

## BIOLOGICAL FRAMEWORKS FOR ENGINEERS

### Session #15 [Cellular Motion and Shape Change]

#### General Objectives:

- ✓ Discuss the importance of cell movement and shape change
- ✓ Discuss mechanisms of cell motion

#### Central Framework:

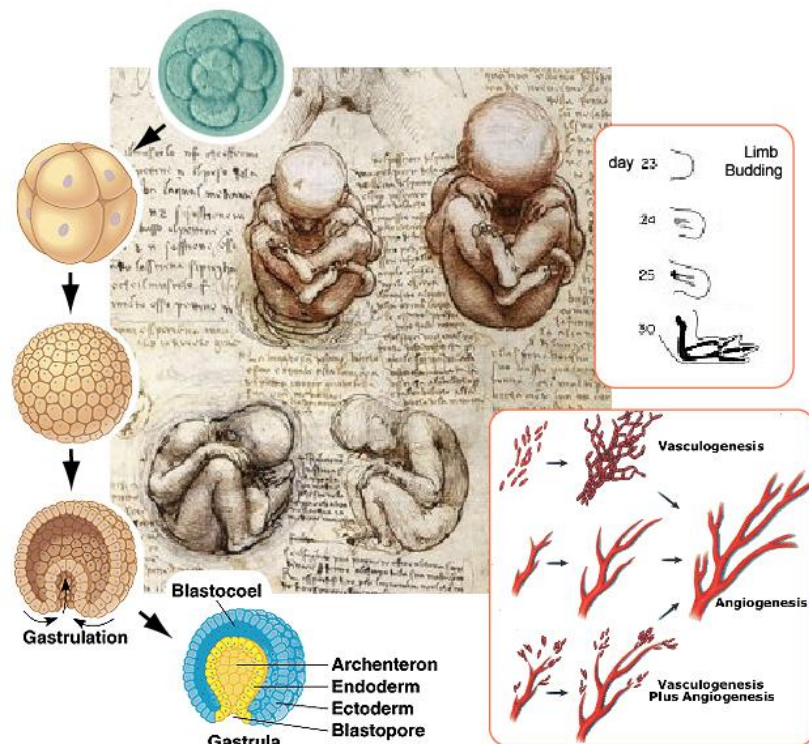
- ✓ Cellular movement and shape change is central to the life of an organism and is accomplished via different mechanisms.

#### Interactive Activity:

- ✓ Videos of cellular motion


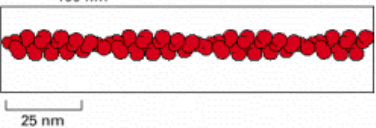

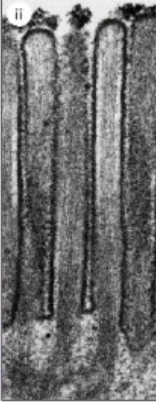
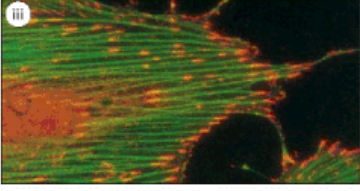
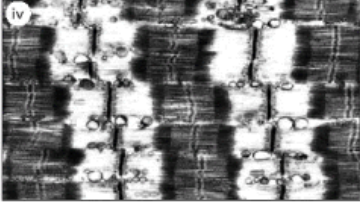
#### Session Outline:

##### A. Importance of Cell Movement



## B. Cytoskeletal Movement


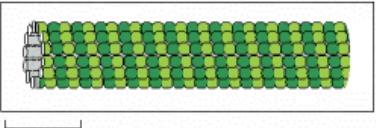

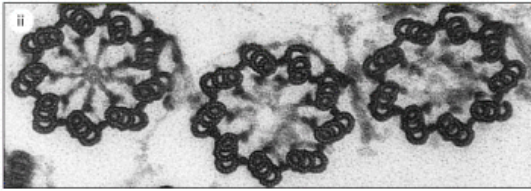
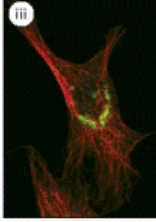
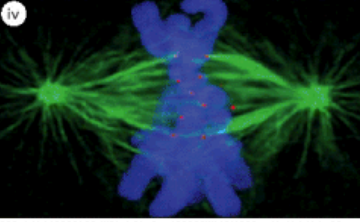
### ACTIN FILAMENTS

**Actin filaments** (also known as *microfilaments*) are two-stranded helical polymers of the protein actin. They appear as flexible structures, with a diameter of 5–9 nm, and they are organized into a variety of linear bundles, two-dimensional networks, and three-dimensional gels. Although actin filaments are dispersed throughout the cell, they are most highly concentrated in the *cortex*, just beneath the plasma membrane.

Micrographs courtesy of Roger Craig (i and iv); P.T. Matsudaira and D.R. Burgess (iii); Keith Burridge (iii).


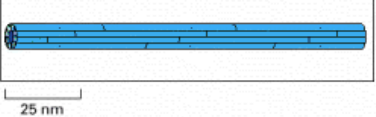

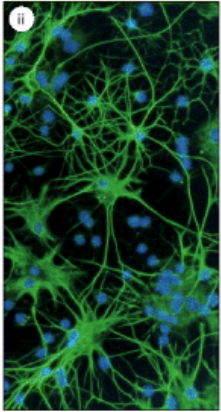
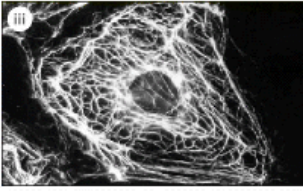
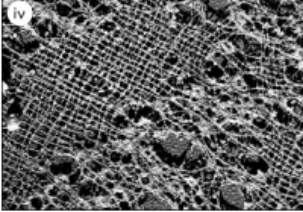
### MICROTUBULES

**Microtubules** are long, hollow cylinders made of the protein tubulin. With an outer diameter of 25 nm, they are much more rigid than actin filaments. Microtubules are long and straight and typically have one end attached to a single microtubule-organizing center (MTOC) called a *centrosome*, as shown here.

Micrographs courtesy of Richard Wade (i); D.T. Woodrow and R.W. Linck (ii); David Shima (iii); A. Desai (iv).

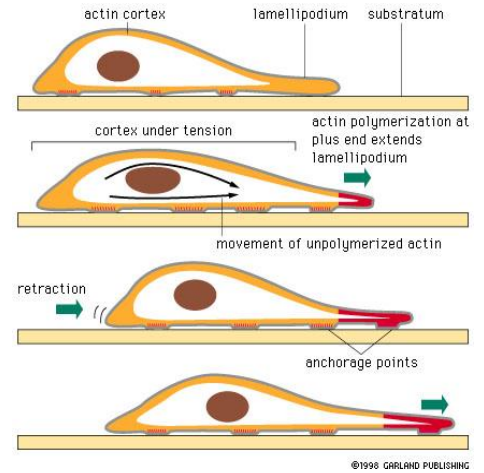
### INTERMEDIATE FILAMENTS

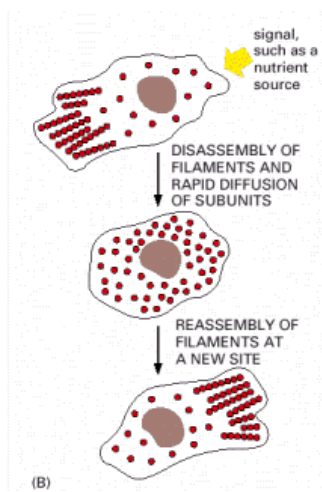
**Intermediate filaments** are ropelike fibers with a diameter of around 10 nm; they are made of intermediate filament proteins, which constitute a large and heterogeneous family. One type of intermediate filament forms a meshwork called the nuclear lamina just beneath the inner nuclear membrane. Other types extend across the cytoplasm, giving cells mechanical strength. In an epithelial tissue, they span the cytoplasm from one cell-cell junction to another, thereby strengthening the entire epithelium.

Micrographs courtesy of Roy Quinlan (i); Nancy L. Kedersha (ii); Mary Osborn (iii); Ueli Aebi (iv).

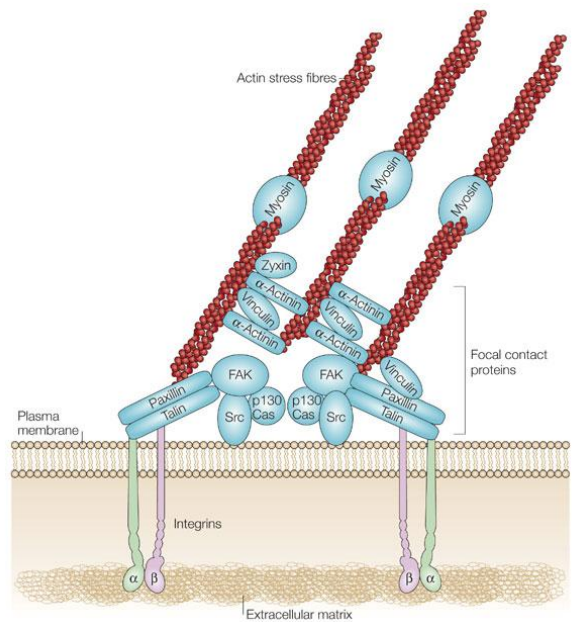
C. Mechanisms of Cell Movement



Polarization

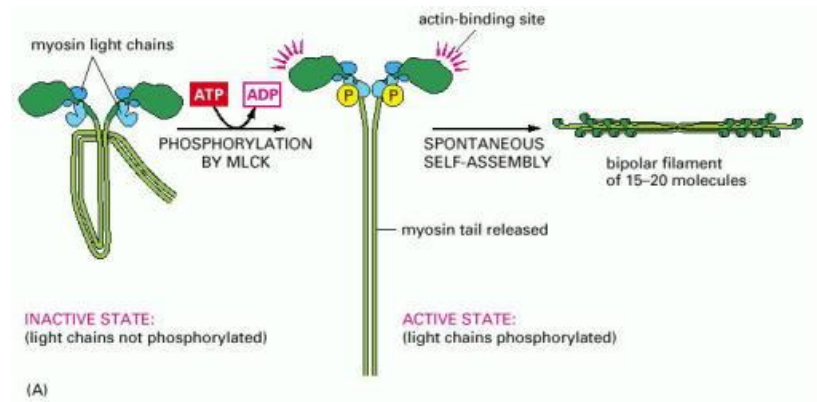
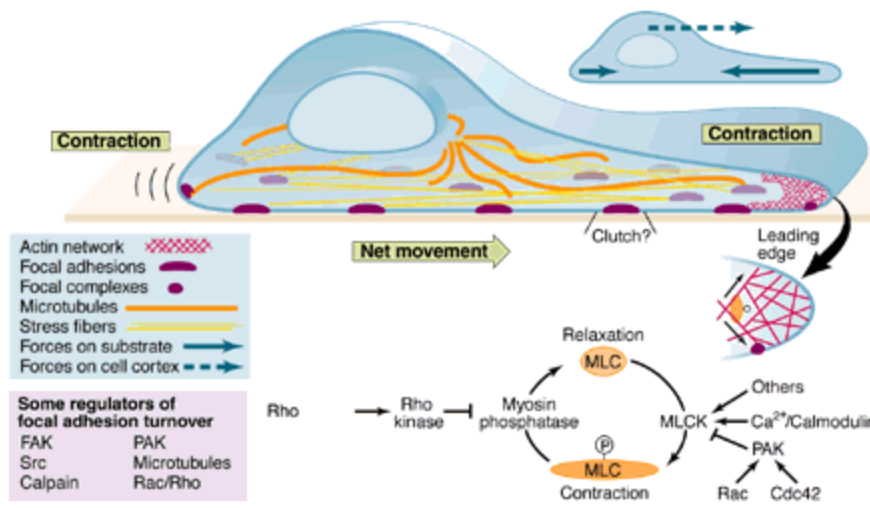
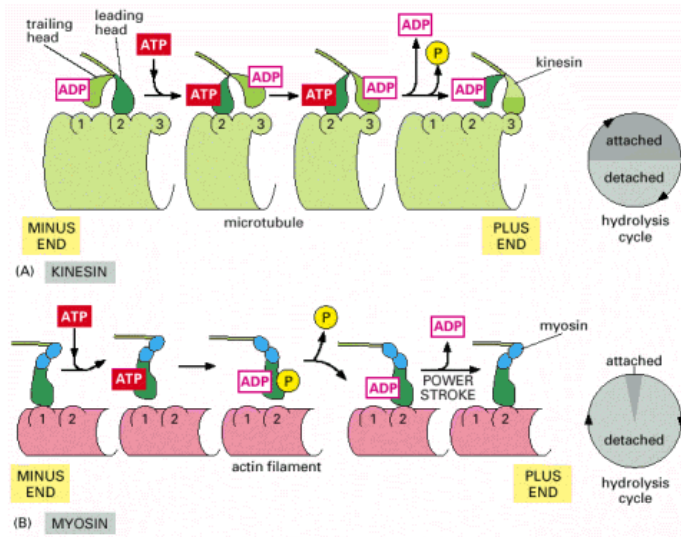


Focal Adhesions





Motor Proteins



Assembly / Disassembly

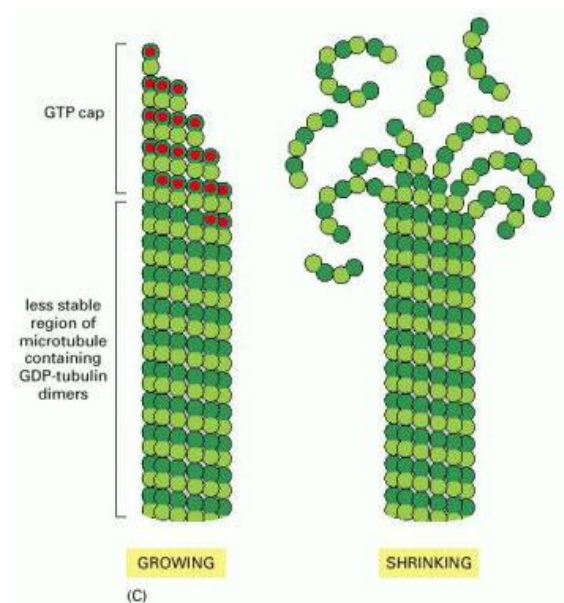
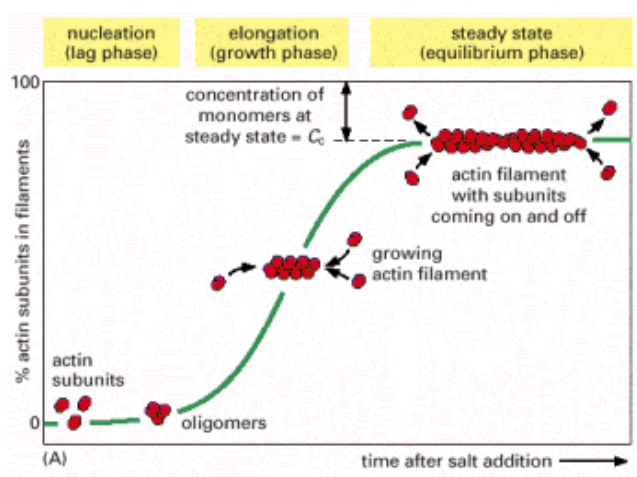
**ON RATES AND OFF RATES**

A linear polymer of protein molecules, such as an actin filament or a microtubule, assembles (polymerizes) and disassembles (depolymerizes) by the addition and removal of subunits at the ends of the polymer. The rate of addition of these subunits (called monomers) is given by the rate constant  $k_{on}$ , which has units of  $M^{-1} sec^{-1}$ . The rate of loss is given by  $k_{off}$  (units of  $sec^{-1}$ ).

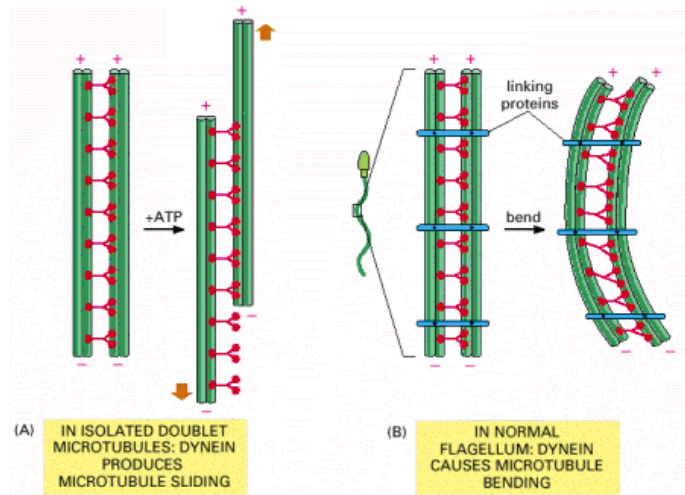
**PLUS AND MINUS ENDS**

The two ends of an actin filament or microtubule polymerize at different rates. The fast-growing end is called the **plus end**, whereas the slow-growing end is called the **minus end**. The difference in the rates of growth at the two ends is made possible by changes in the conformation of each subunit as it enters the polymer.

This conformational change affects the rates at which subunits add to the two ends. Even though  $k_{on}$  and  $k_{off}$  will have different values for the plus and minus ends of the polymer, their ratio  $k_{off}/k_{on}$ —and hence  $C_c$ —must be the same at both ends for a simple polymerization reaction (no ATP or GTP hydrolysis). This is because exactly the same subunit interactions are broken when a subunit is lost at either end, and the final state of the subunit after dissociation is identical. Therefore, the  $\Delta G$  for subunit loss, which determines the equilibrium constant for its association with the end, is identical at both ends: if the plus end grows four times faster than the minus end, it must also shrink four times faster. Thus, for  $C > C_c$ , both ends grow; for  $C < C_c$ , both ends shrink. The nucleoside triphosphate hydrolysis that accompanies actin and tubulin polymerization removes this constraint.



D. Flagella and Cilia



E. Muscle Cell Contraction

