Proteins
Proteins

Multipurpose molecules
Proteins

- Most structurally & functionally diverse group
- Function: involved in almost everything
  - enzymes (pepsin, DNA polymerase)
  - structure (keratin, collagen)
  - carriers & transport (hemoglobin, aquaporin)
  - cell communication
    - signals (insulin & other hormones)
    - receptors
  - defense (antibodies)
  - movement (actin & myosin)
  - storage (bean seed proteins)
Proteins

- **Structure**
  - **monomer** = *amino acids*
    - 20 different amino acids
  - **polymer** = *polypeptide*
    - protein can be one or more polypeptide chains folded & bonded together
    - large & complex molecules
    - complex 3-D shape

- Hemoglobin
- Rubisco
- Growth hormones
Amino acids

- **Structure**
  - central carbon
  - amino group
  - carboxyl group (acid)
  - R group (side chain)
    - variable group
    - different for each amino acid
    - confers unique chemical properties to each amino acid
      - like 20 different letters of an alphabet
      - can make many words (proteins)

Oh, I get it!

- amino = NH$_2$
- acid = COOH
Effect of different R groups:
Nonpolar amino acids

- nonpolar & hydrophobic

Why are these nonpolar & hydrophobic?
Effect of different R groups:

Polar amino acids

- polar or charged & hydrophilic

<table>
<thead>
<tr>
<th>Polar</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Serine (Ser)</td>
<td>Threonine (Thr)</td>
<td>Cysteine (Cys)</td>
<td>Tyrosine (Tyr)</td>
<td>Asparagine (Asn)</td>
<td>Glutamine (Gln)</td>
</tr>
<tr>
<td><img src="image" alt="Serine" /></td>
<td><img src="image" alt="Threonine" /></td>
<td><img src="image" alt="Cysteine" /></td>
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<td><img src="image" alt="Glutamine" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrically charged</th>
<th>Acidic</th>
<th>Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartic acid (Asp)</td>
<td>Glutamic acid (Glu)</td>
<td>Lysine (Lys)</td>
</tr>
<tr>
<td><img src="image" alt="Aspartic acid" /></td>
<td><img src="image" alt="Glutamic acid" /></td>
<td><img src="image" alt="Lysine" /></td>
</tr>
<tr>
<td>Basic Charged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine (Arg)</td>
<td>Histidine (His)</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Arginine" /></td>
<td><img src="image" alt="Histidine" /></td>
<td></td>
</tr>
</tbody>
</table>

Why are these polar & hydrophillic?
## Ionizing in cellular waters

### H+ donors

### Amino Acids with Acidic Side Chains and Their Derivatives

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Structure</th>
<th>Derivative</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartate</td>
<td><img src="image1" alt="Aspartate" /></td>
<td>Asparagine</td>
<td><img src="image2" alt="Asparagine" /></td>
</tr>
<tr>
<td>(Asp, D)</td>
<td><img src="image1" alt="Aspartate" /></td>
<td>(Asn, N)</td>
<td><img src="image2" alt="Asparagine" /></td>
</tr>
<tr>
<td>Glutamate</td>
<td><img src="image3" alt="Glutamate" /></td>
<td>Glutamine</td>
<td><img src="image4" alt="Glutamine" /></td>
</tr>
<tr>
<td>(Glu, E)</td>
<td><img src="image3" alt="Glutamate" /></td>
<td>(Glu, Q)</td>
<td><img src="image4" alt="Glutamine" /></td>
</tr>
</tbody>
</table>

AP Biology
## Ionizing in cellular waters

### H+ acceptors

<table>
<thead>
<tr>
<th>Amino Acids with Basic Side Chains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lysine</strong> (Lys, K)</td>
</tr>
<tr>
<td><img src="image" alt="Lysine structure" /></td>
</tr>
<tr>
<td><strong>Arginine</strong> (Arg, R)</td>
</tr>
<tr>
<td><img src="image" alt="Arginine structure" /></td>
</tr>
<tr>
<td><strong>Histidine</strong> (His, H)</td>
</tr>
<tr>
<td><img src="image" alt="Histidine structure" /></td>
</tr>
</tbody>
</table>

*Note: The structures show the chemical formulas and molecular models of Lysine, Arginine, and Histidine, highlighting their basic side chains.*
Sulfur containing amino acids

- **Form disulfide bridges**
  - covalent cross links between sulfhydryls
  - stabilizes 3-D structure

You wondered why perms smell like rotten eggs?

**H-S – S-H**
Building proteins

- **Peptide bonds**
  - covalent bond between NH$_2$ (amine) of one amino acid & COOH (carboxyl) of another
  - C–N bond

**Dehydration synthesis**

Amino acid 1

\[
\begin{align*}
\text{H—N—C—C—OH} \\
\text{H—N—C—C—OH}
\end{align*}
\]

Amino acid 2

\[
\begin{align*}
\text{H—N—C—C—OH} \\
\text{H—N—C—C—OH}
\end{align*}
\]

\[\text{H}_2\text{O} \rightarrow \text{H}_2\text{O}\]

Polypeptide chain

\[
\begin{align*}
\text{H—N—C—C—N—C—C—OH} \\
\text{H—N—C—C—N—C—C—OH}
\end{align*}
\]

**Peptide bond**
Building proteins

- Polypeptide chains have direction
  - **N-terminus** = NH$_2$ end
  - **C-terminus** = COOH end
  - repeated sequence (N-C-C) is the polypeptide backbone
    - can only grow in one direction
Protein structure & function

- Function depends on structure
  - 3-D structure
    - twisted, folded, coiled into unique shape

hemoglobin

pepsin

collagen
Primary (1°) structure

- Order of amino acids in chain
  - amino acid sequence determined by gene (DNA)
  - slight change in amino acid sequence can affect protein’s structure & its function
    - even just one amino acid change can make all the difference!

lysozyme: enzyme in tears & mucus that kills bacteria
Sickle cell anemia

I’m hydrophilic!

But I’m hydrophobic!

Just 1 out of 146 amino acids!

(a) Normal red blood cells and the primary structure of normal hemoglobin

(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin
Secondary (2°) structure

- “Local folding”
  - folding along short sections of polypeptide
  - interactions between adjacent amino acids
    - H bonds
      - weak bonds between R groups
  - forms sections of 3-D structure
    - α-helix
    - β-pleated sheet
Secondary (2°) structure
Tertiary (3°) structure

“Whole molecule folding”

- interactions between distant amino acids
  - hydrophobic interactions
    - cytoplasm is water-based
    - nonpolar amino acids cluster away from water
  - H bonds & ionic bonds
  - disulfide bridges
    - covalent bonds between sulfurs in sulfhydryls (S–H)
    - anchors 3-D shape
Quaternary (4°) structure

- **More than one polypeptide chain bonded together**
  - only then does polypeptide become functional protein
    - hydrophobic interactions

*collagen = skin & tendons*

*hemoglobin*
Protein structure (review)

1° amino acid sequence determined by DNA

2° R groups H bonds

3° R groups hydrophobic interactions disulfide bridges (H & ionic bonds)

4° multiple polypeptides hydrophobic interactions

1° Primary structure
2° Secondary structure
3° Tertiary structure
4° Quaternary structure
Protein denaturation

- Unfolding a protein
  - conditions that disrupt H bonds, ionic bonds, disulfide bridges
    - temperature
    - pH
    - salinity
  - alter 2° & 3° structure
    - alter 3-D shape
  - destroys functionality
    - some proteins can return to their functional shape after denaturation, many cannot

In Biology, size doesn’t matter, SHAPE matters!
EAT

Let's build some Proteins!
Ghosts of Lectures Past
(storage)
Chaperonin proteins

- Guide protein folding
  - provide shelter for folding polypeptides
  - keep the new protein segregated from cytoplasmic influences

1. An unfolded polypeptide enters the cylinder from one end.
2. The cap attaches to that end, causing the cylinder to change shape in such a way that it creates a hydrophilic environment for the folding of the polypeptide.
3. The cap comes off, and the properly folded protein is released.
Protein models

- Protein structure visualized by
  - X-ray crystallography
  - extrapolating from amino acid sequence
  - computer modelling

lysozyme