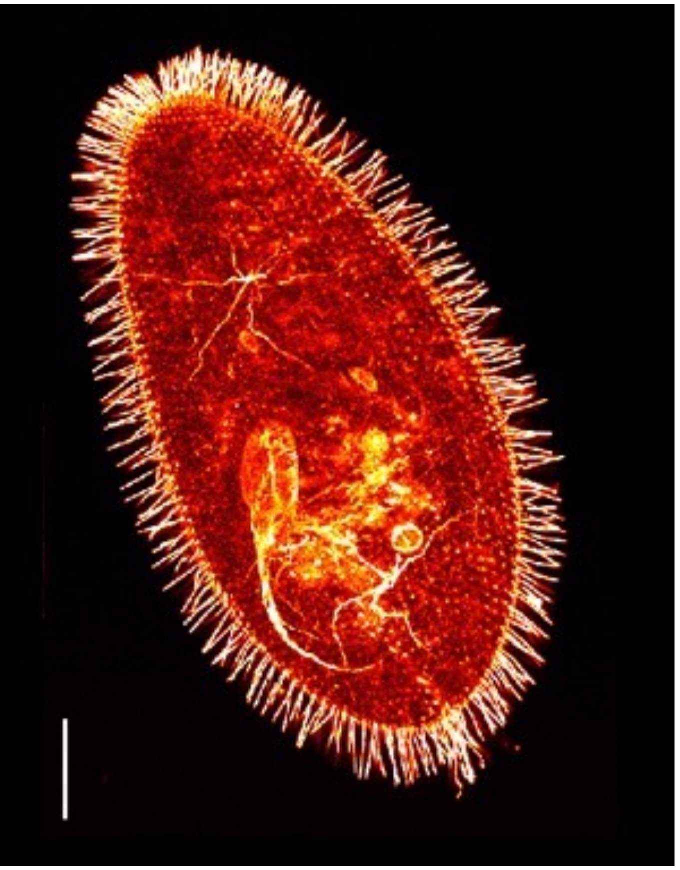


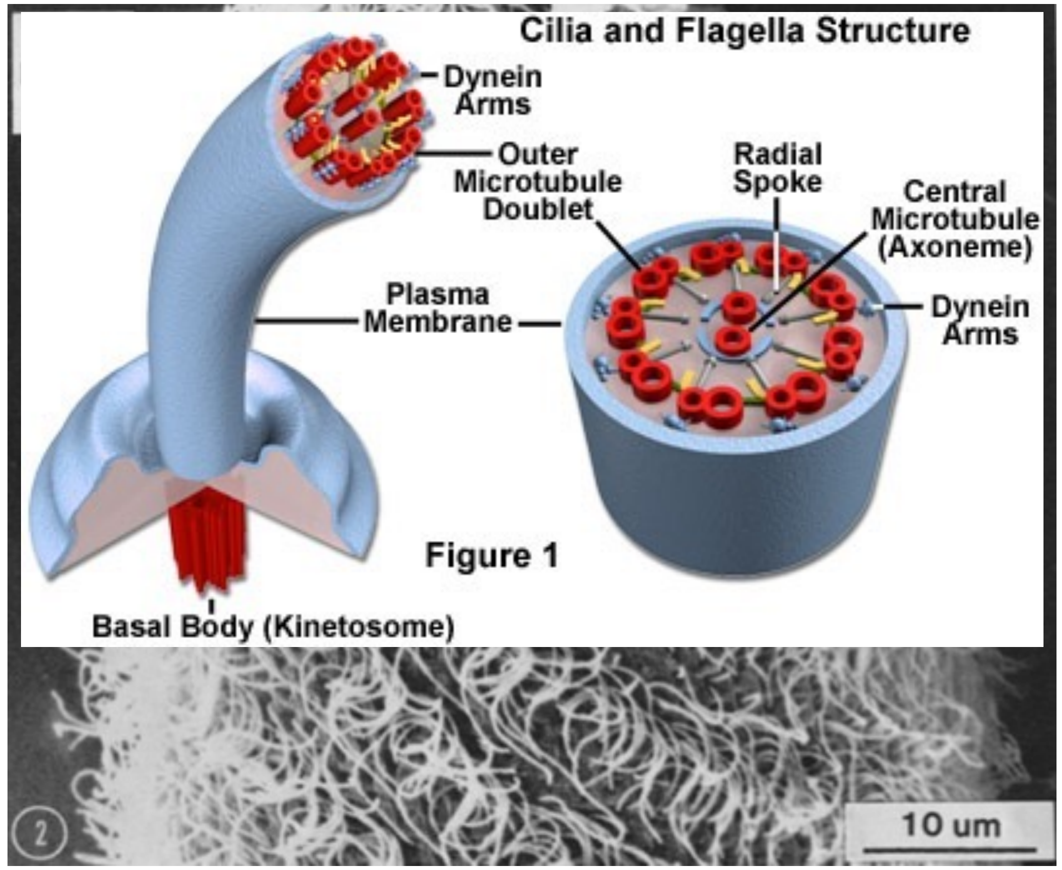
Processive motors transport cargo

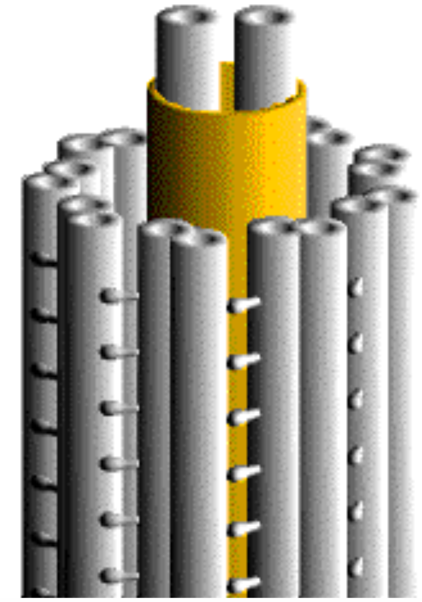


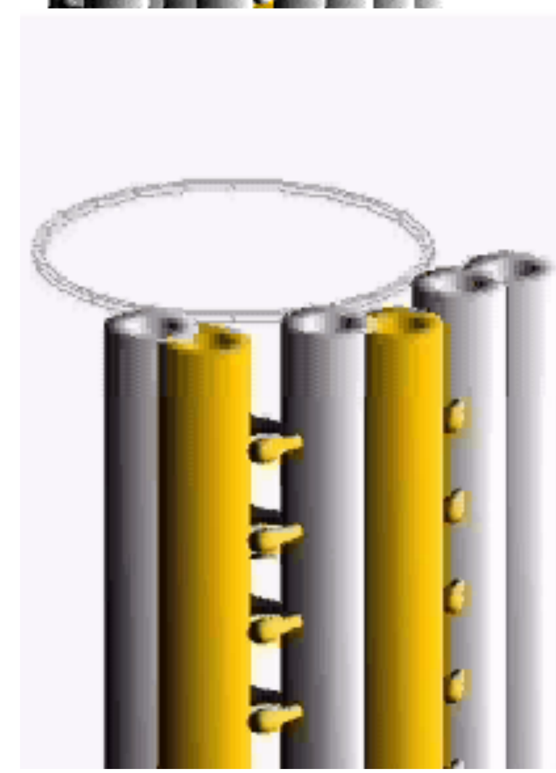
Drew Berry, 2013

Motility at the cellular and sub cellular level: cilia and flagella

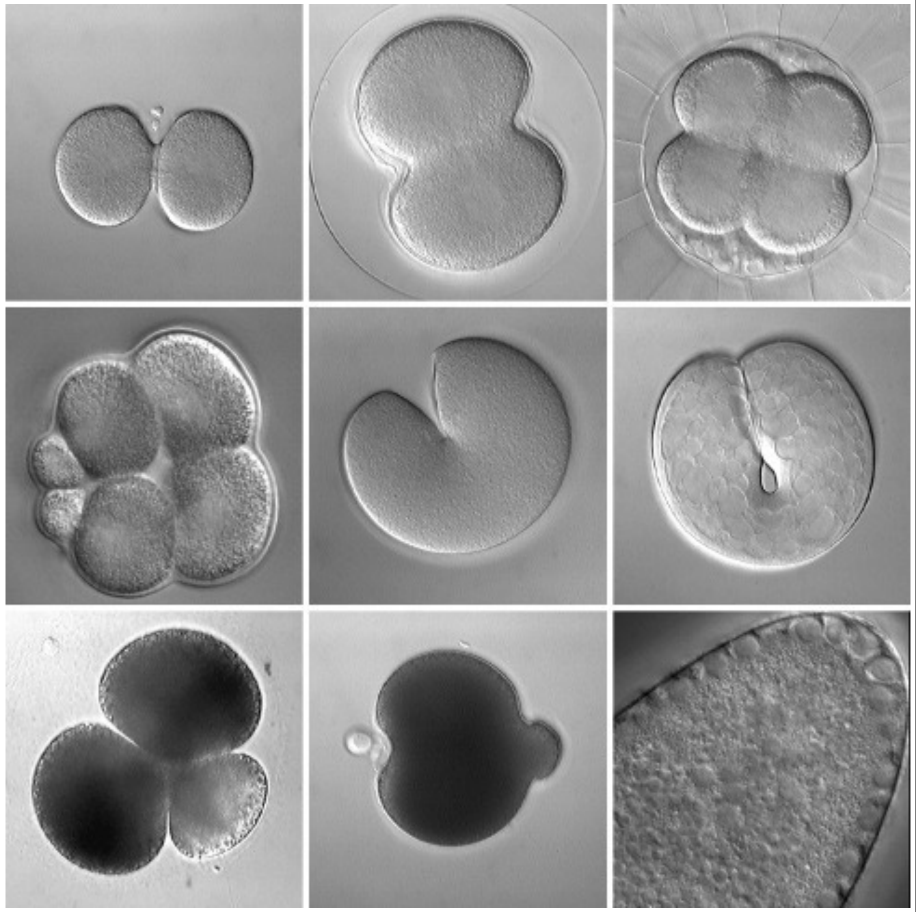


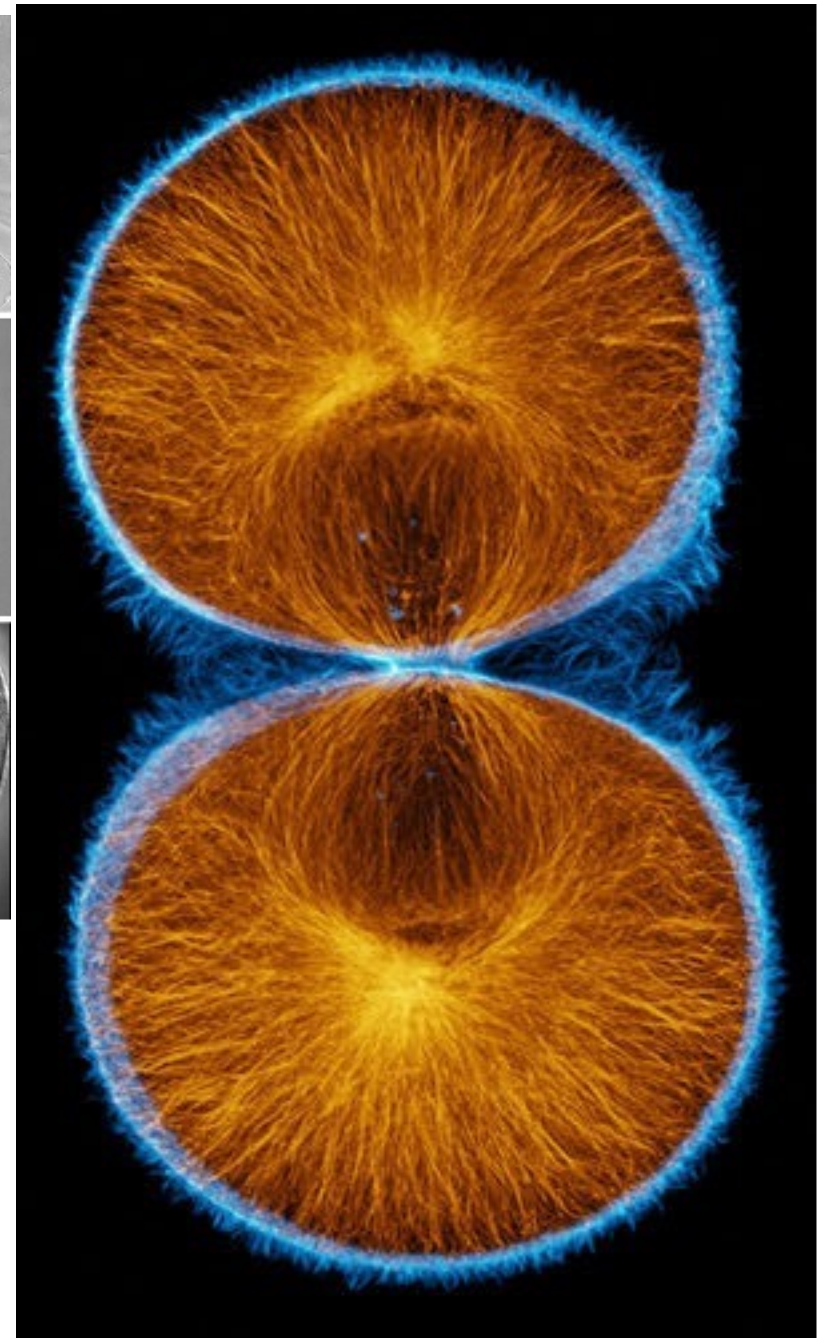


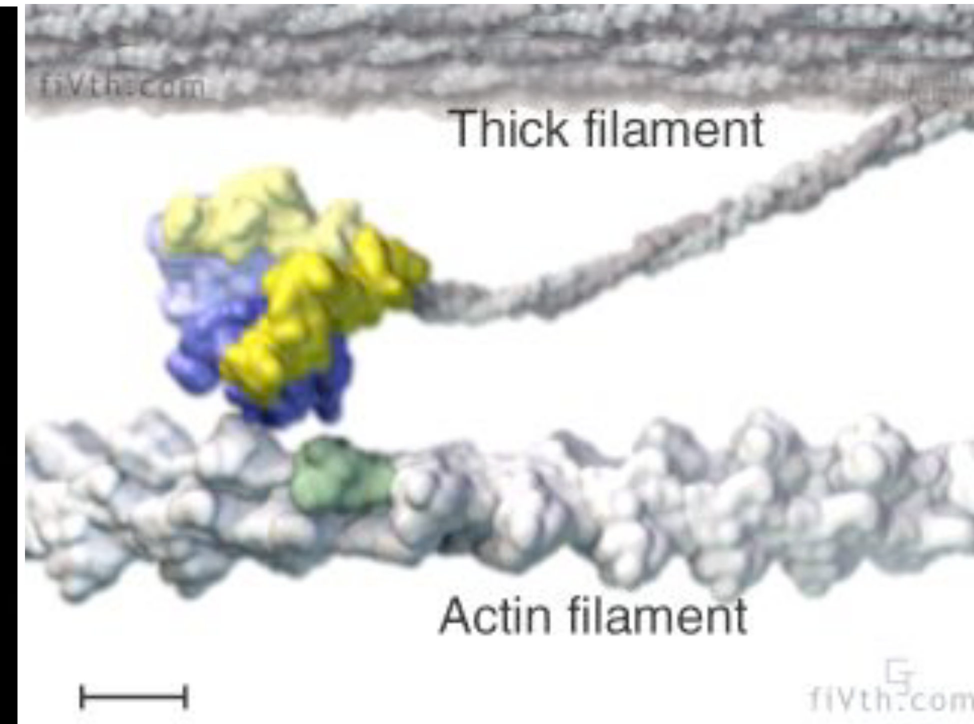




Motility at the cellular and sub cellular level: cell division

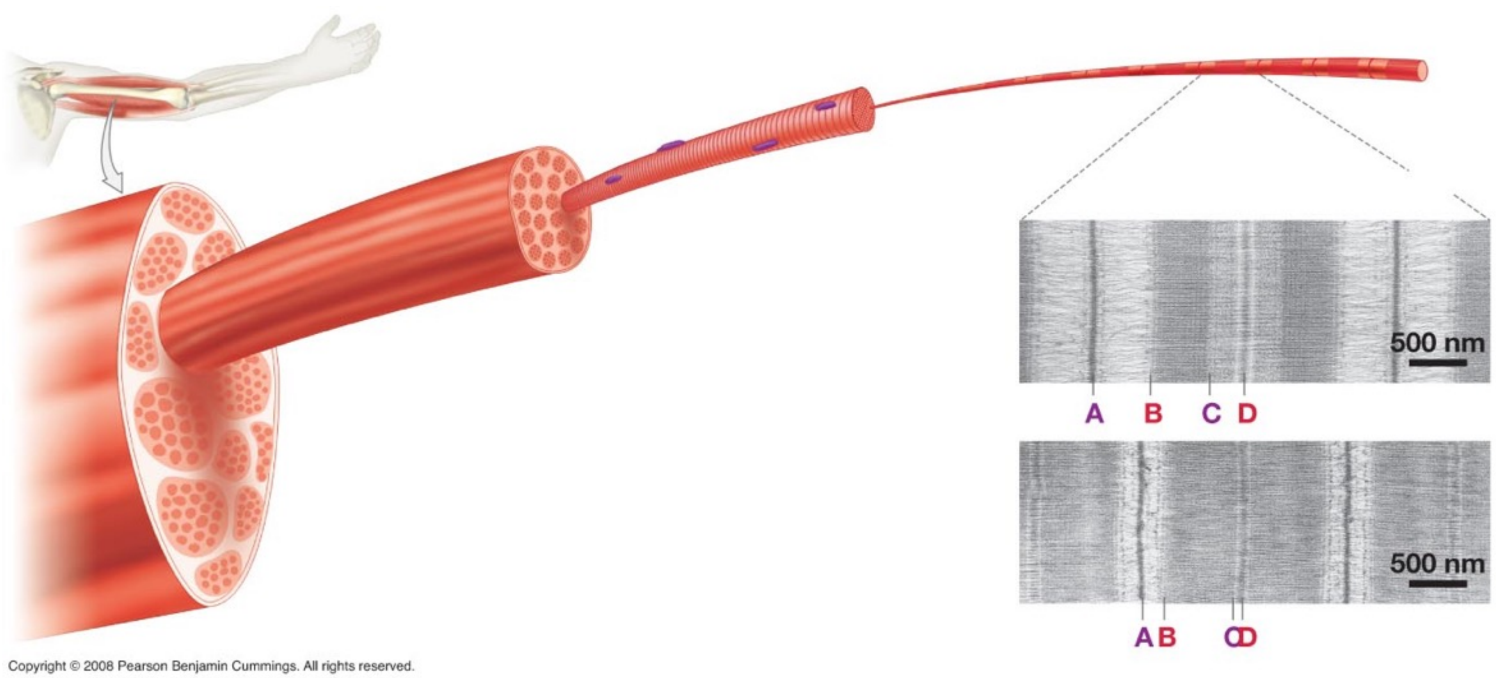


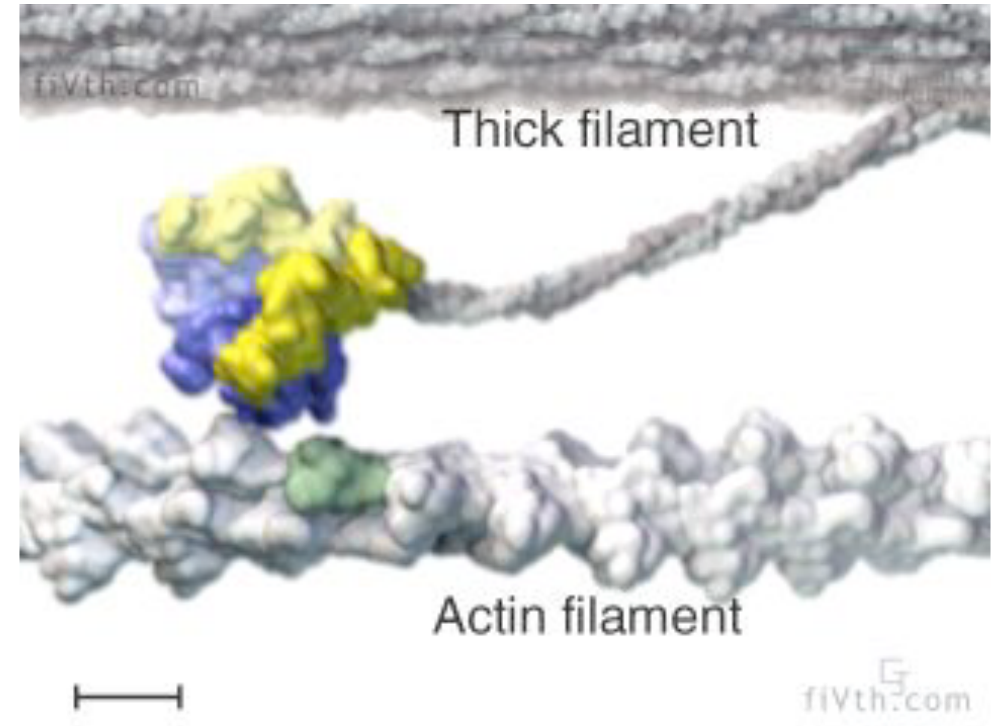




images from von Dassow et al. Friday Harbor Labs

Motility at the cellular and sub cellular level: muscle





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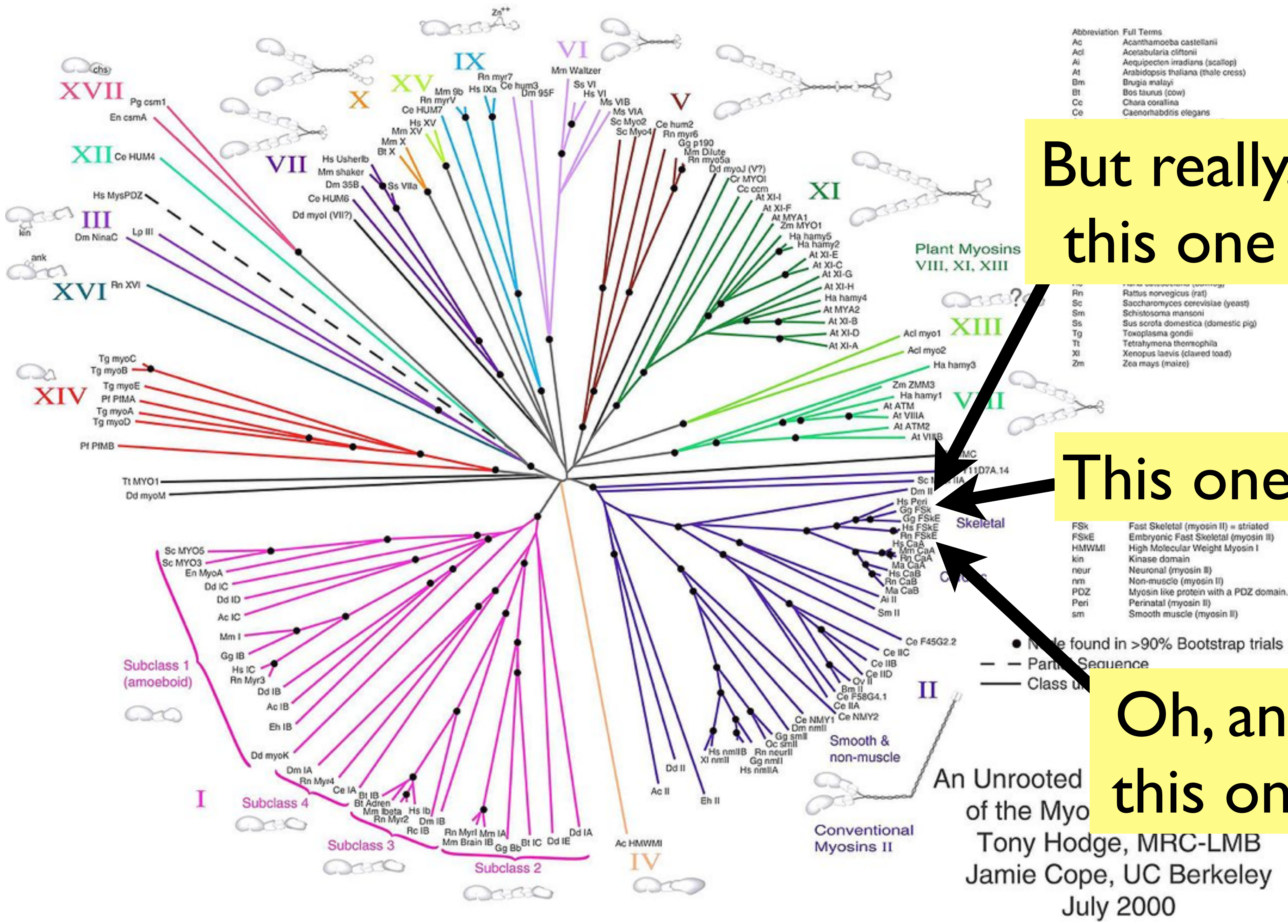
One myosin to stand in for all

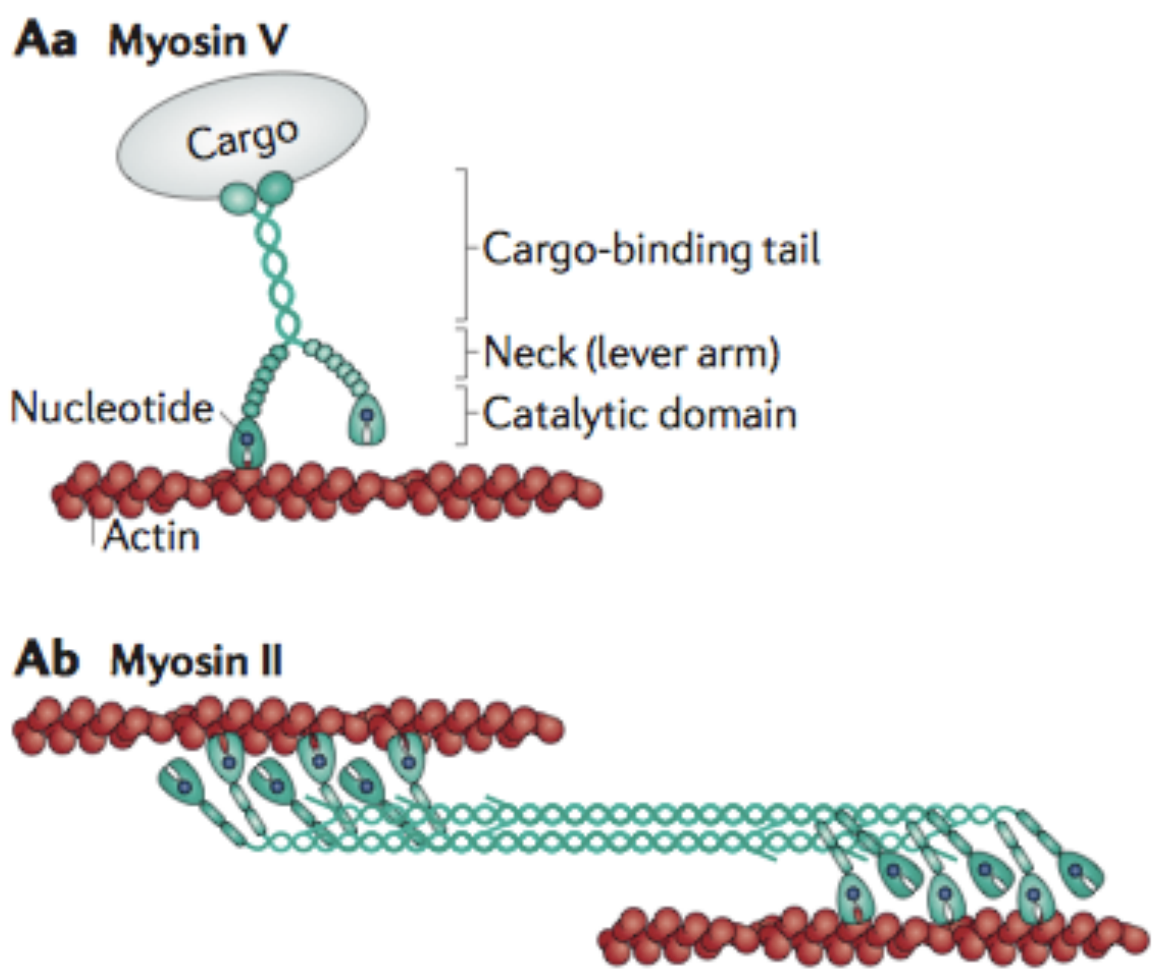


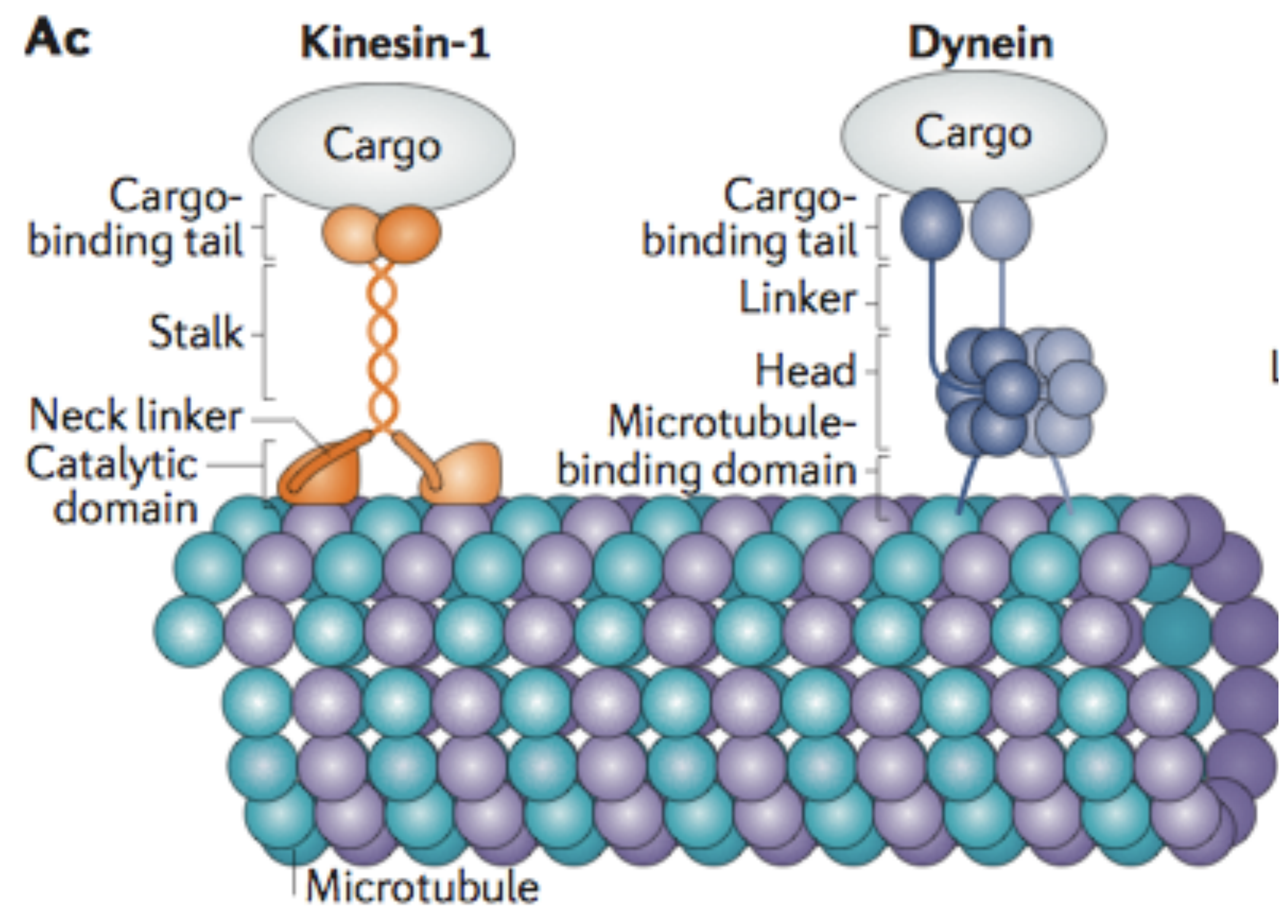
But really, this one

This one

Oh, and this one

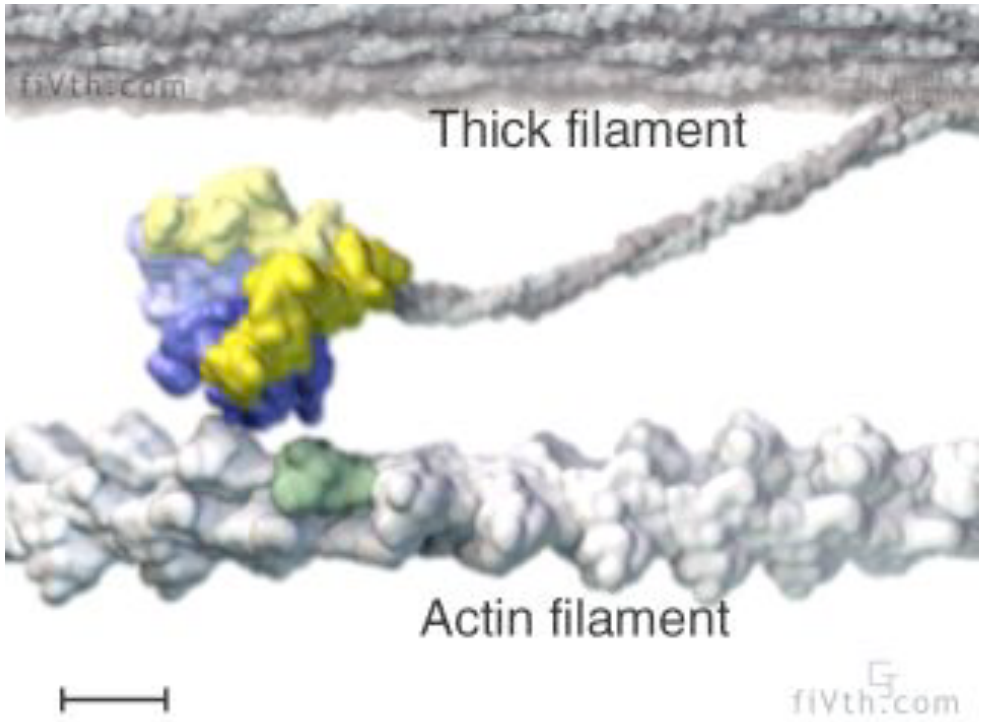
Motility at the cellular and sub cellular level: three motor proteins use the energy of ATP hydrolysis

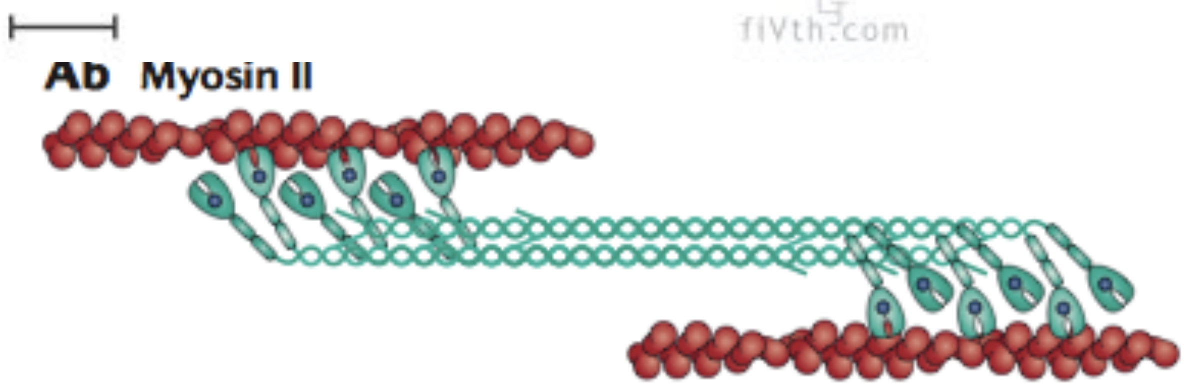




Kinesin: mostly + directed
Dynein: mostly - directed

Motility at the cellular and sub cellular level: three motor proteins use the energy of ATP hydrolysis





ATP ~ 0.7 nm

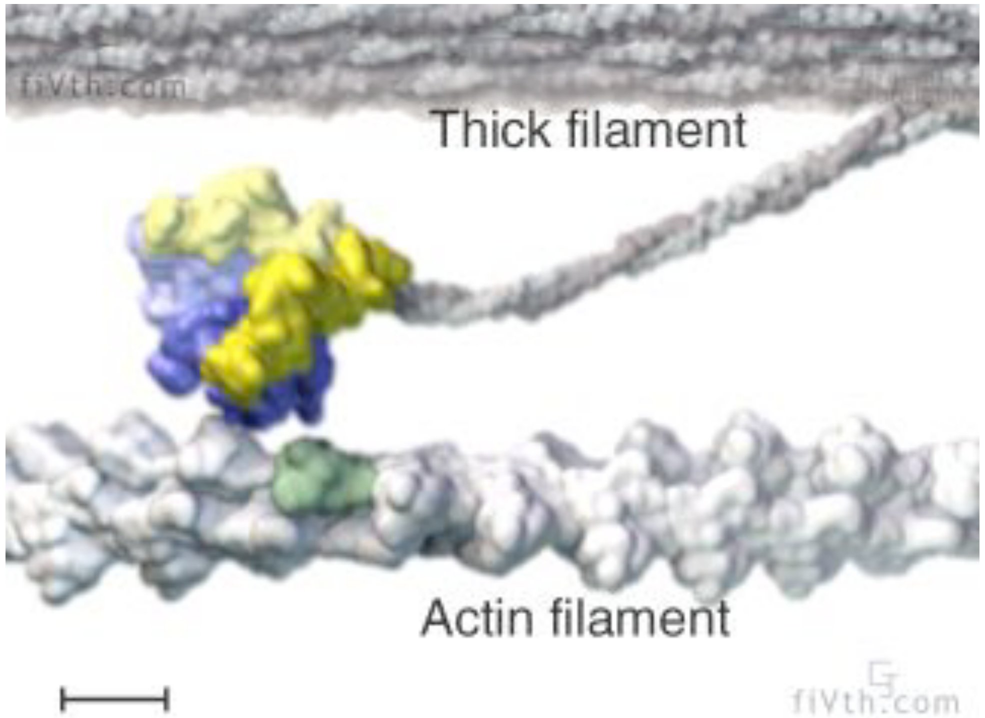
ADP ~ 0.7 nm

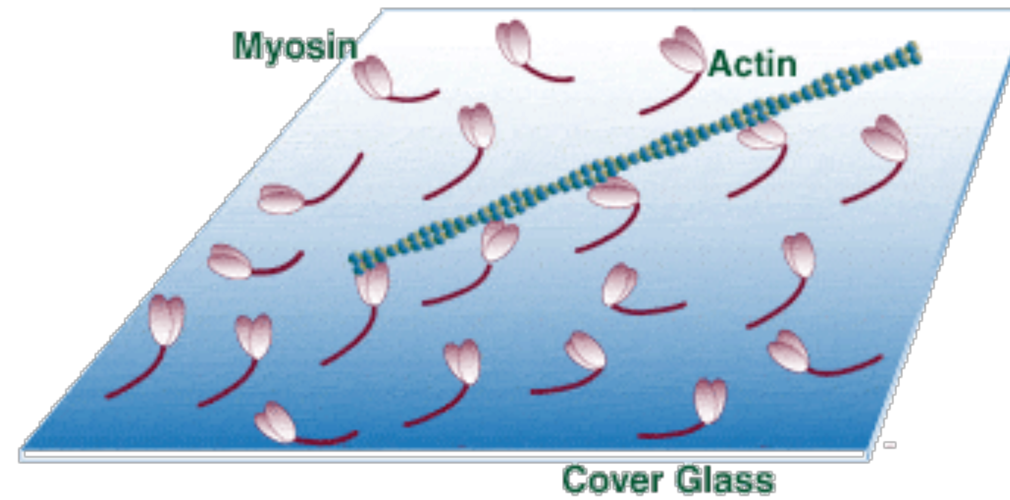
P ~ 0.1 nm

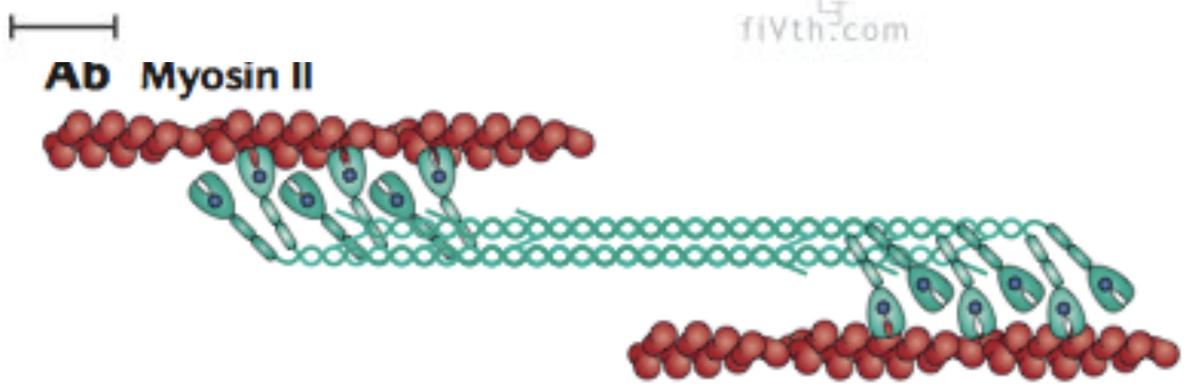
$5.46\ 10^{4}$ J/mol

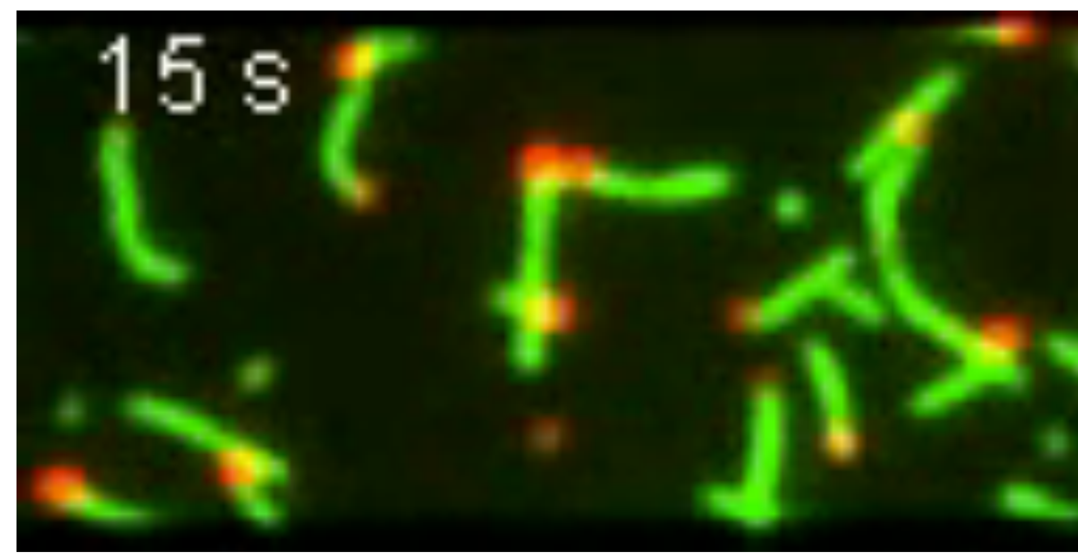
$9\ 10^{-20}$ J

Motility at the cellular and sub cellular level:
measure mechanics and kinematics at this tiny scale









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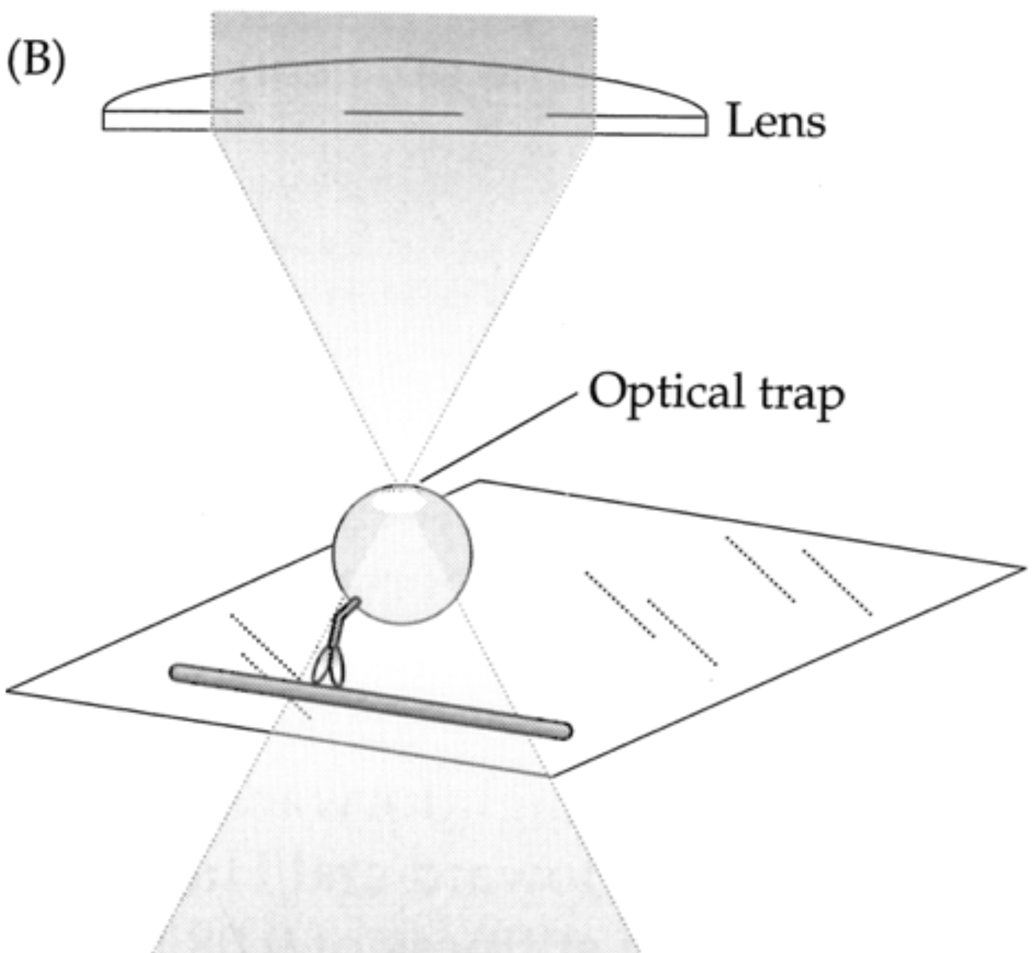
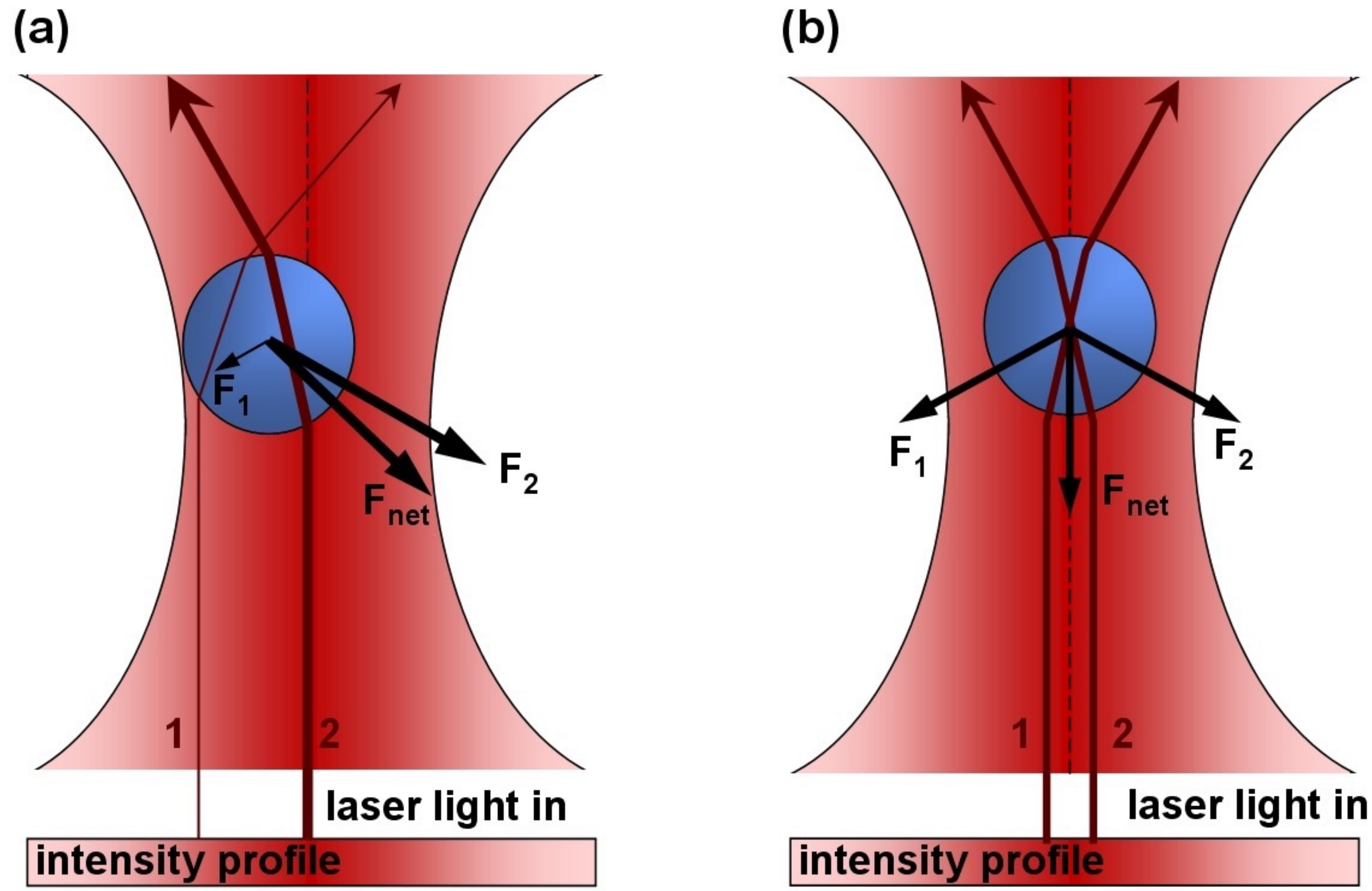
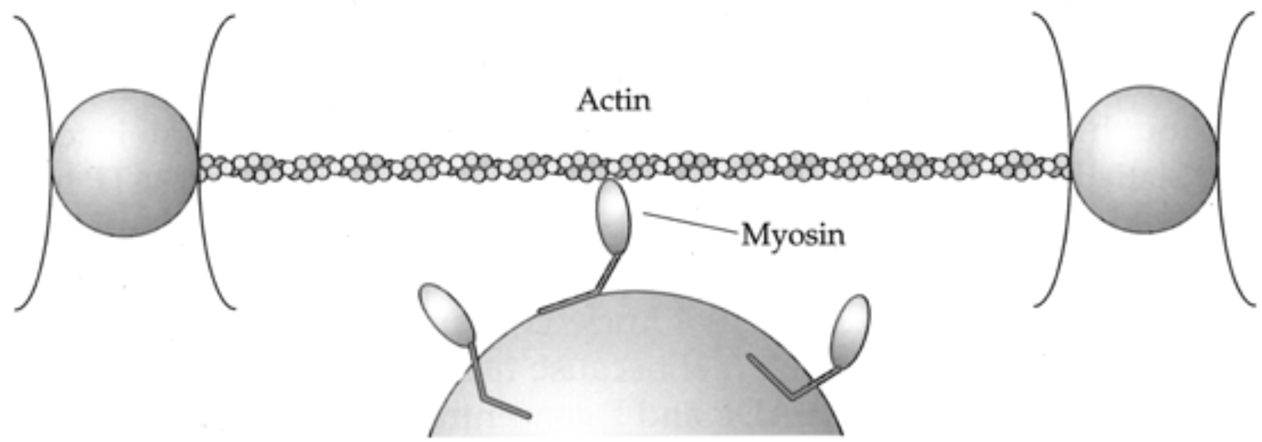
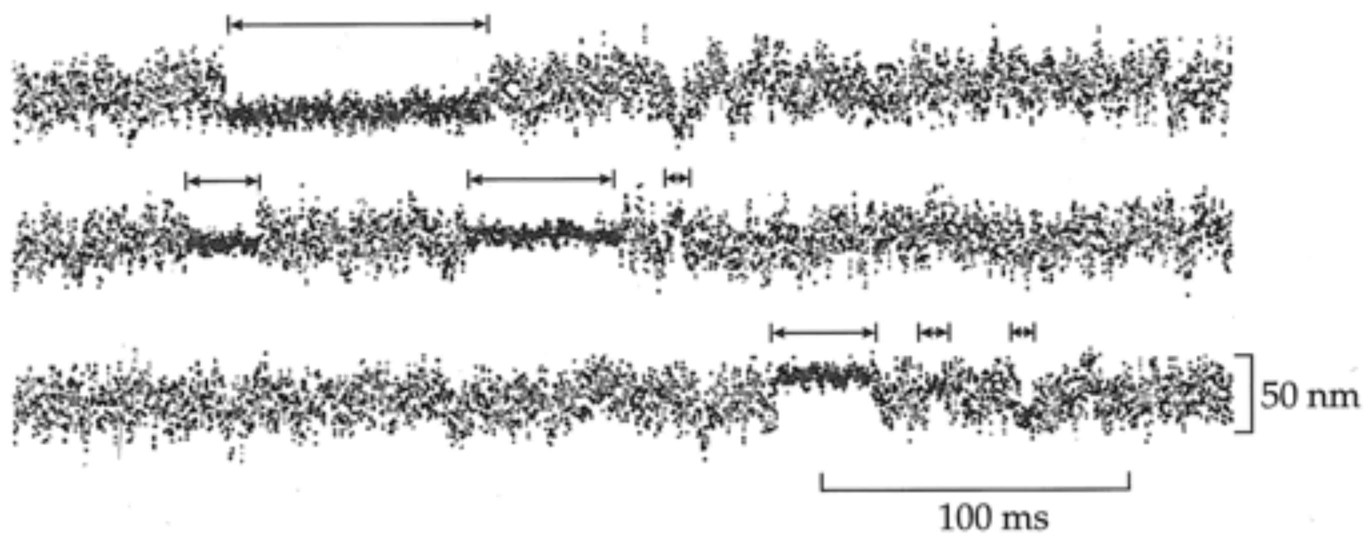


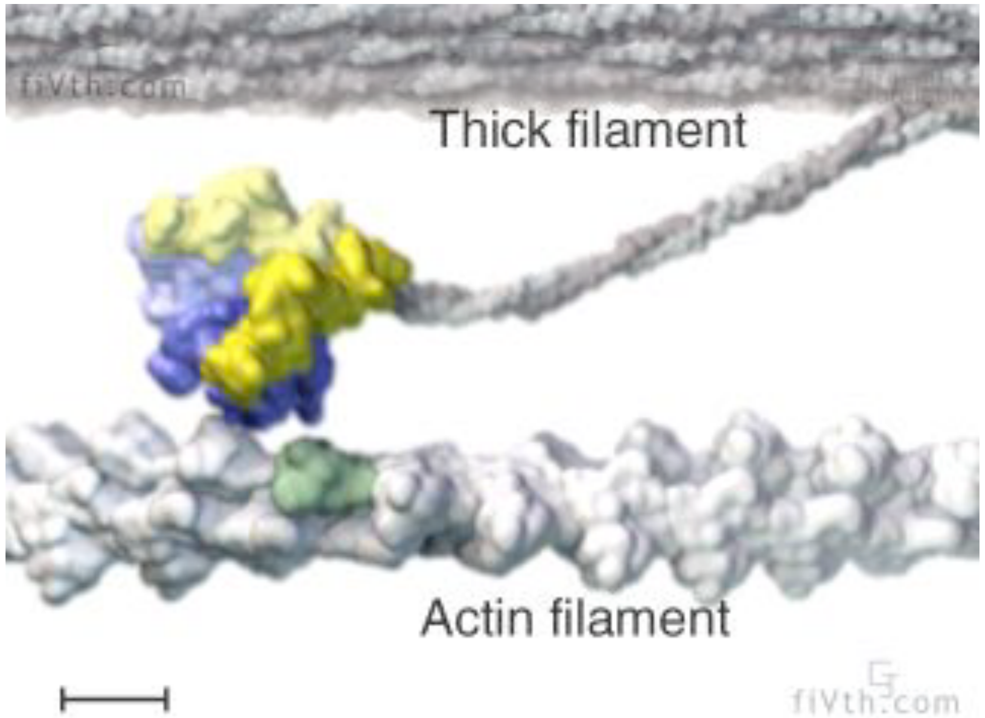


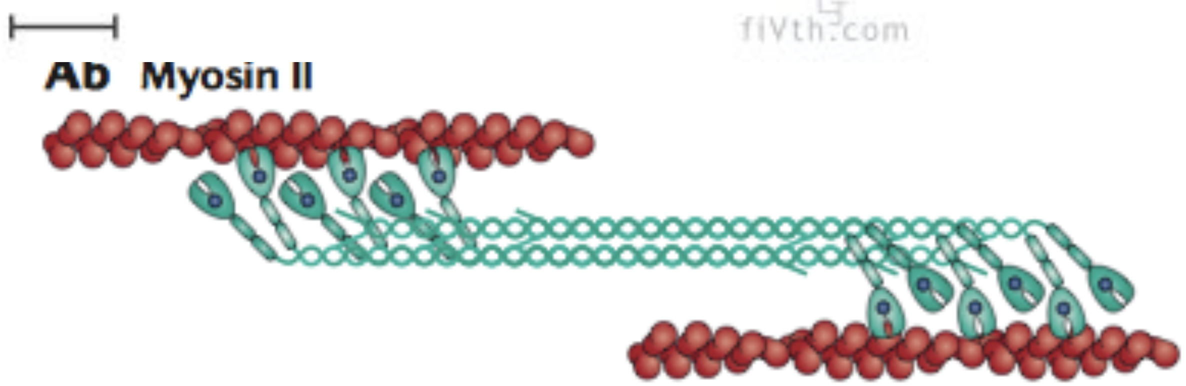




Some images adapted from Viegal et al, 1998, 1999 and Howard, 2001

Motility at the cellular and sub cellular level: three motor proteins use the energy of ATP hydrolysis





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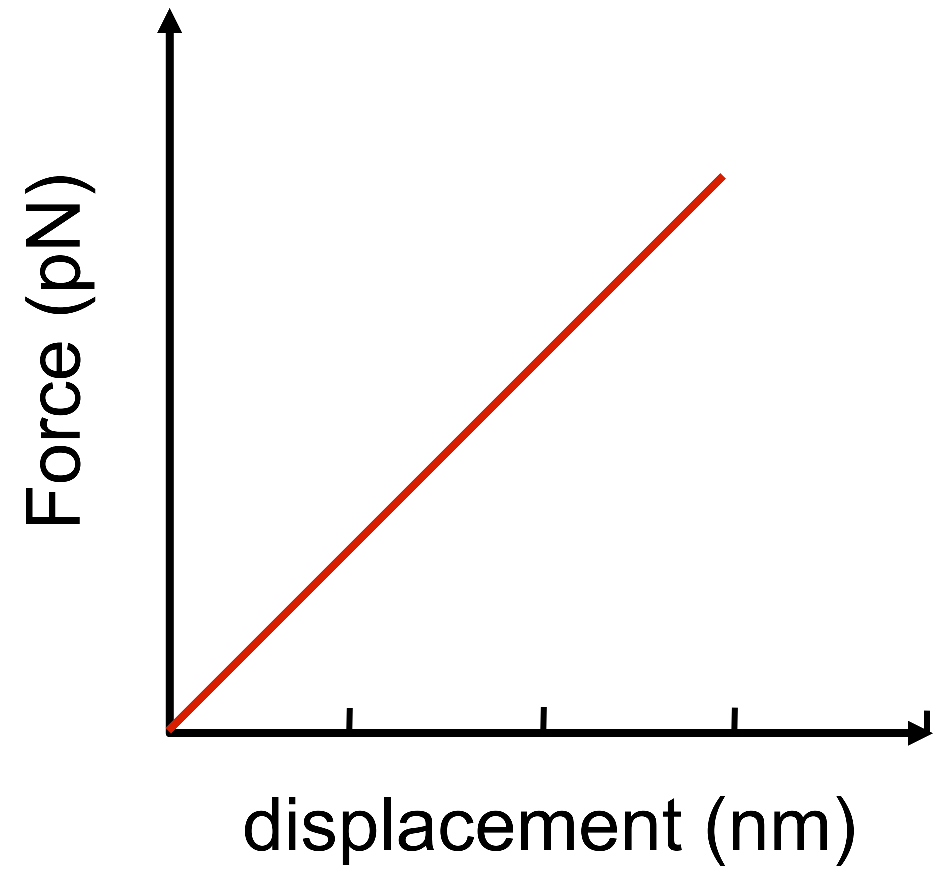

If the step length of a motor protein is 8 nm and it has all of the energy of ATP hydrolysis available, how much force can it generate?

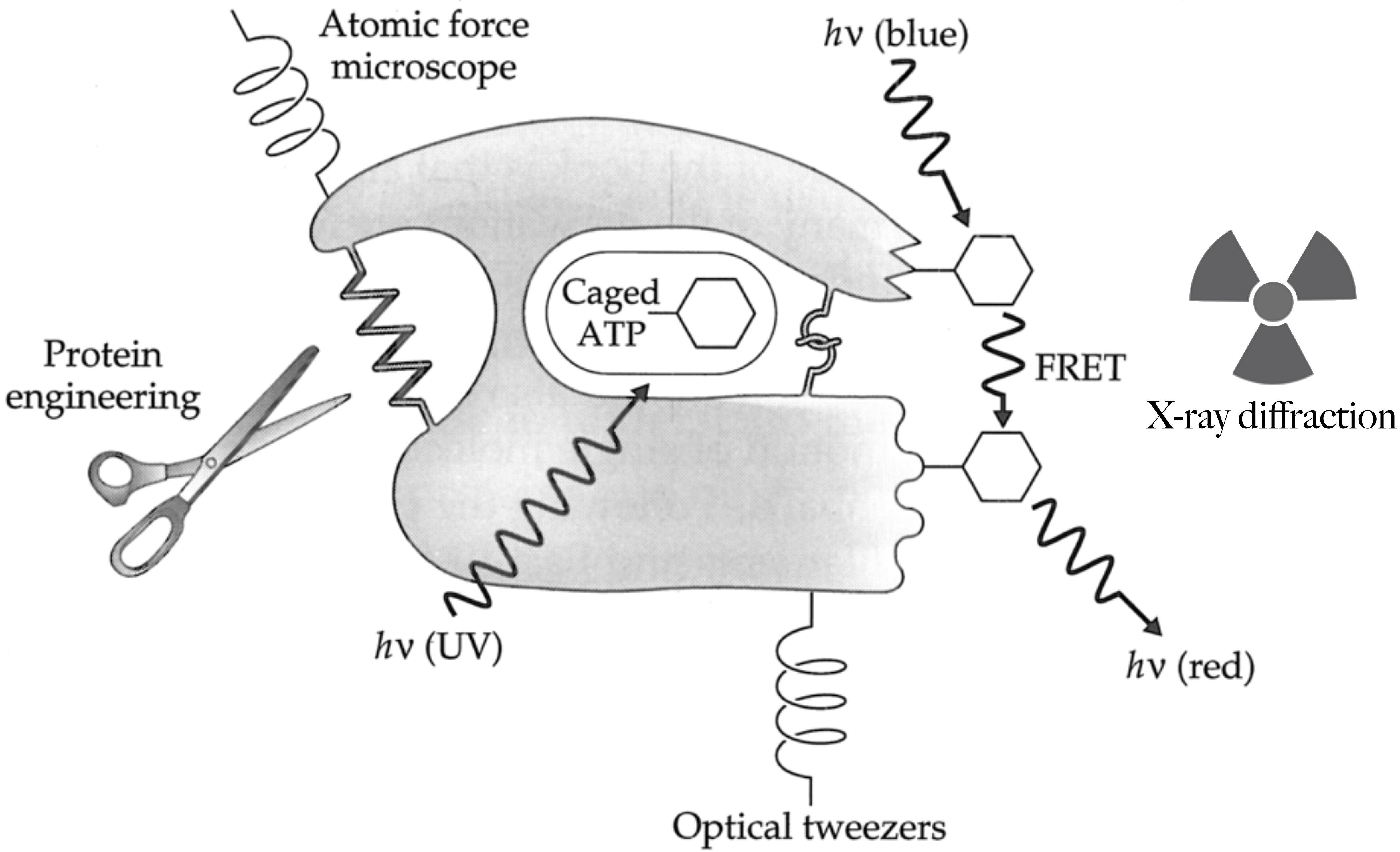

Image adapted from Howard, 2001