• A **polymer** is a large molecule with simple repeating units.
• The simple repeating units are called **monomers**.
• Polymer formulas are described with the formula for the monomer in parentheses with an $n$ as a subscript to indicate some large integer number. The $n$ varies even for a sample of the same polymer.

\[
\left( \text{repeated unit} \right)_n
\]

General polymer formula
• Natural polymers include
  – Starches with glucose monomers
  – Proteins with amino acid monomers

• Synthetic polymers are produced by chemists. Examples include, nylon, polyester, polyethylene, poly(vinyl chloride), polypropylene, and polystyrene.
Formation of Ala-Ser-Gly-Cys

Condensation reaction releases water

peptide bonds (amide functional groups)
Nylon Formation

\[
\text{Di-amine} \quad \text{Di-carboxylic acid}
\]

\[
\begin{align*}
\text{HO-} & \quad \text{OH} + \quad \text{H-N} & \quad \text{N-H} \\
\text{C-(CH}_2\text{)}_x & \quad \text{C-(CH}_2\text{)}_y & \quad \text{C-(CH}_2\text{)}_z & \quad \text{C-(CH}_2\text{)}_w & \quad \text{C} \quad \text{OH} + \quad \text{H-N} & \quad \text{N-H}
\end{align*}
\]

repeated many times

\[
\left(\text{N-(CH}_2\text{)}_x \quad \text{N-C-(CH}_2\text{)}_y \quad \text{C} \right)_n \quad \text{Nylon}
\]

\[
\begin{align*}
\text{Examples} & \quad \text{N-(CH}_2\text{)}_6 & \quad \text{N-C-(CH}_2\text{)}_4 & \quad \text{C} \\
\text{Nylon 66} & \quad \text{N-(CH}_2\text{)}_6 & \quad \text{N-C-(CH}_2\text{)}_8 & \quad \text{C} \\
\text{Nylon 610} & \quad \text{N-(CH}_2\text{)}_6 & \quad \text{N-C-(CH}_2\text{)}_4 & \quad \text{C}
\end{align*}
\]
Condensation polymers are polymers that are formed by condensation reactions in which two molecules are joined and a small molecule, such as water, is released.
Polyester Formation

\[ \text{Ethylene glycol} + \text{Terephthalic acid} \rightarrow \text{Poly(ethylene terephthalate)} \]

\[ \text{H-OCH}_2\text{CH}_2\text{O} + \text{HO-C} = \text{C-} + \text{C-} + \text{HO} \rightarrow \text{H} \]

\[ \text{repeated many times} \]

\[ n = \text{a large integer} \]
• Addition polymers are made from molecules that have the following general formula.

```
  W       X
  \   / \  / \\
  \ /  / \ / \
    C═C  
  /  \\
 Y   Z
```
Polyethylene Formation

$n$ \( \text{C} = \text{C} \quad \text{polymerization} \quad \left( \begin{array}{c} \text{H} \\ \text{H} \\ \text{H} \end{array} \right) \text{H} \text{H} \text{n} \)

Polyethylene

$\text{H} \quad \text{C} = \text{C} \quad \text{polymerization} \quad \text{R} - \text{O} - \text{C} - \text{C} - \left( \text{C} - \text{C} \right) - \text{C} - \text{C} - \text{C} - \left( \text{C} - \text{C} \right) - \text{C} - \text{C} - \text{C} - \text{C} - \text{O} - \text{R}$

or more simply

$\left( \begin{array}{c} \text{H} \\ \text{H} \\ \text{H} \end{array} \right) \text{H} \text{H} \text{n}$

polyethylene

$n = \text{a very large integer}$
High- and Low-Density Polyethylene

• If polyethylene is made under conditions that lead to mostly unbranched chains, the chains are able to pack together tightly forming high-density polyethylene, which is described by the acronym HDPE or sometimes PE-HD.

• If the polyethylene is made in a way that encourages branches, the molecules do not pack together as tightly, forming low-density polyethylene, which is described by the acronym LDPE or sometimes PE-LD.
Poly(vinyl chloride) or PVC
Addition Polymers

Polyethylene (HDPE or LDPE)

Polypropylene (PP)

Poly(vinyl chloride) (PVC)

Polystyrene (PS)
Recycling Codes

1. PET (or PETE)
2. HDPE (or PE-HD)
3. PVC (or V)
4. LDPE (or PE-LD)
5. PP
6. PS
7. OTHER