# Enzymes
# General

**Enzymes:**

- Proteins that catalyze biochemical reactions
- Eduard Buchner (1907) – Nobel prize – living cells not required for enzymes to function
- Accelerate chemical reactions 1-100 million times
- Enzyme Specificity
- Functionality is very specific (1 Enzyme catalyzes 1 Reaction)
- "-ase" ending

**4 Common Features**

- Speed up reactions
- Enzyme not altered in the reaction (reusable)
- Highly specific
- Reversible – One direction usually highly favored

# Terms

**Apoenzyme:** protein part

**Coenzyme:** non-protein part

Holoenzyme = apoenzyme + coenzyme

**Holoenzyme:** enzyme requiring Apo + Co to function

**Activator:** Inorganic part (metal ions)

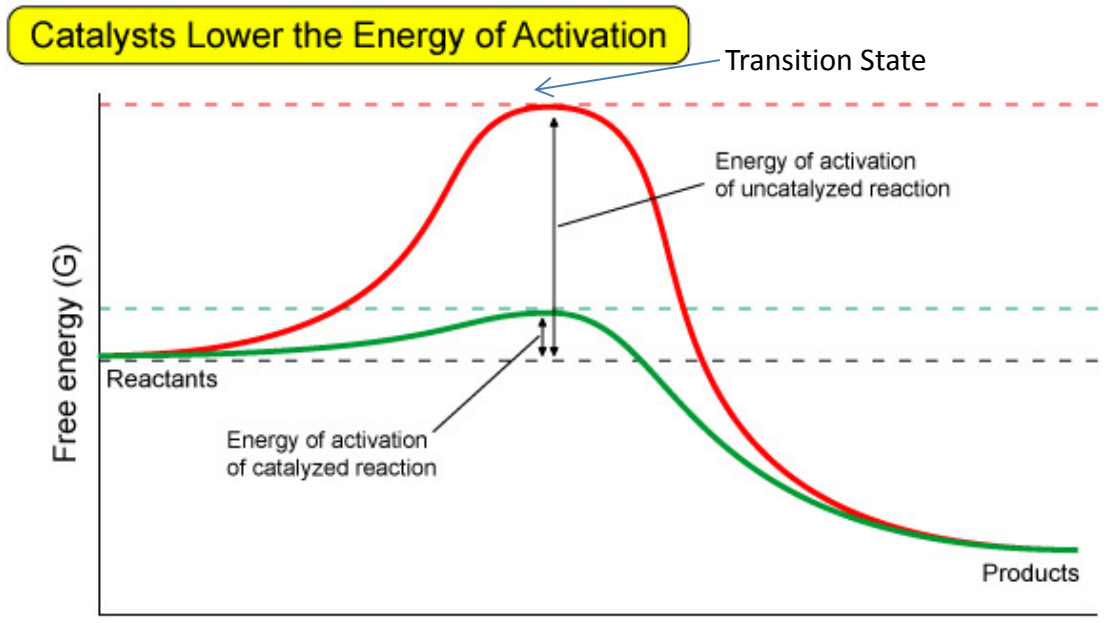
**Substrate:** substance acted on by enzyme

# 6 Classes of Enzymes

**6 Main Classes of Enzymes**

| Class | Function |
|---|---|
| 1. Oxidoreductases | Oxidation-Reduction reactions between 2 substrates |
| 2. Transferases | Transfer of functional group between 2 substrates |
| 3. Hydrolases | Hydrolysis of esters, carbohydrates and proteins |
| 4. Lysases | Removal of functional groups (not by hydrolysis) |
| 5. Isomerases | Interconversion of stereoisomers and structural isomers |
| 6. Ligases | Linkage of 2 compounds via breaking a phosphate anhydride bond in ATP |

# Reaction-Energy Diagram



# Reaction-Energy Terms

**Activation Energy (Barrier):**

- Energy required for a reaction to occur
- The larger the barrier the slower the rate

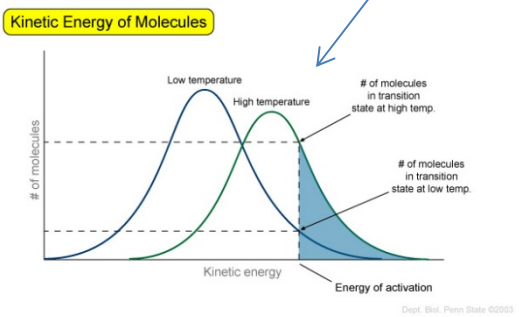
**Transition State:**

- Unstable intermediate state ½ way between reactants and products
- Catalysts work by altering the TS

# Increasing Reaction Rates

**3 Ways to Increase Reaction Rates**

| Method | Description |
|---|---|
| 1. Increase Reactant concentration | Increases number of molecules with enough energy to be able to react |
| 2. Increase Reaction Temperature | Increases number of energy of all molecules therefore increasing the number with E > AE |
| 3. Catalysts | Changes AE, allowing more molecules to react |

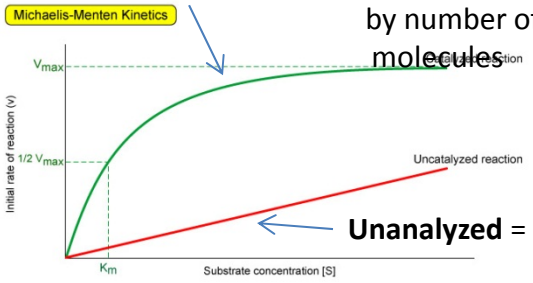


# Enzyme Kinetics

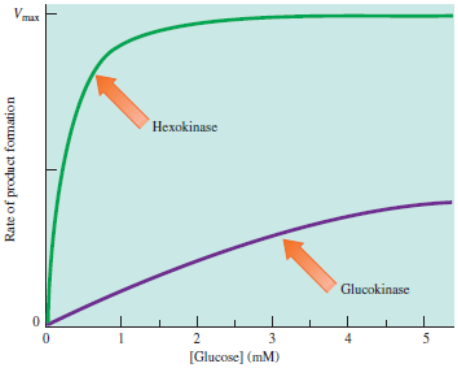
**Michaelis-Menton Plots:**

- Reaction Rate increases with increasing number of reactant molecules
- Enzymes tailored to meet specific metabolic needs

**Enzyme Catalyzed** = Maximum rate limited by number of catalyst molecules




**Unanalyzed** = linear response

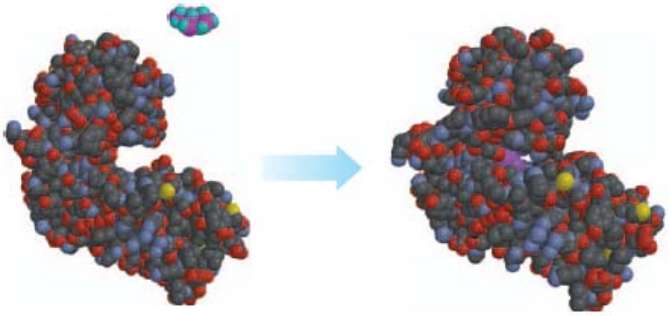


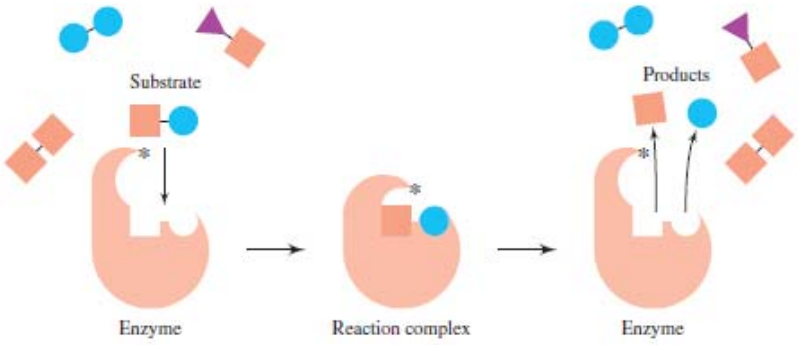

- Level of substrate concentration
  - Hexokinase = low [conc] = energy
  - Glucokinase = high [conc] = storage
- Rate of reaction **(turnover number)**
  - Catalase = fast – destroys toxins
  - Chrymotrypsin = slow - digestion

# Enzyme Active Site

**Enzyme Active Site:**

- Area where catalysis occurs
- Small (1-5%) of total surface area
- Very Specific: 1 enzyme = 1 reaction (Specificity)





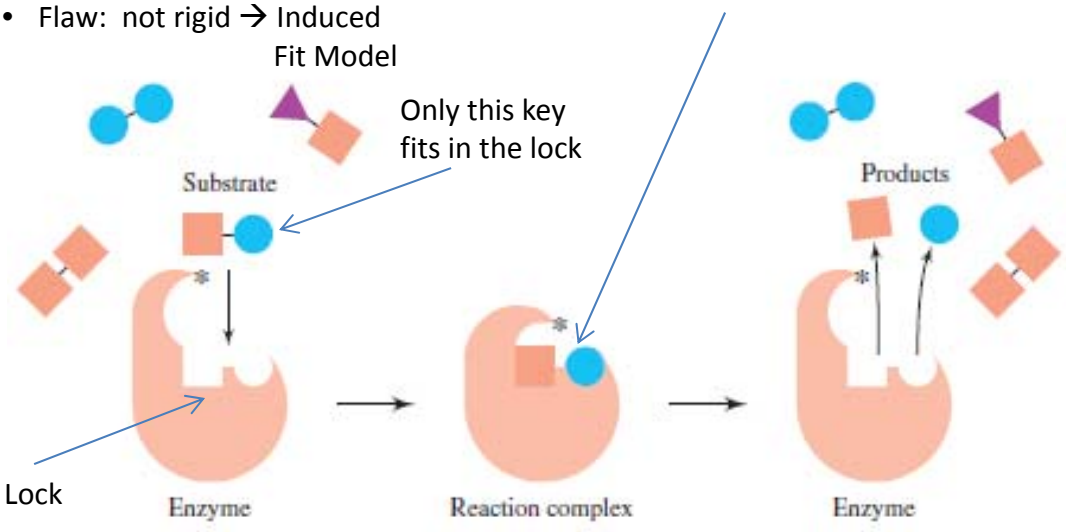
# Lock-and-Key Hypothesis and Induced-Fit Model

**Lock-and-Key Hypothesis:**

- Substrate (Key) fits into the Enzyme (Lock)
- One key, One lock
- Flaw: not rigid → Induced Fit Model

**Induced-Fit Model:**

- Active site is flexible
- Enzyme can change state to bind/catalyze a reaction



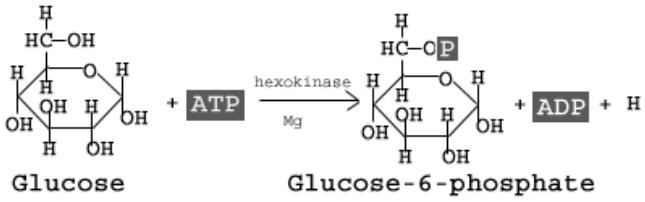
# Proximity Catalysis and Productive Binding

**Proximity Catalysis:**

- Enzyme holds the reactants in close proximity

**Productive Binding:**

- Enzyme holds reactants in proper orientation for reaction to occur




P = phosphate group

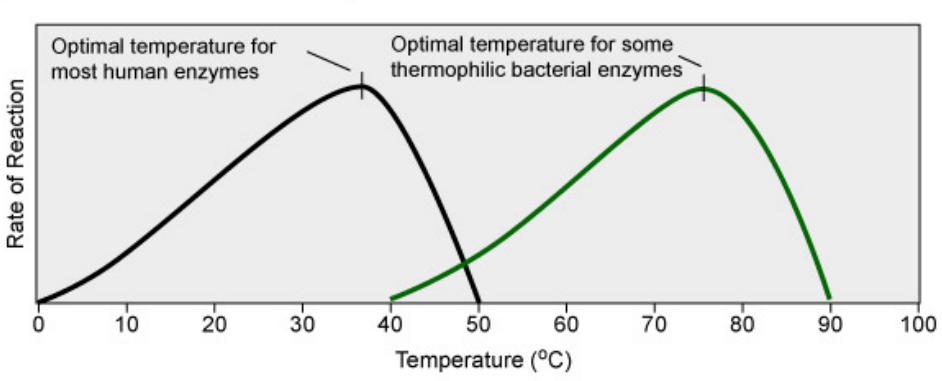
**Example: Glucose → Glucose-6-Phosphate**

- Many parts required (Substrate + ATP + $Mg^{+2}$ ion. (Proximity Catalysis)
- Phosphate only added to #6 carbon (Productive Binding)

# Temperature

**Effect of Temperature on Catalysts:**

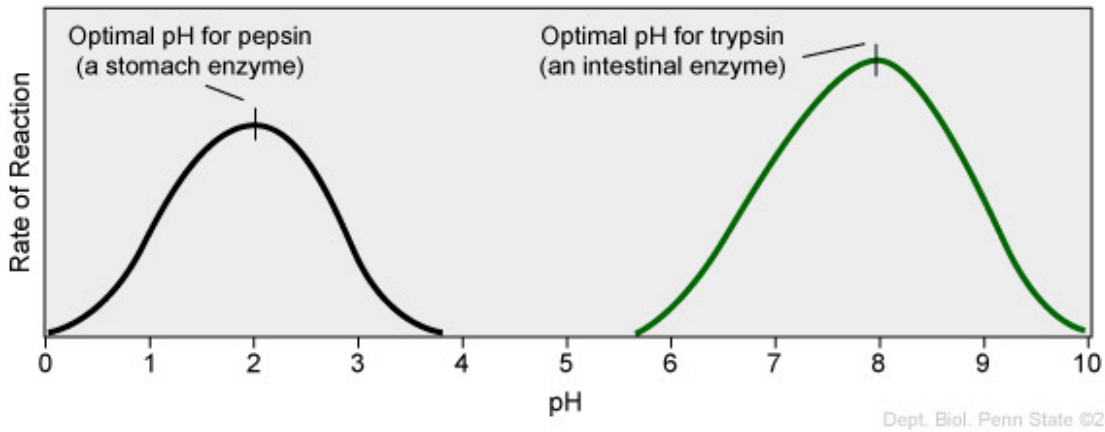
- Any change that effects protein structure effects an enzymes catalytic ability
- Low Temp = Few molecules have AE required to react (+ denaturation)
- High Temp = Enzymes denature



# pH

**Effect of pH on Catalysts:**

- Any change that effects protein structure effects an enzymes catalytic ability
- Charge of –COOH and $–NH_2$ effected by pH → change in 2°/3°/4° structure



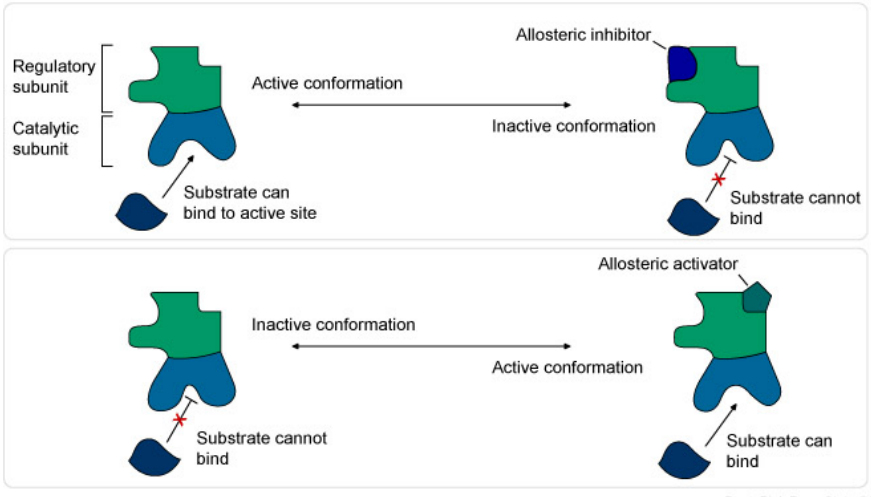
# Enzyme Regulation

**Allosteric Regulation:**

- Active domain – catalyzes the reaction
- Regulatory domain – modulates activity
- Activator/inhibitors bind to Regulatory domain and change the catalytic ability of enzyme

**Covalent Modification:**

- Functional groups bonded to enzyme
- Ex: Phosphorylation



# Feedback Inhibition
# Feedforward Activation

**Feedforward Activation**

- Excess of beginning R/P increases the reaction rate of a later step

- **Feedback Inhibition**

Excess of final product decreases the reaction rate of an earlier step