Biophysics Seminar

(Mechanics of motor proteins and the cytoskeleton)

Chapter 7

Structure of Cytoskeletal Filaments

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Outline

- Introduction
- Structure of subunits
- Families of cytoskeletal proteins
Three major classes of cytoskeletal filaments:

- Actin filaments (microfilaments) ➔ Cable-like
- Intermediate filaments ➔ Rope-like
- Microtubules ➔ Pipe-like
Actin filaments:

- Diameter: \( \sim 6 \text{nm} \)
- Characteristic helical repeat period: 36nm (Apparent period).
Intermediate filaments:

- Diameter: ~ 10 nm
- have greater curvature, indicating that they are more flexible
Microtubules:
• Diameter: ~ 25nm
Table 7.1 Properties of the cytoskeletal proteins and filaments

<table>
<thead>
<tr>
<th>Material</th>
<th>Molecular mass of subunits (kDa)</th>
<th>Number of protofilaments</th>
<th>Diameter (nm)</th>
<th>Cross-sectional area (nm$^2$)$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actin</td>
<td>45</td>
<td>2</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>Tubulin</td>
<td>50</td>
<td>1–3</td>
<td>25</td>
<td>200</td>
</tr>
<tr>
<td>Intermediate filaments</td>
<td>40–180</td>
<td>8</td>
<td>~10</td>
<td>~60</td>
</tr>
<tr>
<td>Coiled coil</td>
<td>—</td>
<td>2</td>
<td>2</td>
<td>1.9</td>
</tr>
</tbody>
</table>

$^a$ Tubulin (Wade and Chretien, 1993); intermediate filaments (Heins et al., 1993).

$^b$ Assuming a density of 1.2 nm$^3$ per 1 kDa of protein, or a volume per amino acid of 0.14 nm$^3$. 
Structure of subunits

- Actin filaments
  - Actin monomer
- Intermediate filaments
  - Intermediate filament dimer
- Microtubules
  - αβ tubulin heterodimer
Structure of actin:

The structure of the actin monomer from skeletal muscle, elucidated by x-ray crystallography

- A globular protein
- Contains a deep cleft
Structure of tubulin:

The structure of the $\alpha\beta$–tubulin dimer from brain determined by electron microscopy
The tubulin dimer is also globular. It has translational symmetry.

Ref. [www.wikipedia.com]
Structure of intermediate filaments:

- Intermediate filament proteins are highly elongated.
- Each monomer is a long α-helix
- They do not bind nucleotides.

Ref. [www.wikipedia.com]
Families of cytoskeletal proteins

What do we actually mean with “actin”, “tubulin”, and “intermediate” family proteins?

Sources of protein variation:
I. Genetic polymorphism of individuals within one species
   The nucleotide sequence of a particular gene may vary from individual to individual. As a consequence, the encoded protein may vary in amino acid sequence. They do the same thing but they are not necessarily composed of the same things.
II. Genetic variations between species
Individuals from different species have similar organization of their genes. The genes are called orthologous and the encoded proteins are called orthologues proteins. When they have both the same organization and function between species, they are called homologues.

III. Gene duplication within individuals
When one species has two or more different genes located at different positions, but are very similar to each other, then the corresponding proteins are called isoforms or paralogues.
Actin:
- Over a dozen classes of proteins
- Actin related proteins (Arps)
  - Arp1 (at the core of the dynactin complex)
  - Arp2
  - Arp3

Tubulin:
- $\alpha, \beta, \gamma, \delta, \text{ and } \epsilon$

Intermediate Filament Proteins:
- More structurally diverse than actin and tubulin
- Keratin
- Vimentin
- Desmin
- Lamin
Thank you