

Course Slides

For note-taking and problem solving
during the Integrated Content Review



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Read this

- Before beginning this video course, take a couple of days to get the bird's eye view on the shape of the project. Look at the bold headings, figures and formulas in your MCAT bookset from cover to cover. Do this with every book from physics to biology. Visit every topic and show it to yourself, one big cycle before you start the course. Ask yourself 'What is the world of this topic?' 'What are the main learning goals?' Then move on as if it were a scouting expedition.
- After you begin the course, use Kaplan or Berkeley Review to prepare a basic understanding of any topic before watching our particular video on that topic. Study their teaching materials on the topic and do some bread-and-butter problems from them before watching the video here. You will need to skip around in the books to follow the course. In other words, do basic homework first before watching my videos. That is how my students would do it. They had homework before the session. The course videos were painstakingly edited from real-world one-on-one sessions in order that they could be more lively and interactive for people watching than ordinary MCAT videos. Pauses are built into the discussions for you to answer the questions in the videos.
- The videos of this MCAT course ARE NOT standalone topic videos you can watch in any order. This is a spiraling course. In a spiraling curriculum design, ideas are introduced early and returned to with greater complexity.
- This content review does not have videos beyond the molecular level in biology. In other words, some topics in cell biology and human physiology were self-studied by my students and quizzed by me. My students started early and performed spaced repetition study cycles with the cell biology and physiology.
- It can take time to get used to the scale of MCAT science. As your knowledge-base takes on better completeness and structure, you will begin to see how reading MCAT passages is a kind of performance.

Spiraling Content Review

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Physics

MECHANICS

Kinematics
Newton's Laws
Work, Energy, and Power
Harmonic Motion
Elastic Properties of Solids
Fluid Mechanics

WAVES

Waves

GRAVITATION

Gravitation

THERMODYNAMICS

Heat & Temperature
The Ideal Gas and Kinetic Theory
The First Law of Thermodynamics
The Second Law of Thermodynamics and Heat Engines

ELECTRICITY & MAGNETISM

Electricity
DC Current
Magnetism

LIGHT & OPTICS

The Properties of Light
Geometric Optics
Wave Optics

MODERN PHYSICS & NUCLEAR PHYSICS

Modern Physics
Nuclear Physics

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Kinematics

Newton's Laws

Work, Energy, & Power

Electricity

Ideal Gas & Kinetic Theory

Atomic Theory

Periodic Properties

The Chemical Bond

Intermolecular Forces

Organic Functional Groups

Stereochemistry

Temperature & Heat Flow

1st Law of Thermodynamics

Stoichiometry

Thermochemistry

2nd Law & Heat Engines

Chemical Thermodynamics & Equilibrium

The States of Matter

Organic Physical Properties

Solutions

Acids & Bases

Organic Reaction Mechanisms

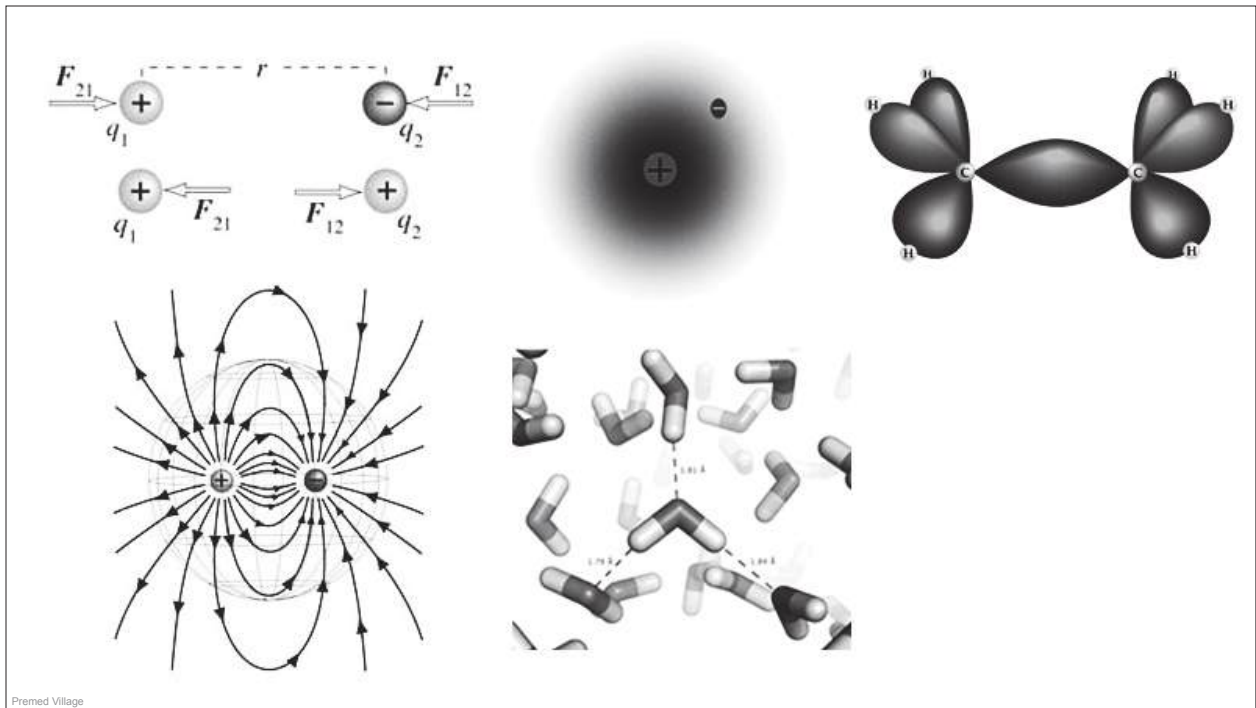
Amino Acids & Protein Structure

Fluid Mechanics

Deformations, Oscillations & Vibrations

Waves

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KINEMATICS

Displacement, Velocity and Acceleration

$$\bar{v} = \frac{x - x_0}{\Delta t}$$

$$\bar{a} = \frac{v - v_0}{\Delta t}$$

The Kinematics of Constant Acceleration

$$v = v_0 + at$$

$$x - x_0 = \frac{1}{2}(v + v_0)t$$

$$x - x_0 = v_0t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

Motion in Two Dimensions

$$a_r = \frac{v^2}{r}$$

Uniform Circular Motion

Projectile Motion

$$v_y = v_{y0} - gt$$

$$v_x = v_{x0} = \text{constant}$$

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Four Equations of Kinematics for Constant Acceleration

$$v = v_0 + at$$

$$x - x_0 = \frac{1}{2}(v + v_0)t$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = v_0t + \frac{1}{2}at^2$$

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DYNAMICS

Newton's Laws of Motion

$$\Sigma F = 0 \text{ then } a = 0$$

$$F = ma$$

$$F_{12} = -F_{21}$$

Free Body Diagrams

Friction Force

$$F_s \leq \mu_s N$$

$$F_k = \mu_k N$$

The Fundamental Forces

$$F = G \frac{m_1 m_2}{r^2}$$

Gravitation

$$F = k \frac{q_1 q_2}{r^2}$$

$$F = qB v \sin \theta$$

Electromagnetism

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WORK, ENERGY, AND POWER**Work**

$$W = (F \cos \theta)s$$

Kinetic Energy

$$K = \frac{1}{2}mv^2$$

Potential Energy

$$U = mgh$$

$$U_{\text{spr}} = \frac{1}{2}kx^2$$

$$U_e = k \frac{q_1 q_2}{r}$$

Conservation of Energy

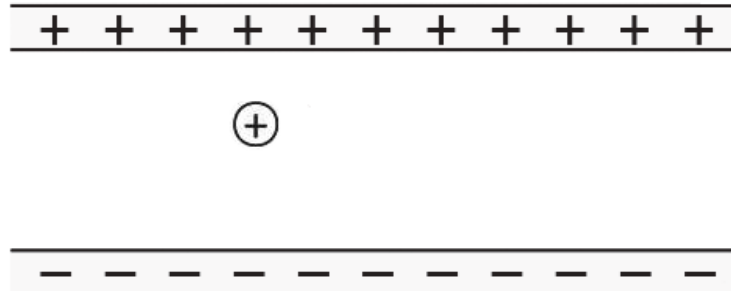
$$K_i + U_i = K_f + U_f$$

Power

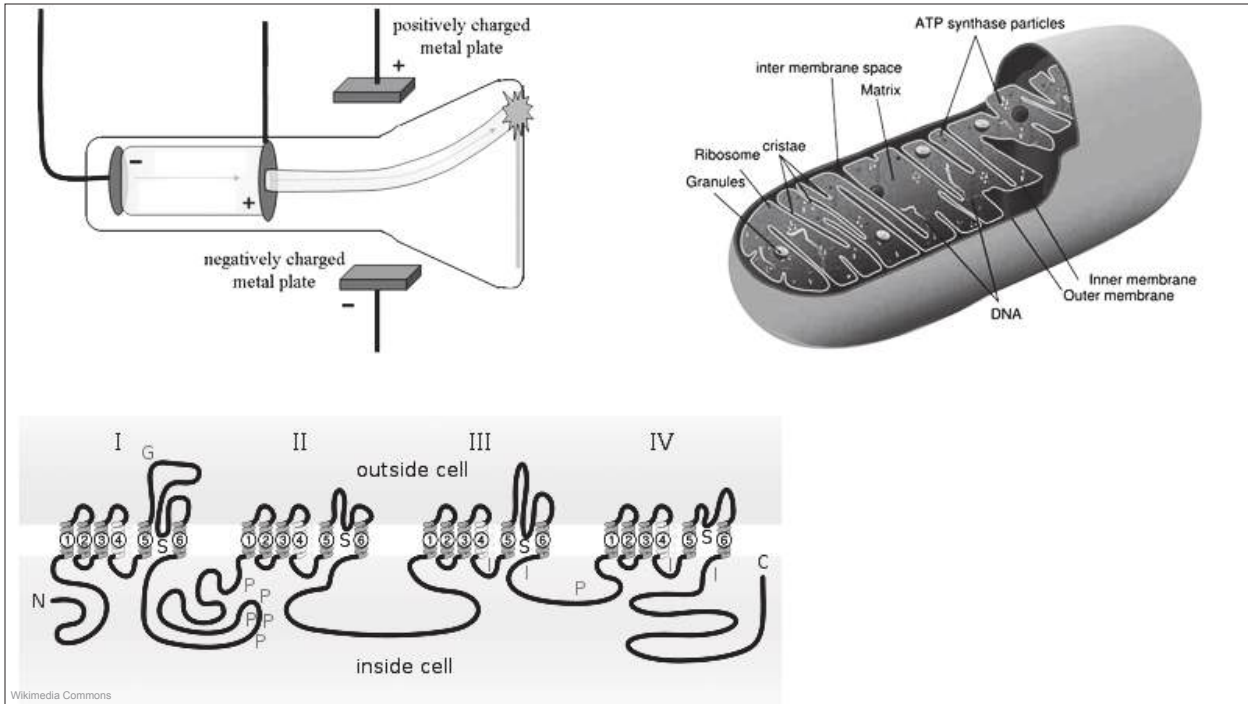
$$\bar{P} = \frac{\Delta W}{\Delta t}$$

$$P = Fv$$

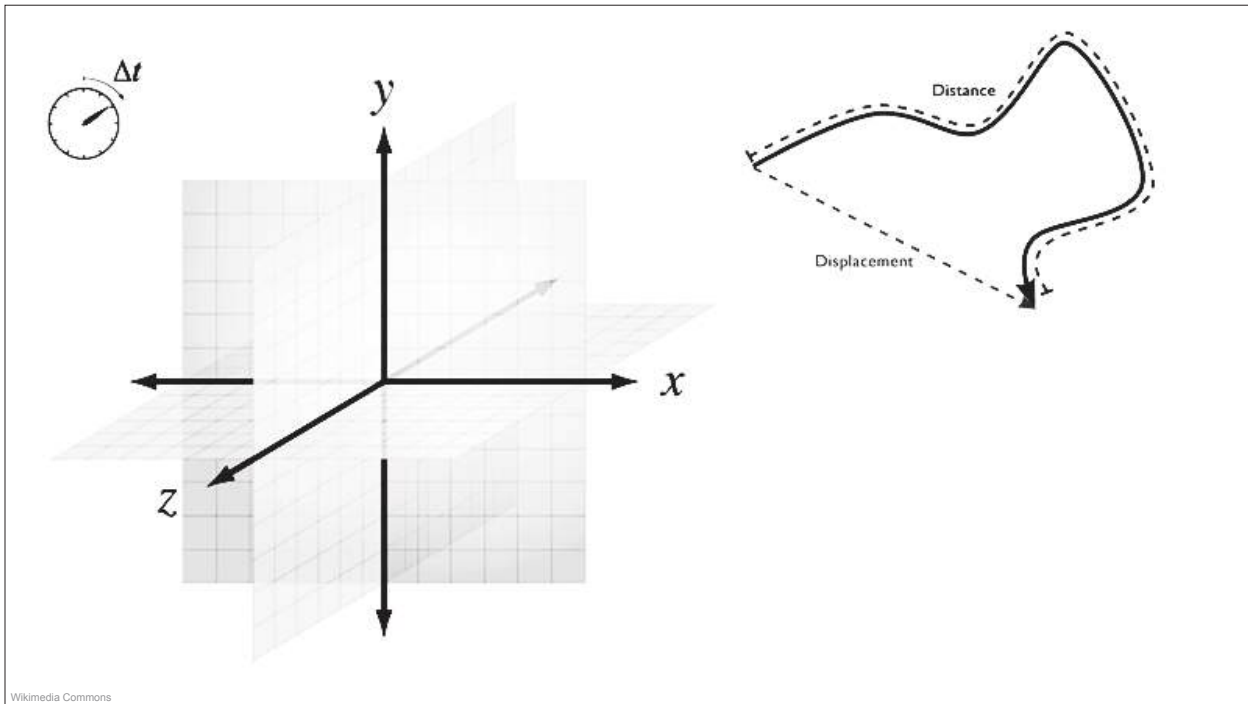
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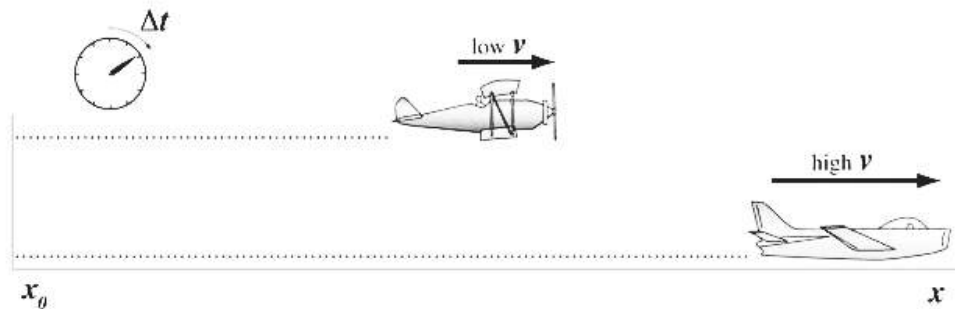
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Velocity

$$\bar{v} = \frac{x - x_0}{\Delta t}$$

$$x - x_0 = \bar{v} \Delta t$$

\bar{v} = average velocity
 $x - x_0$ = change in position
 Δt = change in time



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Acceleration

$$\bar{a} = \frac{v - v_0}{\Delta t}$$

$$v - v_0 = \bar{a} \Delta t$$

\bar{a} = average acceleration
 $v - v_0$ = change in velocity
 Δt = change in time

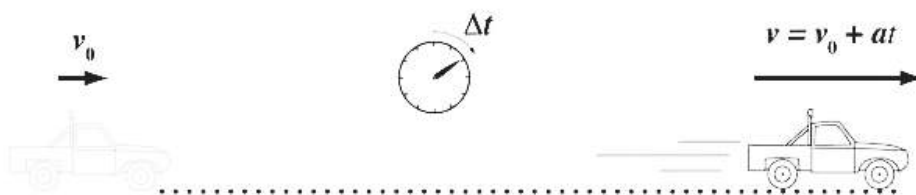


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Velocity as a Function of Time

$$v = v_0 + at$$

- v = velocity
- v_0 = initial velocity
- a = acceleration (constant)
- t = time

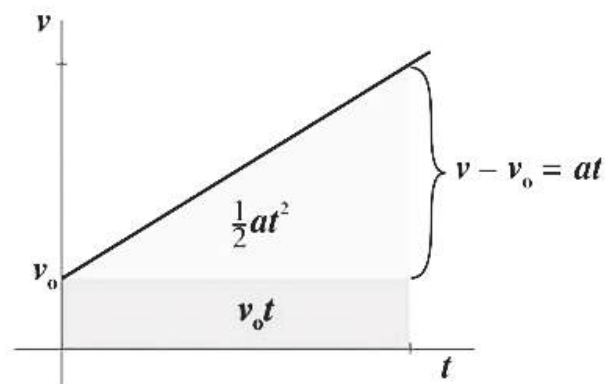


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Displacement Equation

$$x - x_0 = v_0 t + \frac{1}{2} at^2$$

- $x - x_0$ = change in position
- v_0 = initial velocity
- t = change in time
- a = acceleration (constant)



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The tallest apple tree in the world is 12 meters tall.

Approximately how long would it take an apple falling from the highest branch to hit the ground?

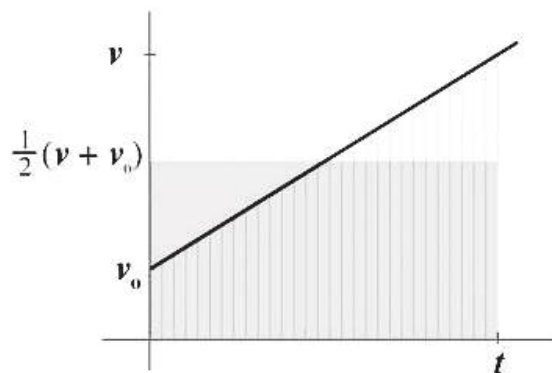
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Displacement is the Product of Average Velocity and Time

$$x - x_0 = \frac{1}{2}(v + v_0)t$$

constant acceleration

$x - x_0$ = change in position
 v = velocity
 v_0 = initial velocity
 t = change in time



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Velocity as a Function of Displacement

$$v^2 = v_0^2 + 2a(x - x_0)$$

constant acceleration

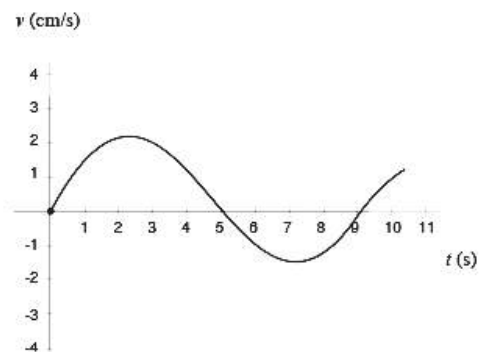
- v = velocity
- v_0 = initial velocity
- a = acceleration (constant)
- $x - x_0$ = change in position (displacement)



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The accompanying graph was derived from measurements of blood velocity within the port of a hemodialysis catheter carried out over ten seconds. Which of the following is the nearest approximation of the average acceleration of a volume element within the blood during that time period?

- A. 0.001 m/s^2
- B. 0.01 m/s^2
- C. 0.1 m/s^2
- D. 10 m/s^2



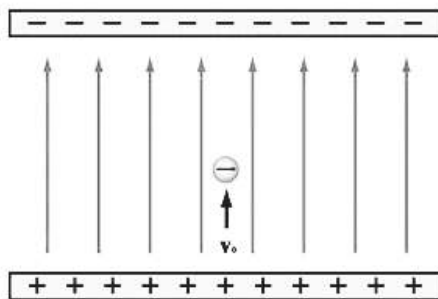
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Discounting air friction, approximately how far will the boulder have fallen in 3 seconds?

- a. 20 m
- b. 45 m
- c. 30 m
- d. 90 m



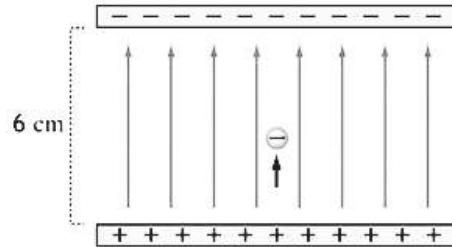
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The application of heat causes emission of an electron by the positive plate of a parallel plate capacitor. The electron moves into the uniform electric field between the plates with an initial velocity of 2.0×10^3 m/s perpendicular to the plate. The electron undergoes an acceleration of magnitude 4.0×10^7 m/s² perpendicular to the plates within the electric field. How long is the electron in flight?

- a. 2.0×10^{-5} s
- b. 5.0×10^{-5} s
- c. 1.0×10^{-4} s
- d. 4.0×10^{-4} s



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Projectile Motion

$$v_x = v_{x0} = \text{constant}$$

$$v_y = v_{y0} - gt$$

v_x = horizontal velocity

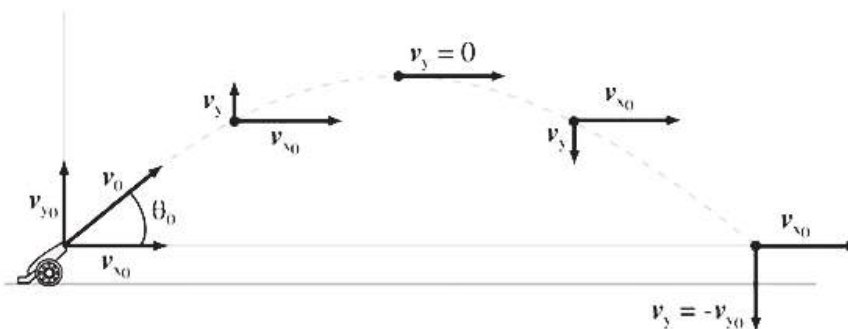
v_y = vertical velocity

v_{x0} = initial horizontal velocity

v_{y0} = initial vertical velocity

g = acceleration due to gravity (9.8 m/s^2)

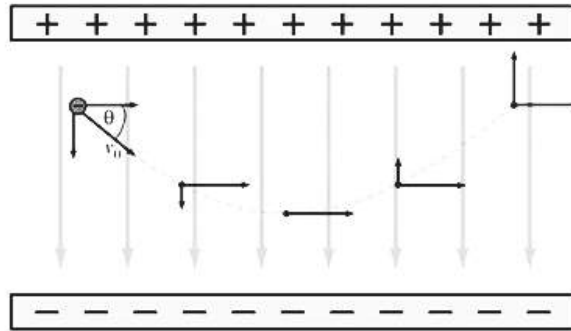
t = time



The shape of the path of projectile motion is a parabola.

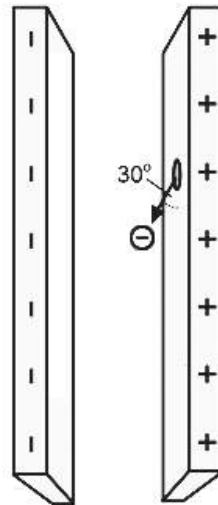
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A charged particle experiences constant acceleration within a region occupied by a uniform electric field. A negatively charged particle moves into a uniform electric field with an initial velocity at an angle, θ , to the electric field. What kind of kinematics results?







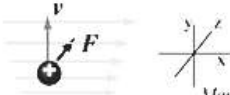
- a. uniform circular motion
- b. constant velocity
- c. constant speed
- d. parabolic motion

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The Classical Fundamental Forces

Gravitation	Electromagnetism
 <p><i>Gravitational force between two masses</i></p> $F = G \frac{m_1 m_2}{r^2}$	 <p><i>Electrostatic force between two point charges</i></p> $F = k \frac{q_1 q_2}{r^2}$
 <p><i>Gravitational force on a mass within the uniform gravitational field on the earth's surface</i></p> $W = mg$	 <p><i>Electrostatic force on a point charge within a uniform electric field</i></p> $F = Eq$
	 <p><i>Magnetic force on a point charge moving through a magnetic field</i></p> $F = qB v \sin \theta$

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Newton's First Law

An isolated object at rest will remain at rest. An object moving with uniform velocity will maintain that motion unless acted on by a net external force.

Newton's Second Law

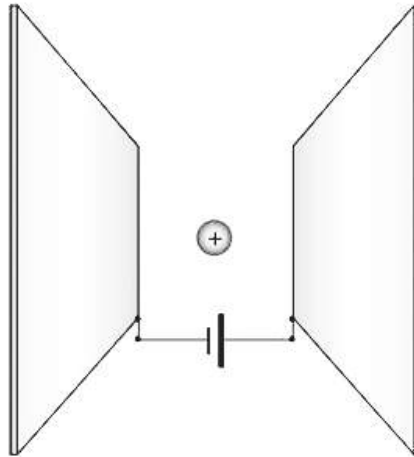
$$\mathbf{F} = m\mathbf{a}$$

Newton's Third Law

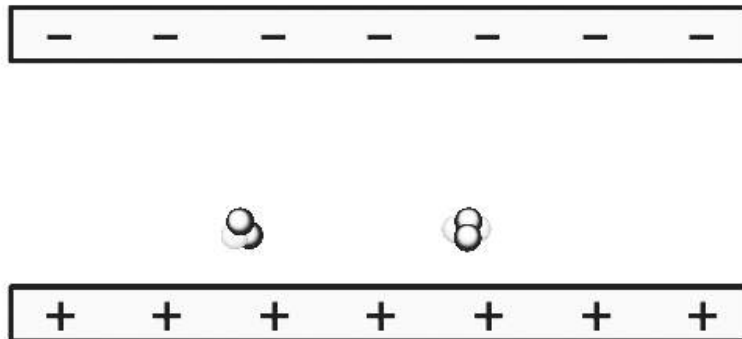
$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

A motionless, 20 kg, positively charged sphere is suspended in a weightless environment. An externally applied electric field subjects the sphere to a 10 N force for 4 seconds. At the end of four seconds, what is the speed of the sphere?

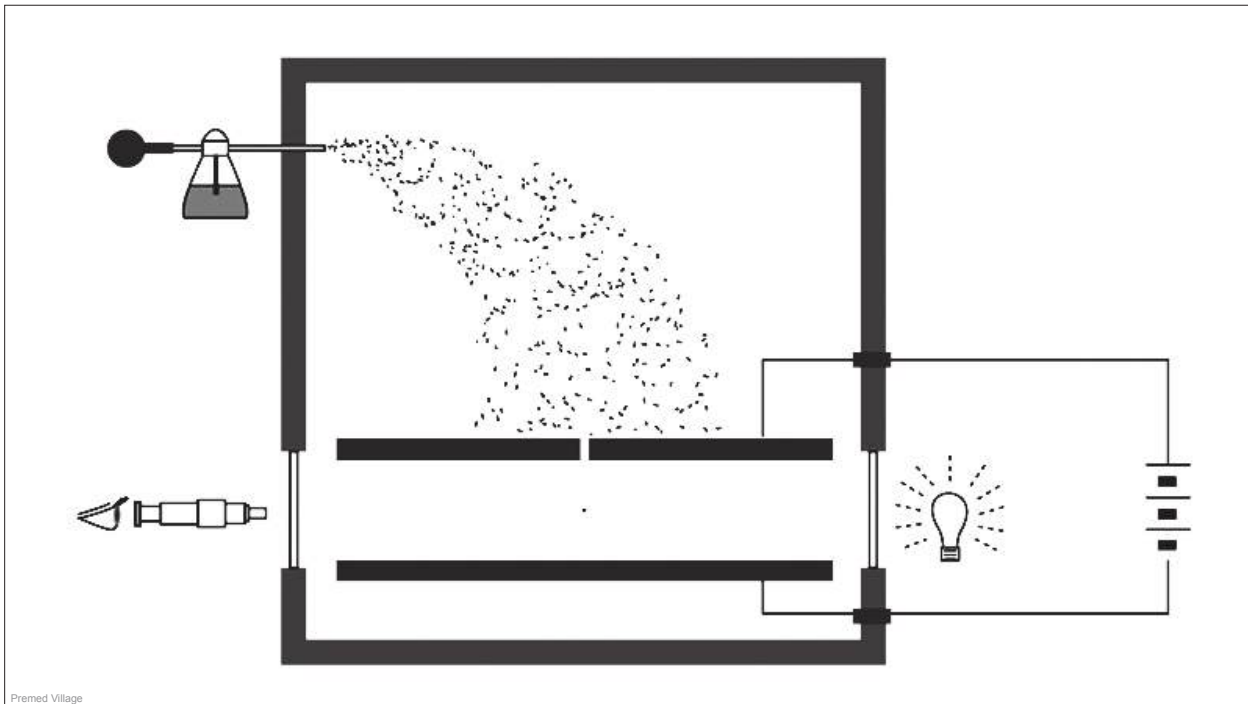
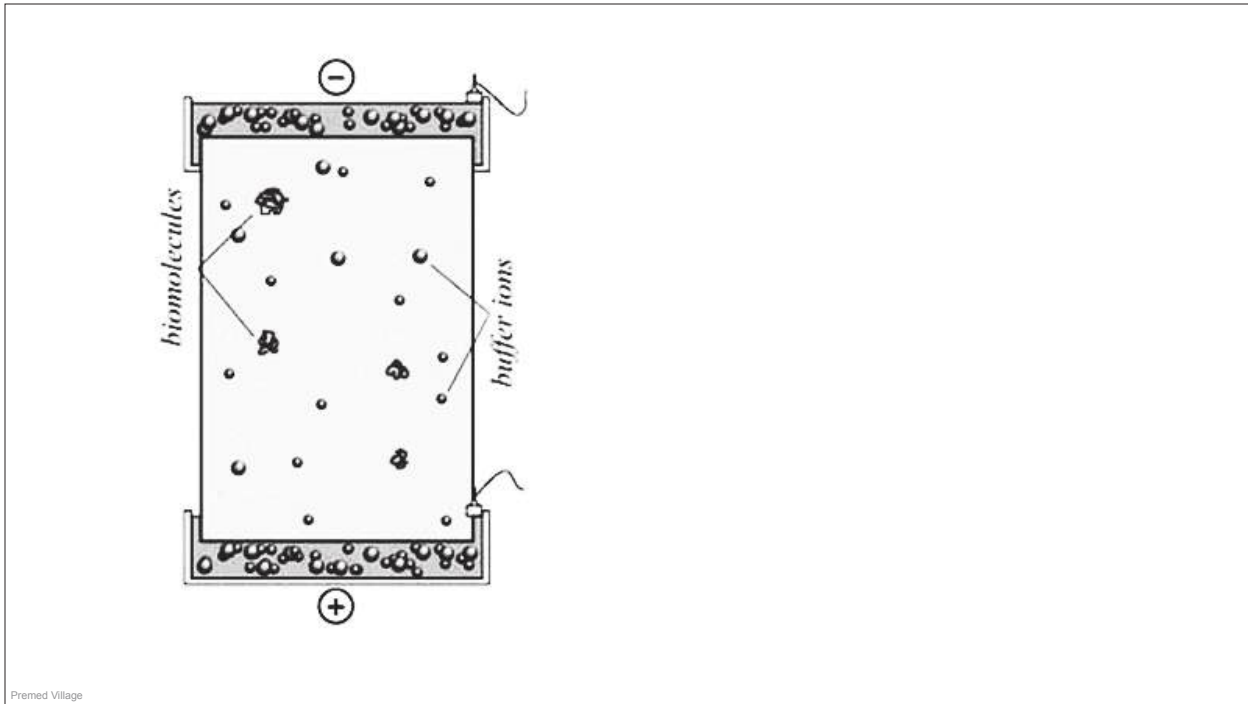
- a. 0.08 m/s
- b. 0.5 m/s
- c. 2.0 m/s
- d. 8.0 m/s



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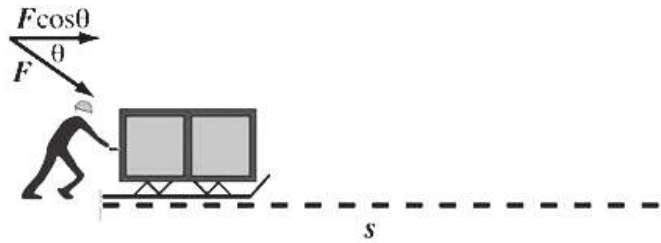
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Mechanical Work

$$W = (F \cos \theta)s$$

Work equals force parallel to the displacement times the displacement.



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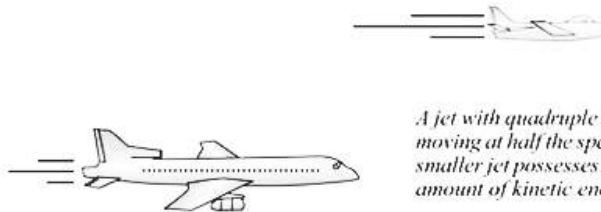
Kinetic Energy

$$K = \frac{1}{2}mv^2$$

K = kinetic energy

m = mass

v = speed



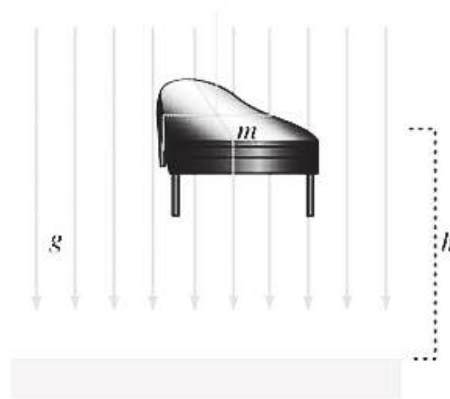
A jet with quadruple the mass moving at half the speed of the smaller jet possesses an equal amount of kinetic energy.

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Potential Energy

$$U = mgh$$

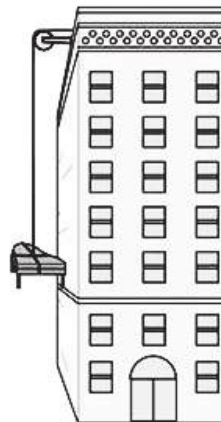
U = potential energy
 m = mass
 g = acceleration due to gravity (9.8 m/s^2)
 h = height



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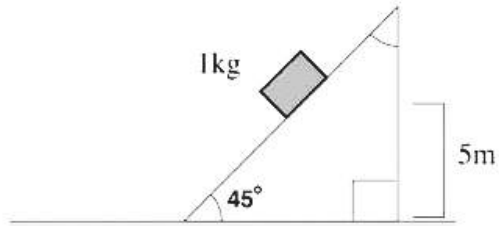
What is the minimum work required to raise a 500 kg piano from street level to a window at 20m elevation?

- a. 10,000 J
- b. 25000 J
- c. 100,000 J
- d. 2.0×10^5 J



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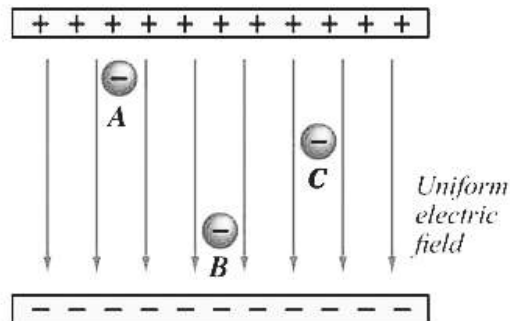
A 1kg block is released from a vertical height of 5m to begin sliding down a frictionless 45° inclined plane. What is the speed of the block when it reaches the base of the plane?



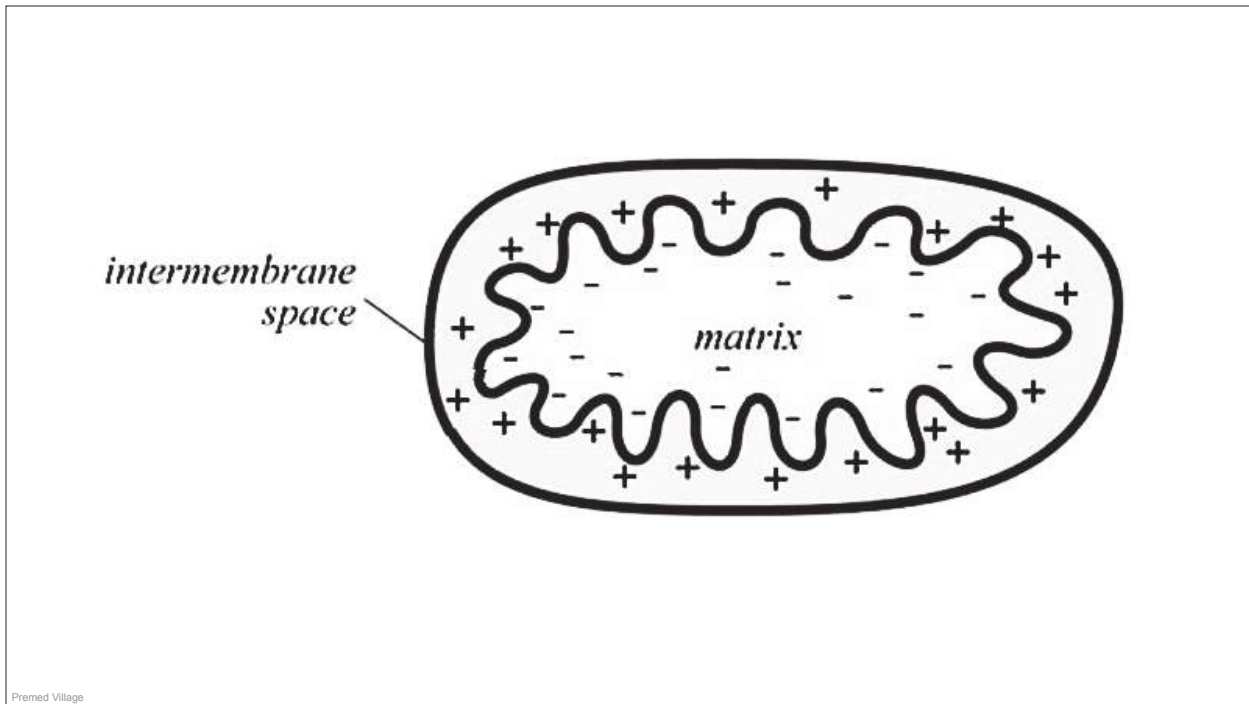
- a. 1.7 m/s
b. $(5)(\sqrt{2})$ m/s
c. 10 m/s
d. 45 m/s

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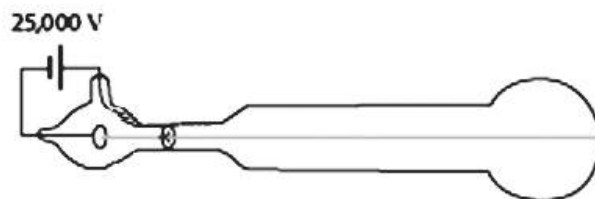
Shown below are the locations of three electrons within the electric field between the plates of a parallel plate capacitor. If electric force from the plates is the only significant force on the particles, which electron has greater potential energy?

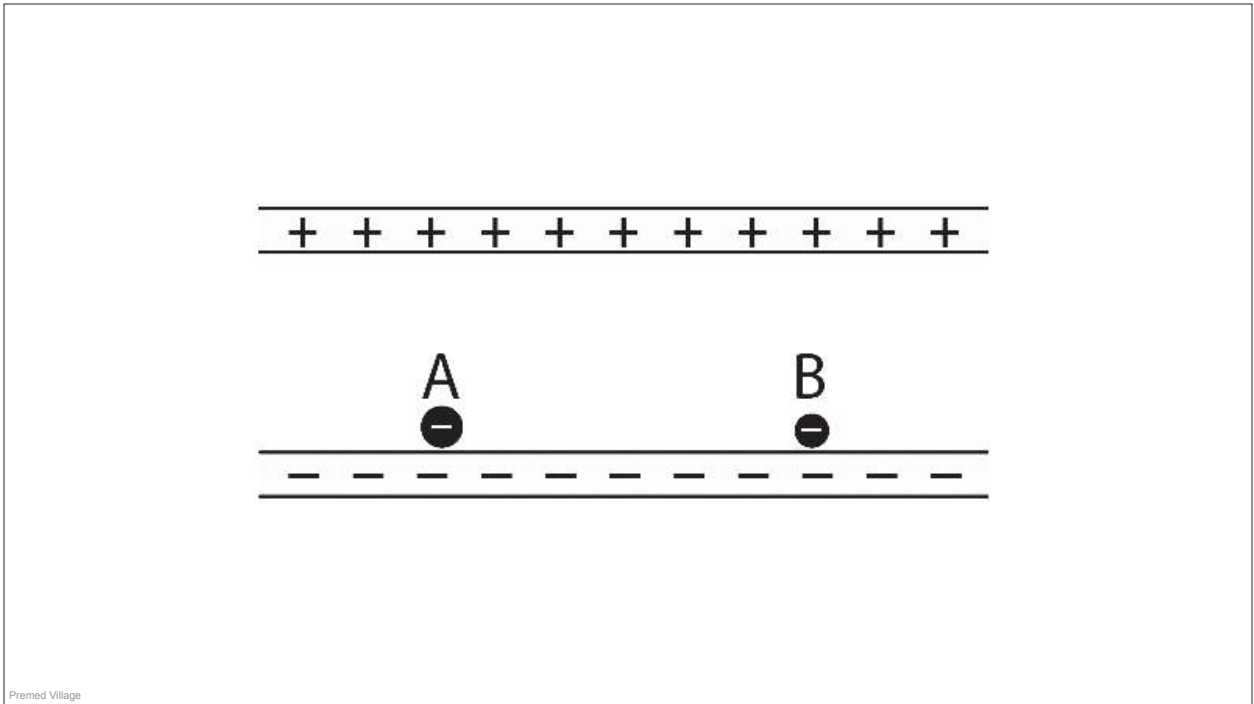


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What is the kinetic energy of an electron entering the cathode ray tube shown below?





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Gravitational and Electrostatic Potential Energy

system of two masses or two point charges

A diagram showing a large sphere with horizontal stripes and a smaller sphere with a dotted pattern. Below them is a graph with a vertical axis labeled 'U' and a horizontal axis labeled 'r'. The curve starts at a negative value on the U-axis and increases towards the r-axis as r increases.

$$U_g = -G \frac{m_1 m_2}{r}$$

A diagram showing a sphere with a '-' sign and a sphere with a '+' sign. Below them is a graph with a vertical axis labeled 'U' and a horizontal axis labeled 'r'. The curve starts at a positive value on the U-axis and decreases towards the r-axis as r increases.

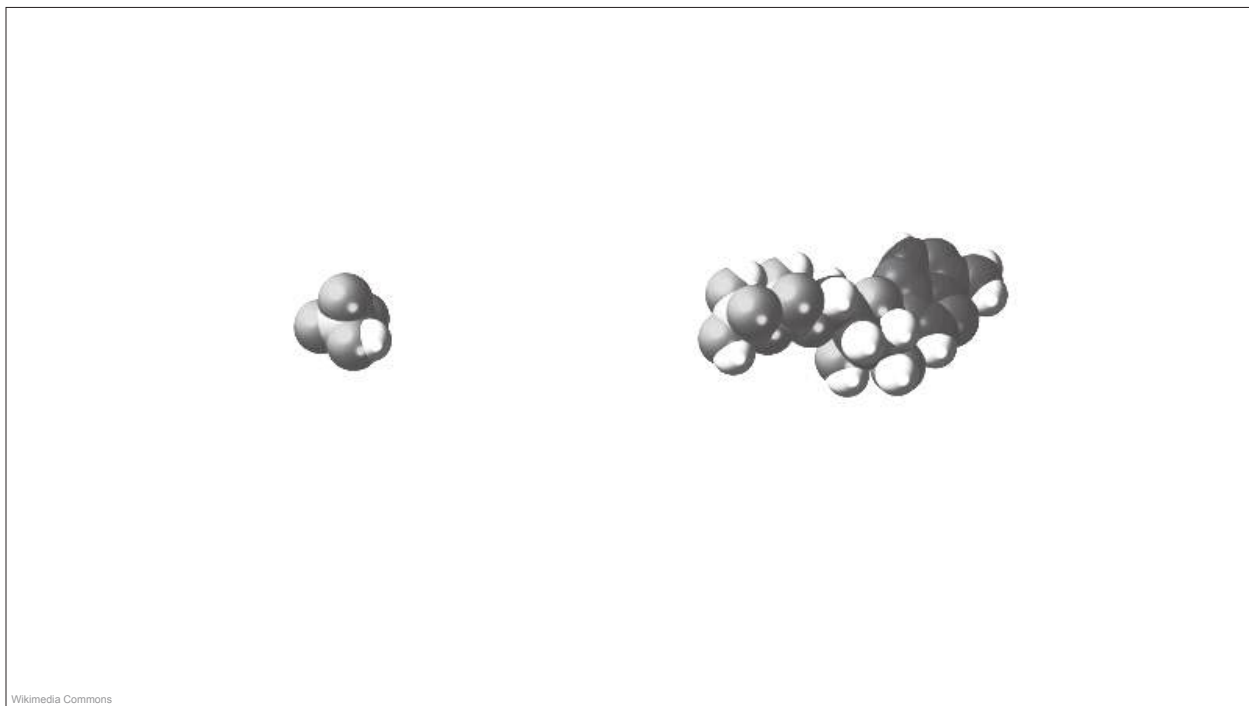
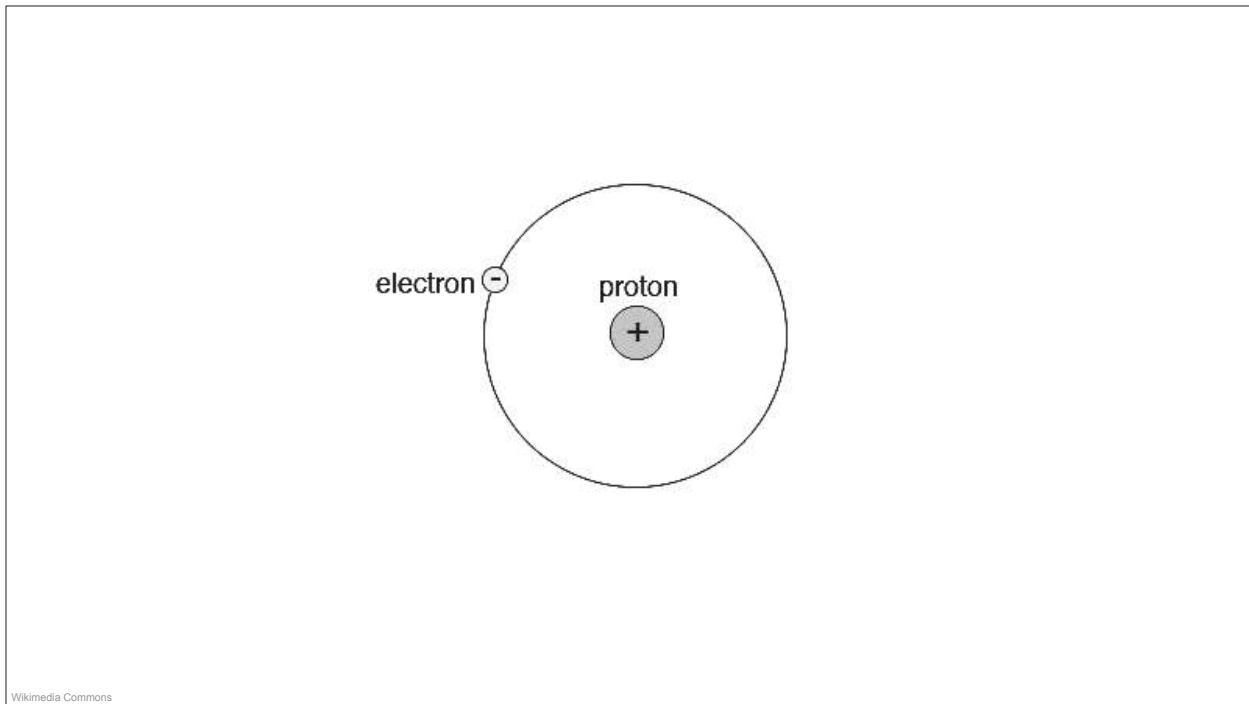
$$U_e = k \frac{q_1 q_2}{r}$$

Unlike Charges

A diagram showing two spheres, both with '+' signs. Below them is a graph with a vertical axis labeled 'U' and a horizontal axis labeled 'r'. The curve starts at a positive value on the U-axis and decreases towards the r-axis as r increases.

Like Charges

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Which of the following occurs with an increase in electrostatic potential energy?

- A. A gaseous sodium ion captures an electron.
- B. Negative charges introduced at a point on a neutral metal sphere spreads over its surface area with uniform distribution.
- C. One glucose molecule reacts with six molecules of oxygen to form six molecules of carbon dioxide and six molecules of water.
- D. A globular polypeptide unfolds from its native configuration in high temperature conditions.

Physics

MECHANICS

Kinematics
Newton's Laws
Work, Energy, and Power
Harmonic Motion
Elastic Properties of Solids
Fluid Mechanics

WAVES

Waves

GRAVITATION

Gravitation

THERMODYNAMICS

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ELECTRICITY & MAGNETISM

Electricity
DC Current
Magnetism

LIGHT & OPTICS

The Properties of Light
Geometric Optics
Wave Optics

MODERN PHYSICS & NUCLEAR PHYSICS

Modern Physics
Nuclear Physics

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General Chemistry

THE STRUCTURE OF MATTER

Atomic Theory
Periodic Properties
The Chemical Bond
Intermolecular Forces

STOICHIOMETRY

Stoichiometry

CHEMICAL THERMODYNAMICS AND CHEMICAL KINETICS

Thermochemistry
The States of Matter
Chemical Thermodynamics and the Equilibrium State
Chemical Kinetics

SOLUTIONS AND AQUEOUS SYSTEMS

Water
Solutions
Acids and Bases

OXIDATION REDUCTION AND ELECTROCHEMISTRY

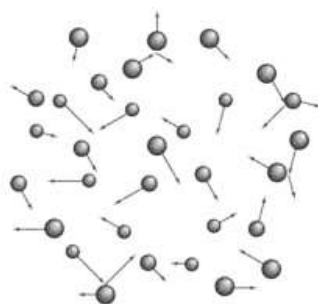
Oxidation/Reduction
Electrochemistry

COORDINATION CHEMISTRY

Coordination Chemistry

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The Internal Energy of an Ideal Gas Depends on Temperature



$$U = \frac{3}{2}NkT$$

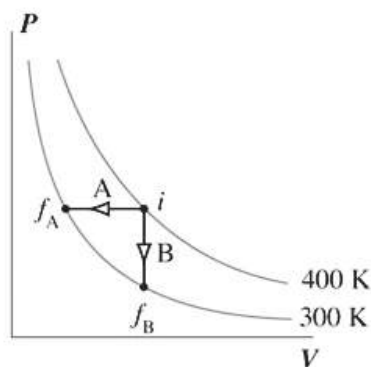
U = internal energy
 N = number of molecules
 k = Boltzmann's constant
 = R / Avogadro's number
 T = temperature

$$U = \frac{3}{2}nRT$$

n = moles of gas
 R = ideal gas constant

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The graph at right shows two isotherms corresponding to pressure vs. volume of a sample of ideal gas at 400K and 300K respectively. Path A shows the *isobaric* compression of the gas from initial state i to final state f_A . Path B shows *isovolumetric* cooling from initial state i to final state f_B . Which of the two transformations represents the greatest internal energy decrease for the gas?

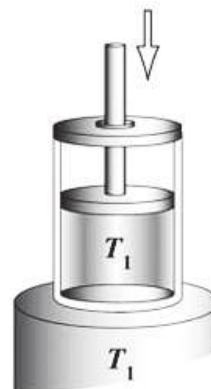


- a. Path A
 b. Path B
 c. The internal energy changes are equal
 d. Both paths increase internal energy

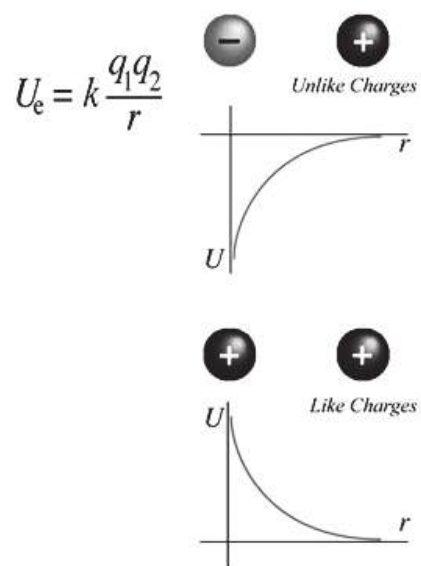
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A piston containing ideal gas is slowly compressed in thermal contact with a heat reservoir. Constant temperature is maintained throughout the compression. Which of the following must have occurred?

- Heat flowed into the reservoir.
- The pressure of the gas decreased.
- The internal energy of the gas increased.
- The internal energy of the gas decreased.

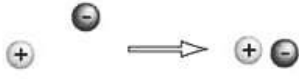


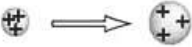
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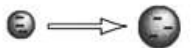


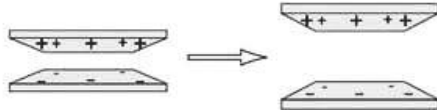
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Which of the following changes represents an increase in electrostatic potential energy?

a.  *Two oppositely charged particles are moved closer together.*

b.  *A sphere containing a uniform distribution of a fixed amount of positive charge increases in radius.*

c.  *A sphere containing a uniform distribution of a fixed amount of negative charge increases in radius.*

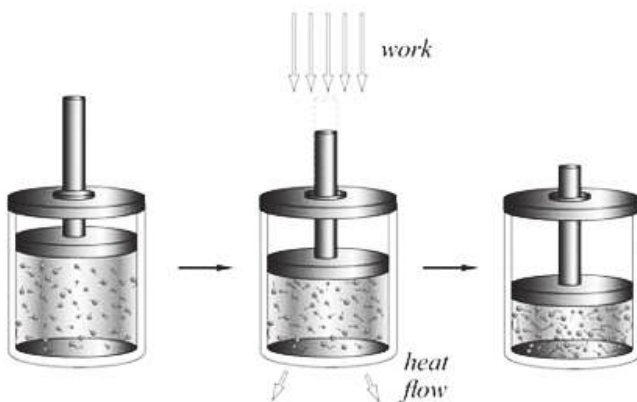
d.  *The distance is increased between the positive and negative plates of a capacitor containing a fixed amount of charge.*

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$$\Delta U = Q - W$$

$$= Q - P^* \Delta V$$

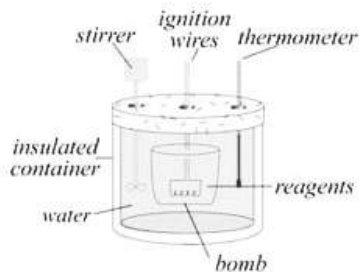
ΔU = internal energy change
 Q = heat flow
 W = macroscopic work
 P^* = constant pressure
 ΔV = volume change



Internal energy change results from the combination of heat flow and work between the system and its surroundings. In this example, the internal energy of our ideal gas system became greater (the particles are moving faster in the final state) because more energy entered the system through work than departed the system as heat flow.

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Internal energy change in most chemical reactions mainly derives from the difference in the energy of old versus new chemical bonds in the reagents versus the products. Which of the following is a direct, practical method for determining the internal energy change in a chemical reaction?



A Bomb Calorimeter

- measure the thermodynamic work performed by the system during the reaction at constant temperature
- measure the strength of the intermolecular forces in the reagents
- measure the heat absorbed or evolved by the reaction at constant volume
- measure enthalpy change, i.e. the heat of the reaction at constant pressure

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The heat of vaporization of water (cal/g)

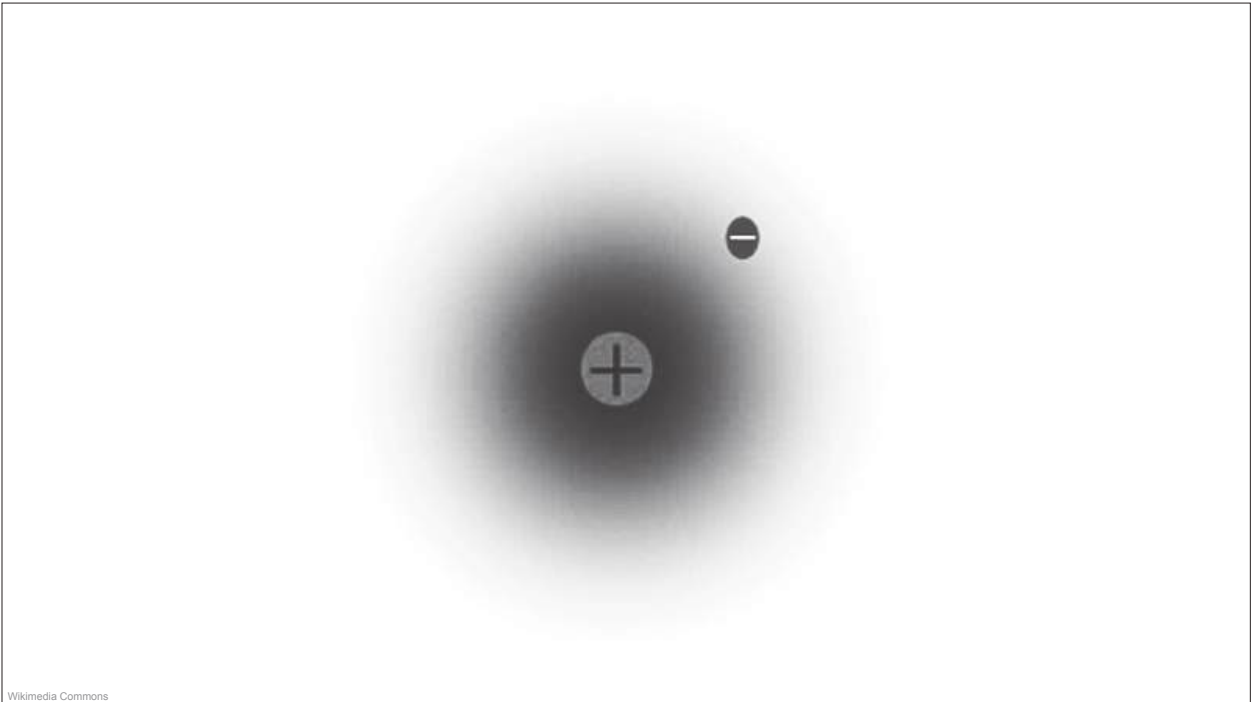
- equals the internal energy change per gram of water in transforming from liquid to gas at 1 atm of pressure
- is greater than the internal energy change per gram of water in transforming from liquid to gas at 1 atm of pressure
- equals the electrostatic potential energy increase among water molecules along lines of intermolecular force
- results in an increase in the kinetic energy of water vapor molecules at 100°C compared to molecules of liquid water at 100°C

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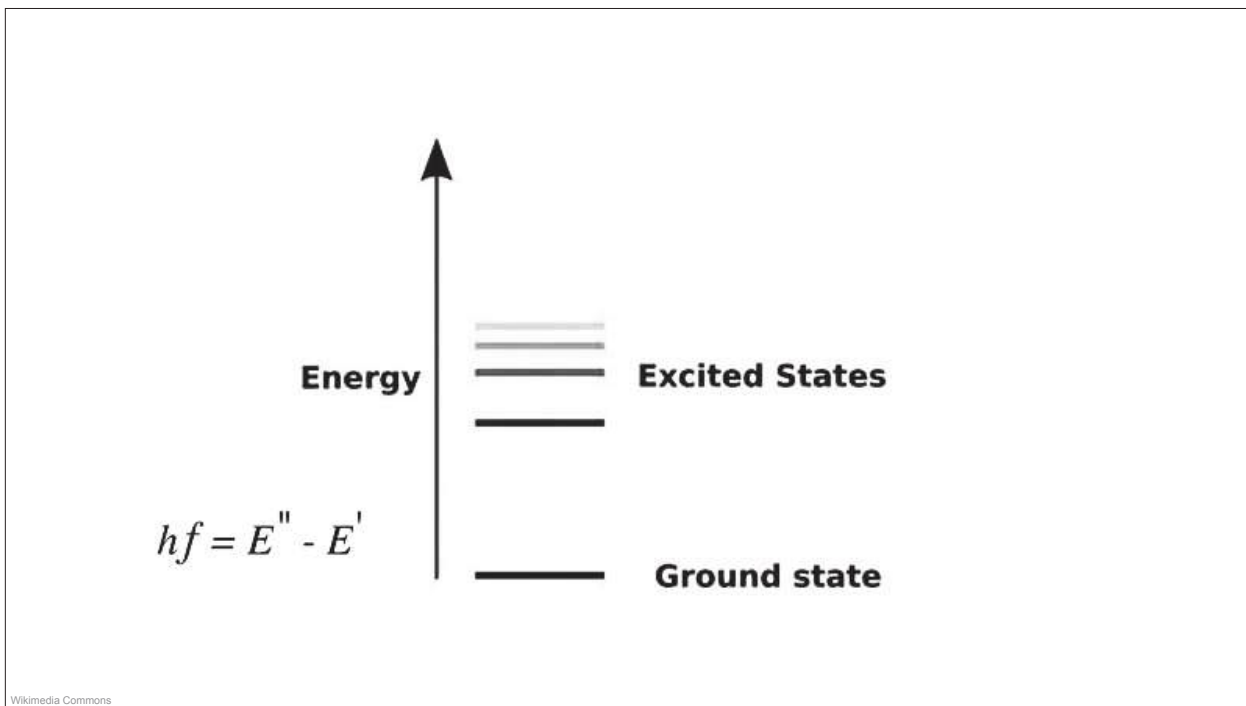
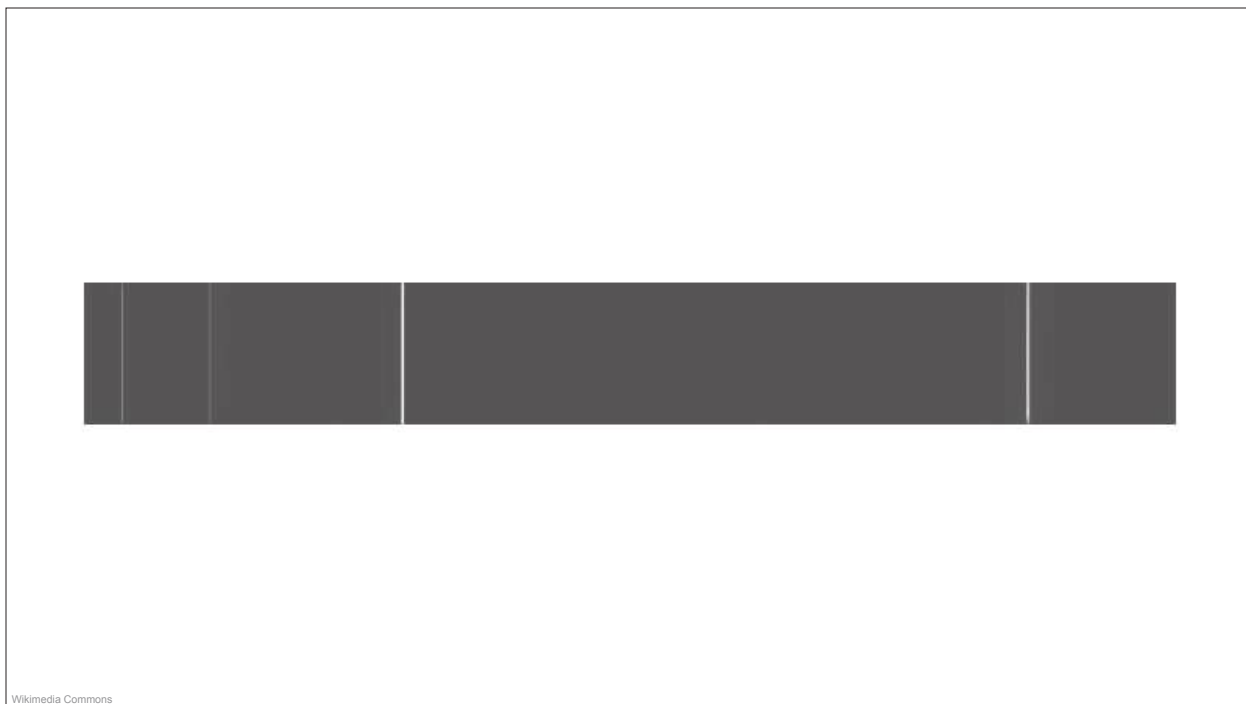
In biochemical processes enthalpy change and internal energy change are often essentially equal because

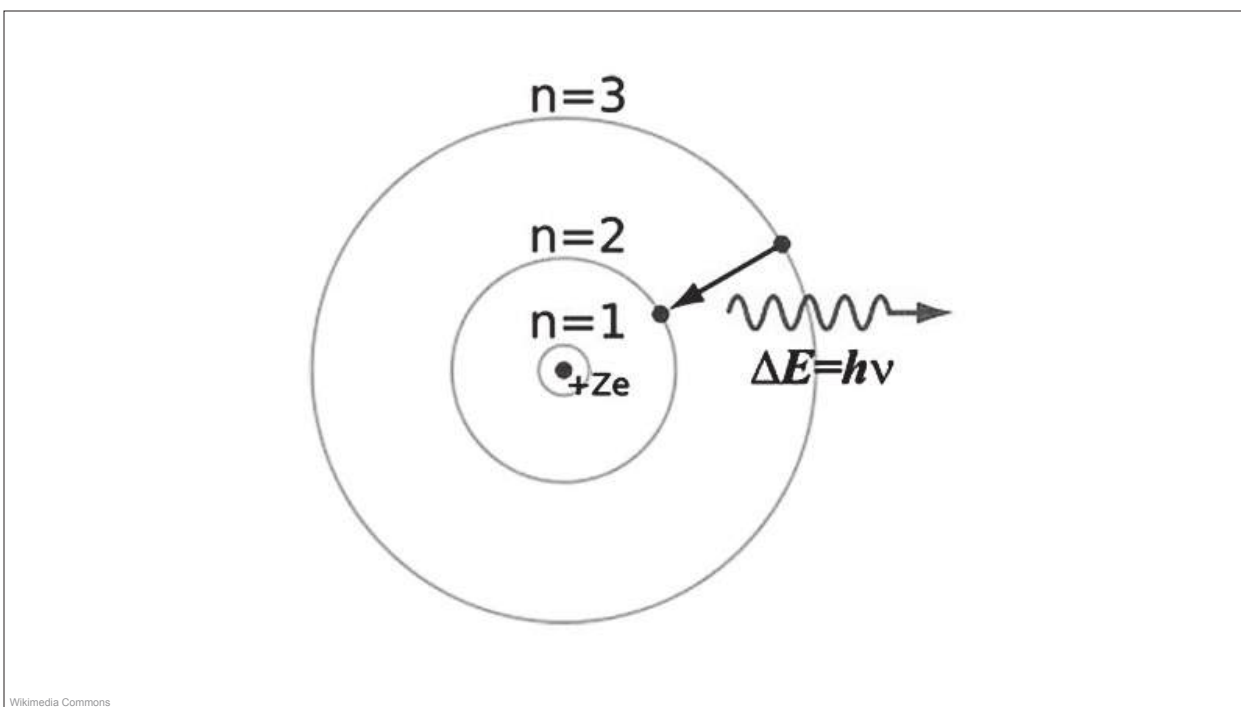
- A.** biochemical processes normally occur in liquids and solids
- B.** biochemical processes are most likely to be carried out at constant pressure
- C.** biochemical processes are often coupled
- D.** biochemical processes are most likely to be carried out at constant temperature

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In the Bohr theory of the atom the energy of the n -th level for any atom is given by the following equation

$$E \approx \frac{-13.6Z^2}{n^2} \text{ eV}$$

where Z is the atom's atomic number. Which of the following is a true statement according to the theory?

- A. A ground state hydrogen electron has about 13.6 eV less energy than an electron far from the nucleus.
- B. The ionization energy of hydrogen is approximately 50 eV.
- C. The minimum energy possible for a hydrogen electron is zero.
- D. Less energy is required to elevate an electron from the ground state to the 2nd energy level than from the 2nd to the 3rd.

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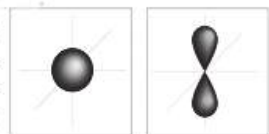
Quantum Numbers and Atomic Orbitals

n = principle quantum number

Electron energy within an atom mainly depends on the principle quantum number, n , which can have values of 1, 2, 3 . . . Orbitals with the same principle quantum number are said to belong to the same *shell*. Shells are designated with the letters 1 = K, 2 = L, 3 = M, and so on.

l = angular momentum quantum number

l determines what kind of *subshell* contains the electron. l values are constrained by n . For a given value of n , l can be any integer: 0, 1, 2 . . . $n - 1$. The subshell determines the shape of the electron orbital. Subshells are designated with letters corresponding to 0 = s , 1 = p , 2 = d , 3 = f , etc.



s subshell orbital *p* subshell orbital

m_l = magnetic quantum number

m_l determines the *orbital* within a subshell. It's values are constrained by l . For a given l , m_l can be any integer between $-l$ and l . Thus, an s subshell ($l = 0$) has one orbital, while a p subshell ($l = 1$) has three ($m_l = -1, 0$ or 1).



The three orbitals of a *p* subshell.

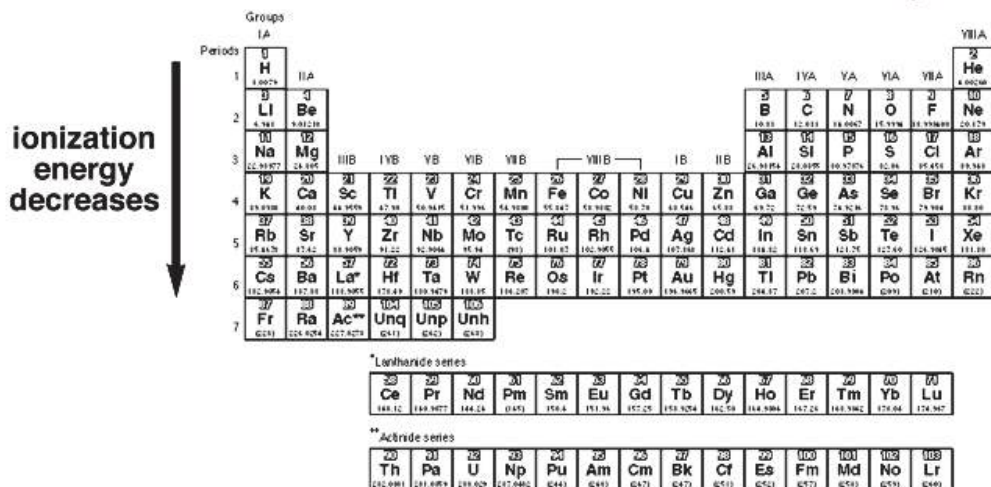
m_s = spin quantum number

In addition to orbital angular momentum, characterized by l , electrons possess quantized angular momentum corresponding to rotation about their own axis. The values of electron spin are designated by the spin quantum number, m_s , which can be either $+\frac{1}{2}$ or $-\frac{1}{2}$.

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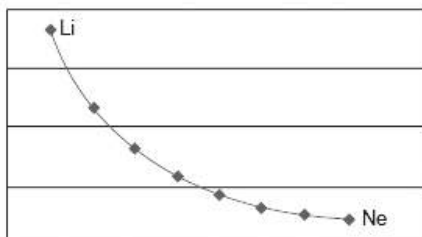


ionization energy increases \rightarrow



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The graph below shows the variation across the 2nd period of the periodic table of this property



- A. ionization energy
- B. electron affinity
- C. atomic radius
- D. electronegativity

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electronegativity increases

electronegativity decreases

Periods	Groups																																			
	IA											IIIA	IVA	VA	VIA	VIIA	VIIIA																			
1	H 1.0079											B 10.81	C 12.011	N 14.007	O 16.00	F 18.998	Ne 20.179																			
2	Li 6.941	Be 9.0021											Al 13.01	Si 12.01	P 14.01	S 16.00	Cl 17.00	Ar 19.92																		
3	Na 22.99	Mg 24.31	Al 13.01	Si 12.01	P 14.01	S 16.00	Cl 17.00	Ar 19.92	K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 51.99	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.71	Cu 63.55	Zn 65.38	Ga 69.72	Ge 72.64	As 74.92	Se 78.96	Br 79.90	Kr 83.80										
4	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 98.91	Ru 101.07	Rh 102.91	Pd 106.42	Ag 107.87	Cd 112.41	In 114.82	Sn 118.71	Sb 121.76	Te 127.60	I 126.91	Xe 131.29	Cs 132.91	Ba 137.33	La* 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.23	Ir 192.22	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po 209	At 210	Rn 222
5	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 98.91	Ru 101.07	Rh 102.91	Pd 106.42	Ag 107.87	Cd 112.41	In 114.82	Sn 118.71	Sb 121.76	Te 127.60	I 126.91	Xe 131.29	Cs 132.91	Ba 137.33	La* 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.23	Ir 192.22	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po 209	At 210	Rn 222
6	Cs 132.91	Ba 137.33	La* 138.91	Hf 178.49	Ta 180.95	W 183.85	Re 186.21	Os 190.23	Ir 192.22	Pt 195.08	Au 196.97	Hg 200.59	Tl 204.38	Pb 207.2	Bi 208.98	Po 209	At 210	Rn 222	Fr 223	Ra 226	Ac** 227	Unq 232	Unp 233	Unh 234												
7	Fr 223	Ra 226	Ac** 227	Unq 232	Unp 233	Unh 234													III A	IV A	V A	VII A	VIII A													

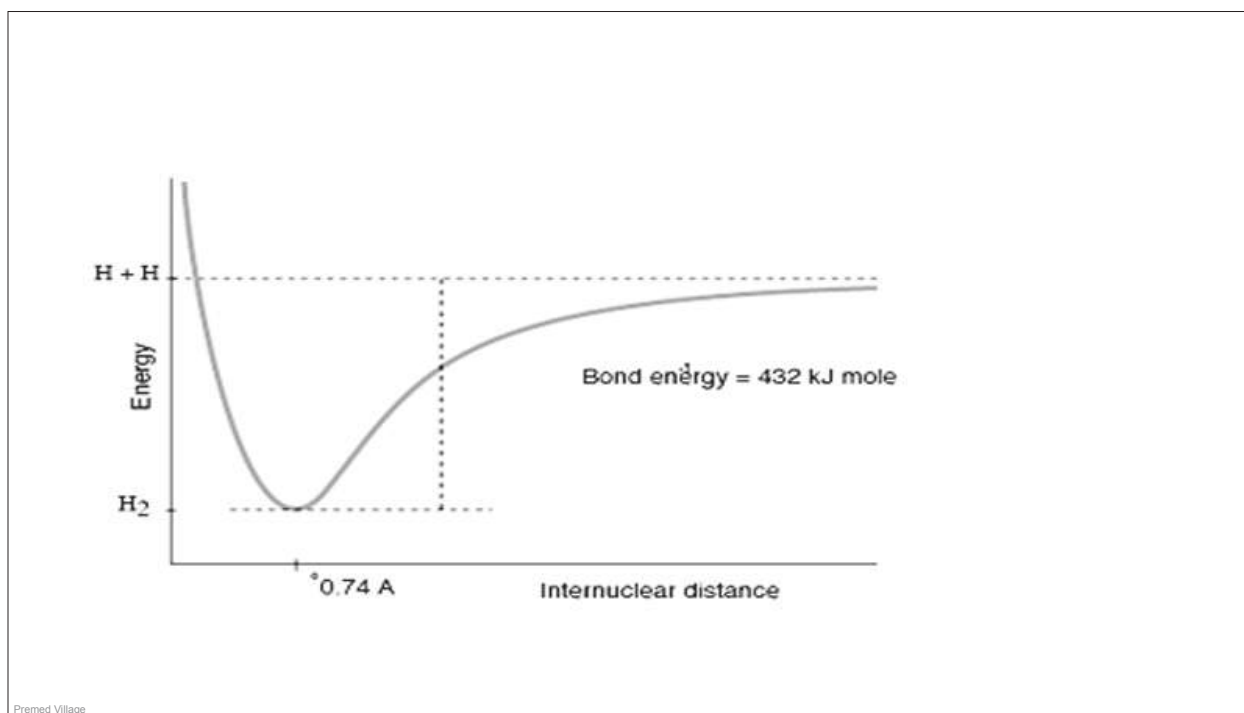
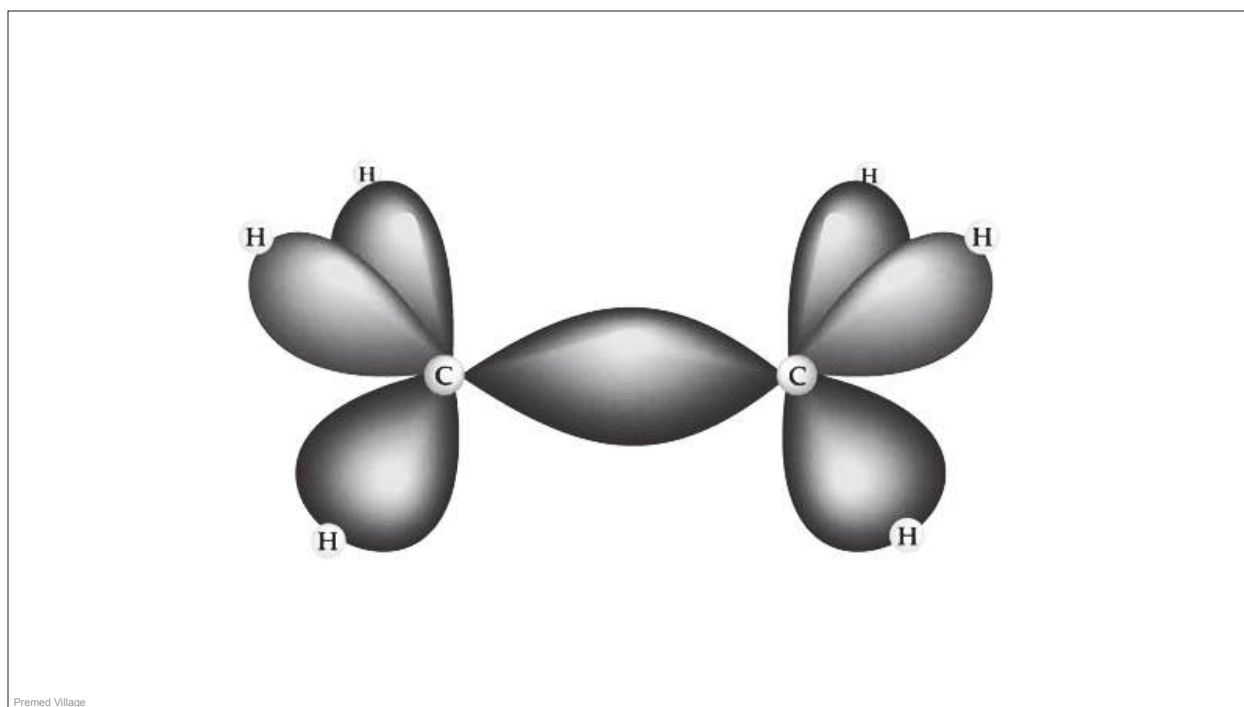
*Lanthanide series

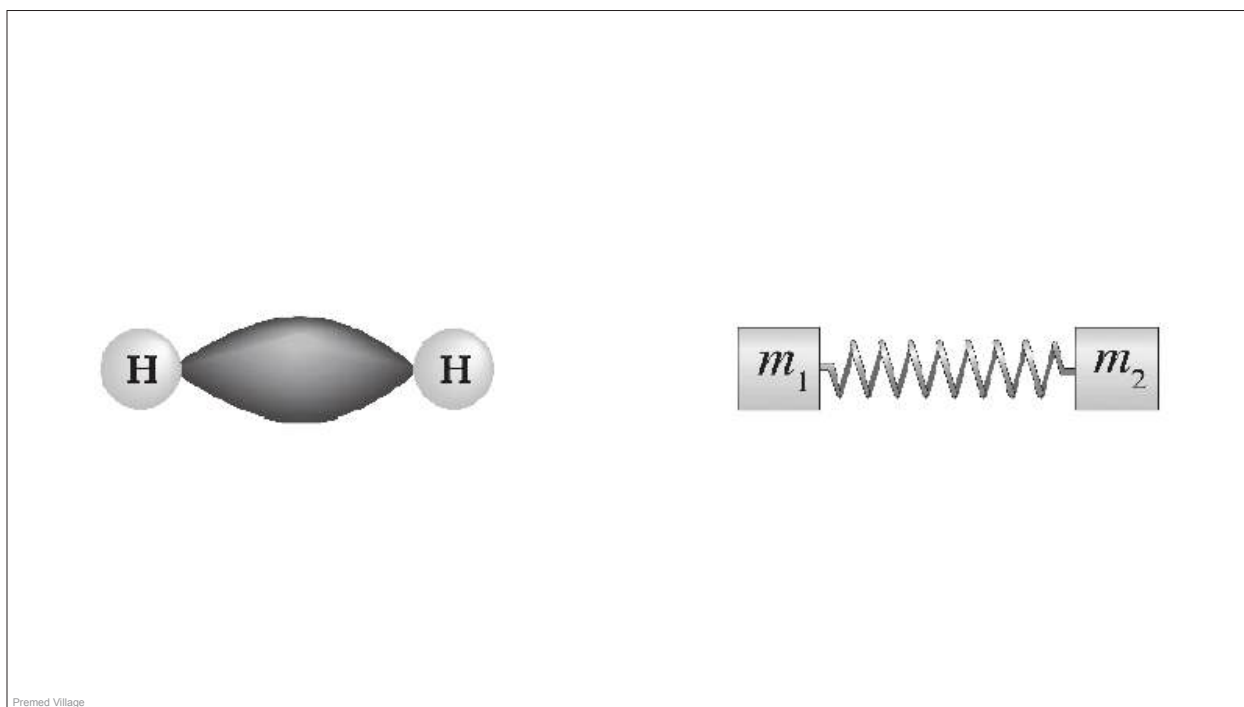
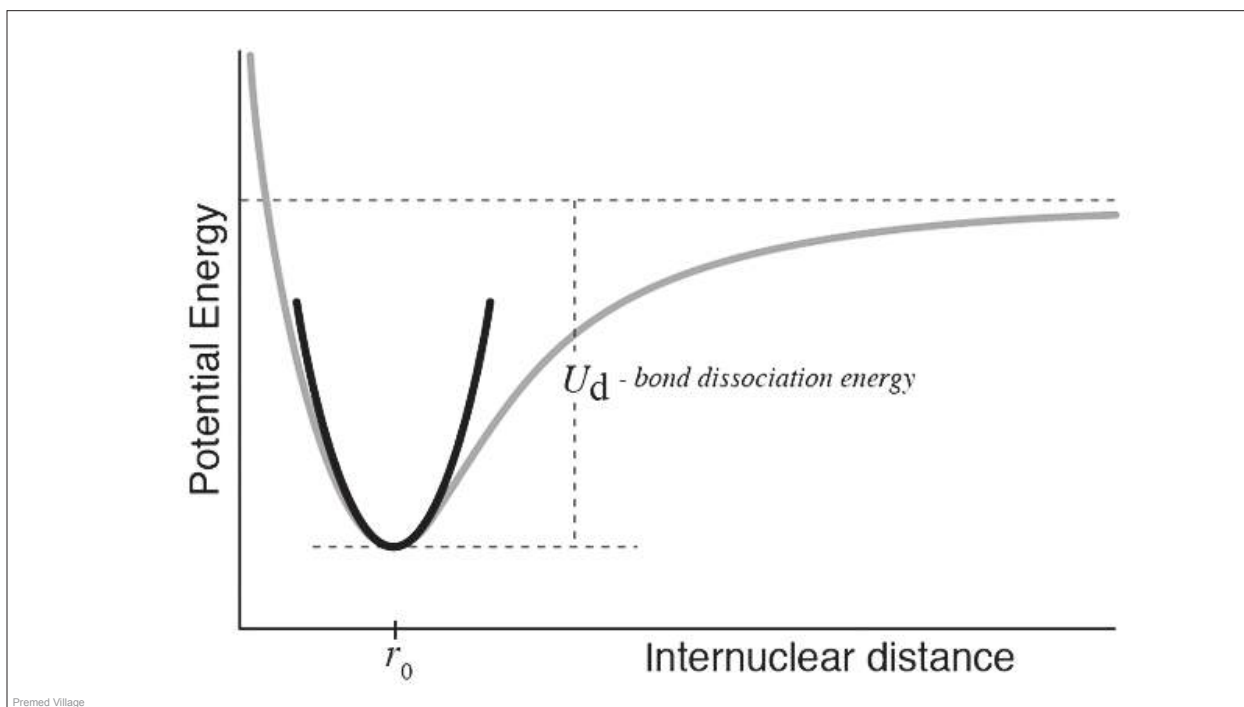
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
140.12	140.907	144.24	(145)	150.36	151.96	157.25	158.925	162.50	164.9304	167.259	168.934	173.04	174.967	

**Actinide series

89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	
232.0377	231.03688	238.02891	237.04817	244.06392	247.07125	251.0794	257.1037	261.10888	267.12344	272.14331	287.10602	289.10151	293.10713	

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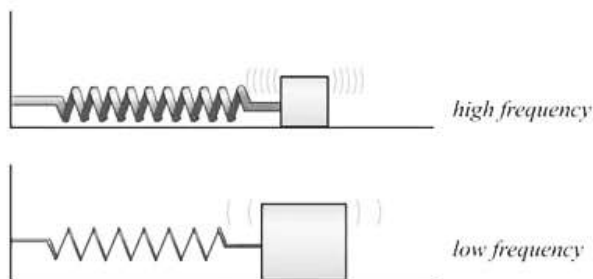




The Frequency of a Mass-Spring

$$\omega = \sqrt{\frac{k}{m}} \quad f = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

ω = angular frequency (rad/s)
 f = frequency (Hz)
 k = spring constant
 m = mass

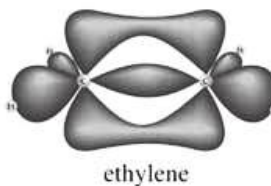
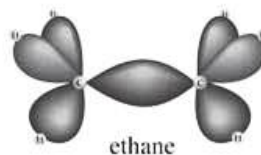


A strong spring (high k) with a small mass oscillates at a higher frequency than a weak spring with a large mass.

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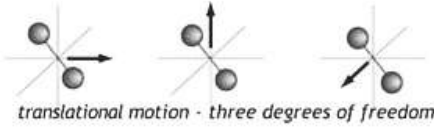
The stretching vibrations along the bond axis of a C–H bond in ethane absorb infrared radiation of lower frequency than the IR radiation absorbed by a C–H bond of ethylene. Which of the following statements can be deduced from this evidence?

- The carbon-hydrogen bonds in ethylene are stronger than the carbon-hydrogen bonds in ethane
- Ethane has free rotation about the C–C bond axis
- The C–H bonds are shorter in ethane.
- The percent composition of ethane is greater for hydrogen.

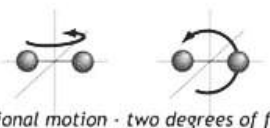


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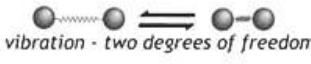
A monatomic gas molecule such as **He** possesses only kinetic energy deriving from its linear motion. A diatomic gas molecule, like **Cl₂**, in addition to translational motion, can also rotate and vibrate. What does this difference tell us?



translational motion - three degrees of freedom



rotational motion - two degrees of freedom


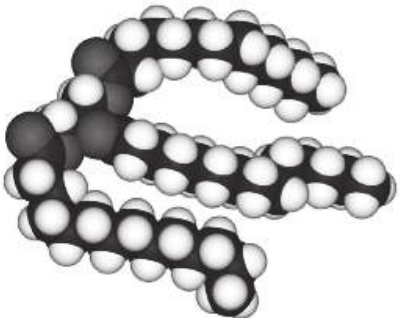


vibration - two degrees of freedom

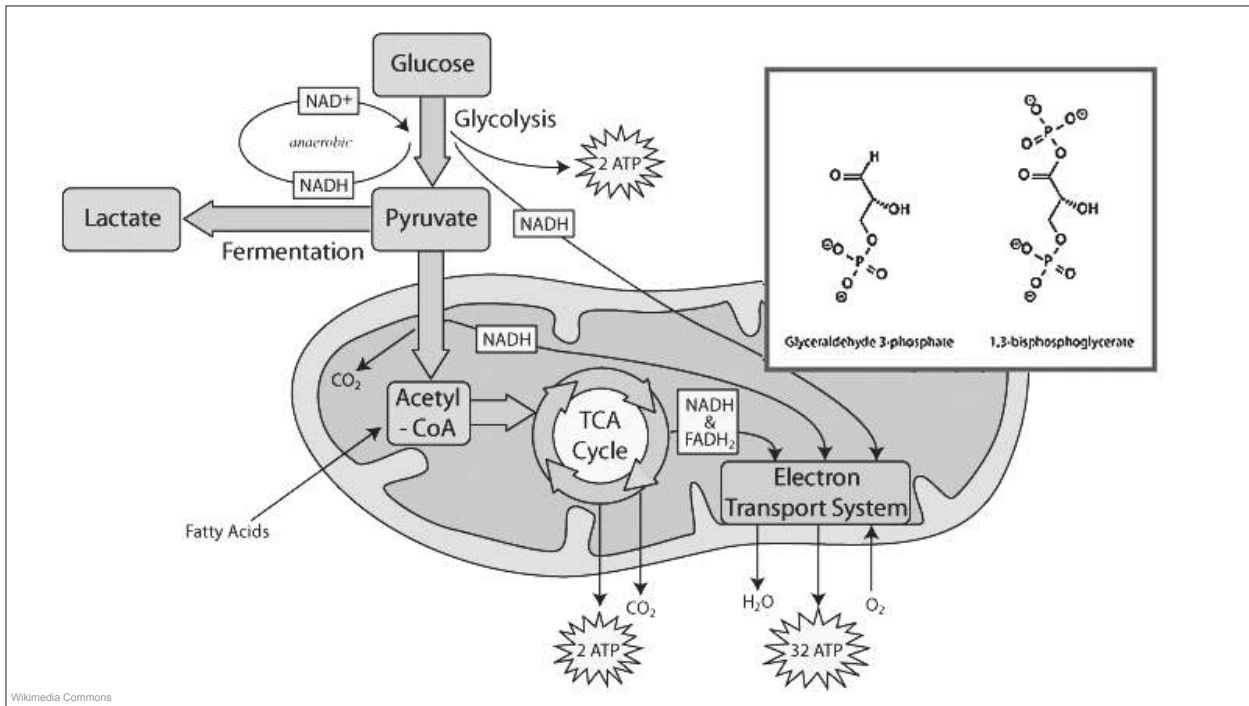
- Helium is a noble gas.
- Chlorine has a higher molar heat capacity than helium.
- At a given temperature, helium molecules have greater average translational kinetic energy than chlorine molecules.
- The chlorine molecules have greater average translational kinetic

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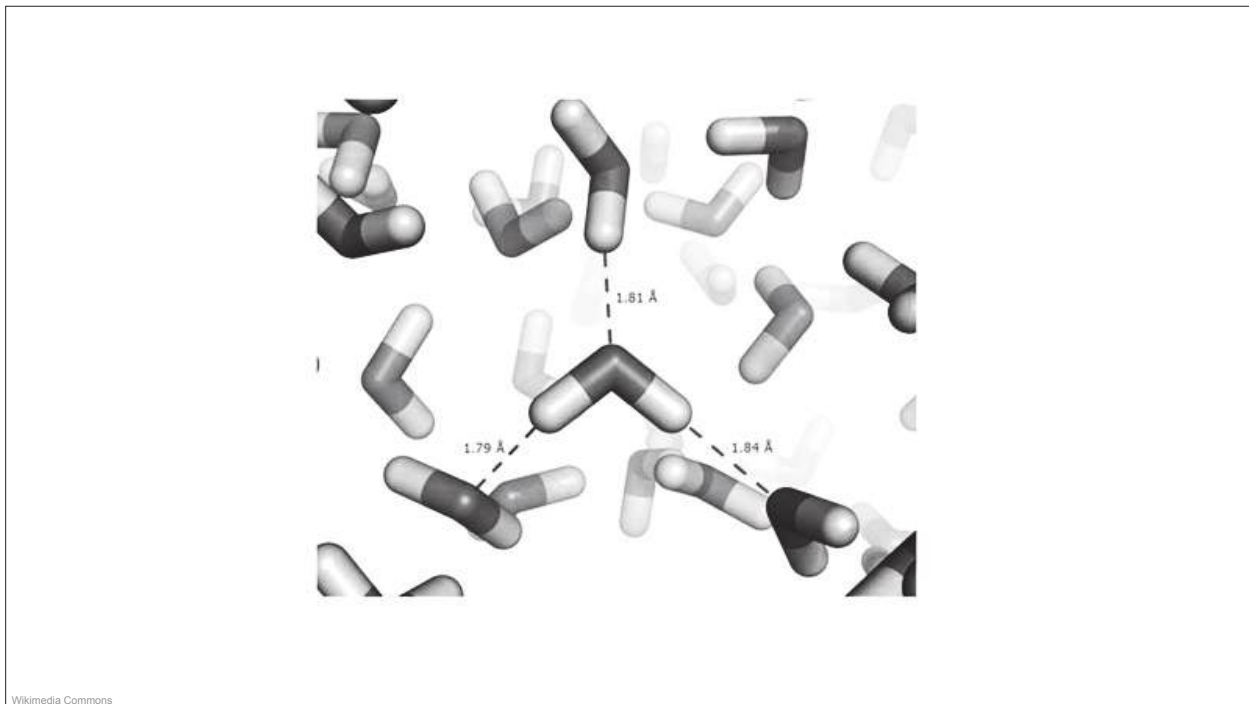
Heats of Combustion of Nutrient Molecules

<p>Glucose 466 kJ/mol carbon</p> 	<p>Triglyceride 626 kJ/mol carbon</p> 
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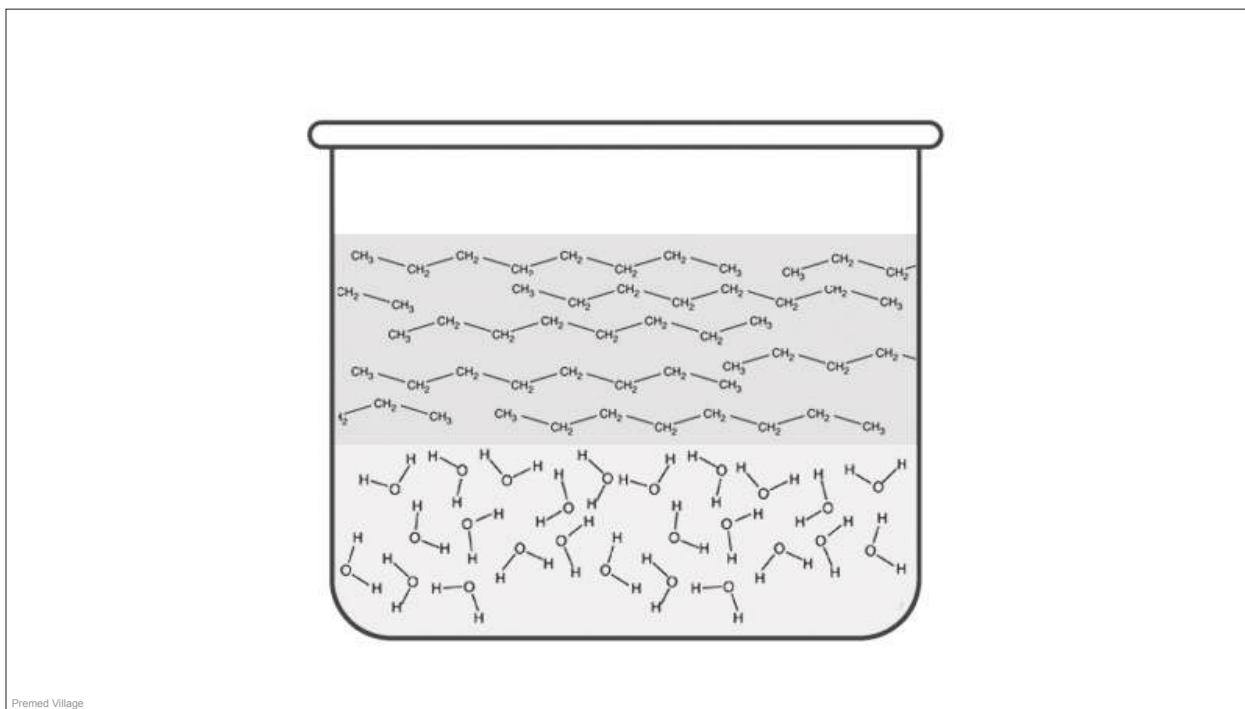
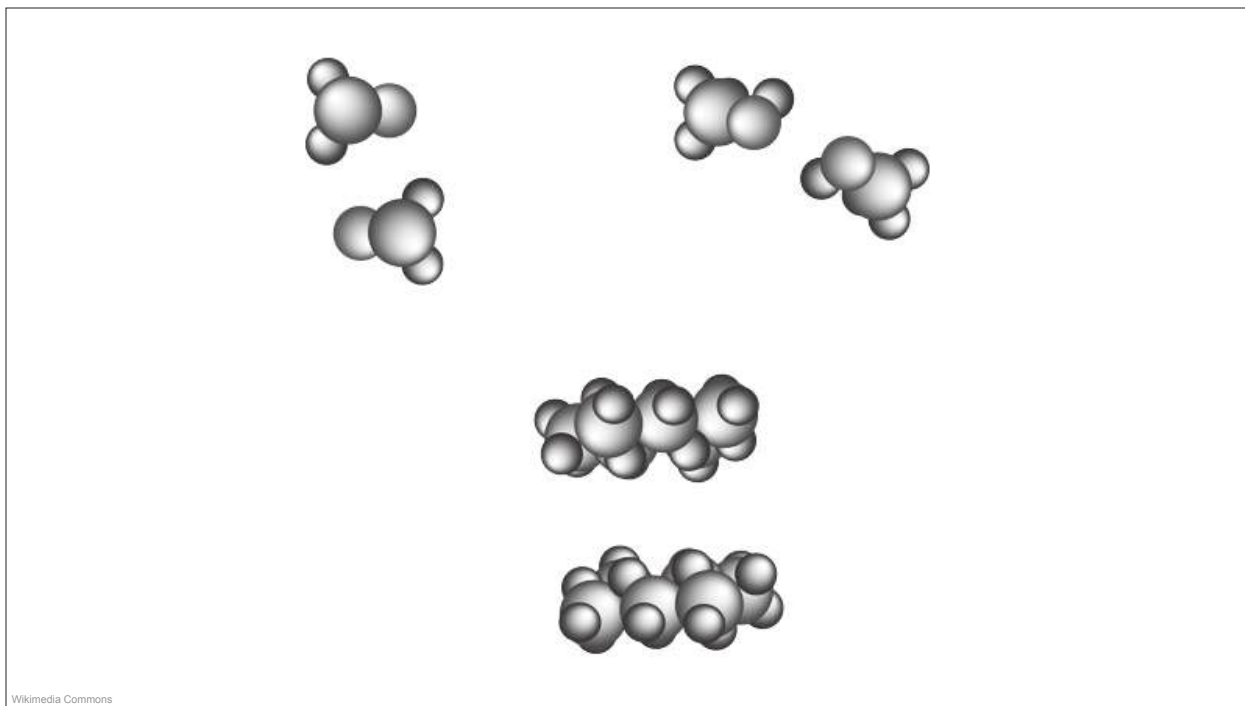
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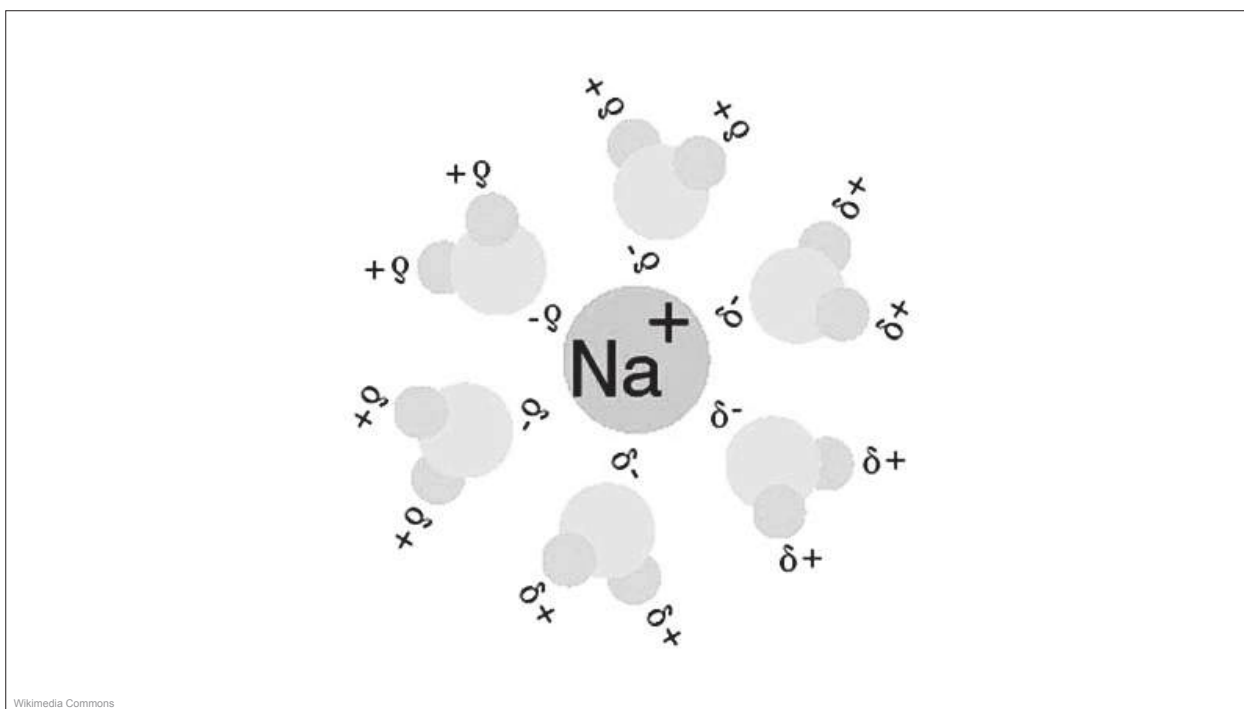
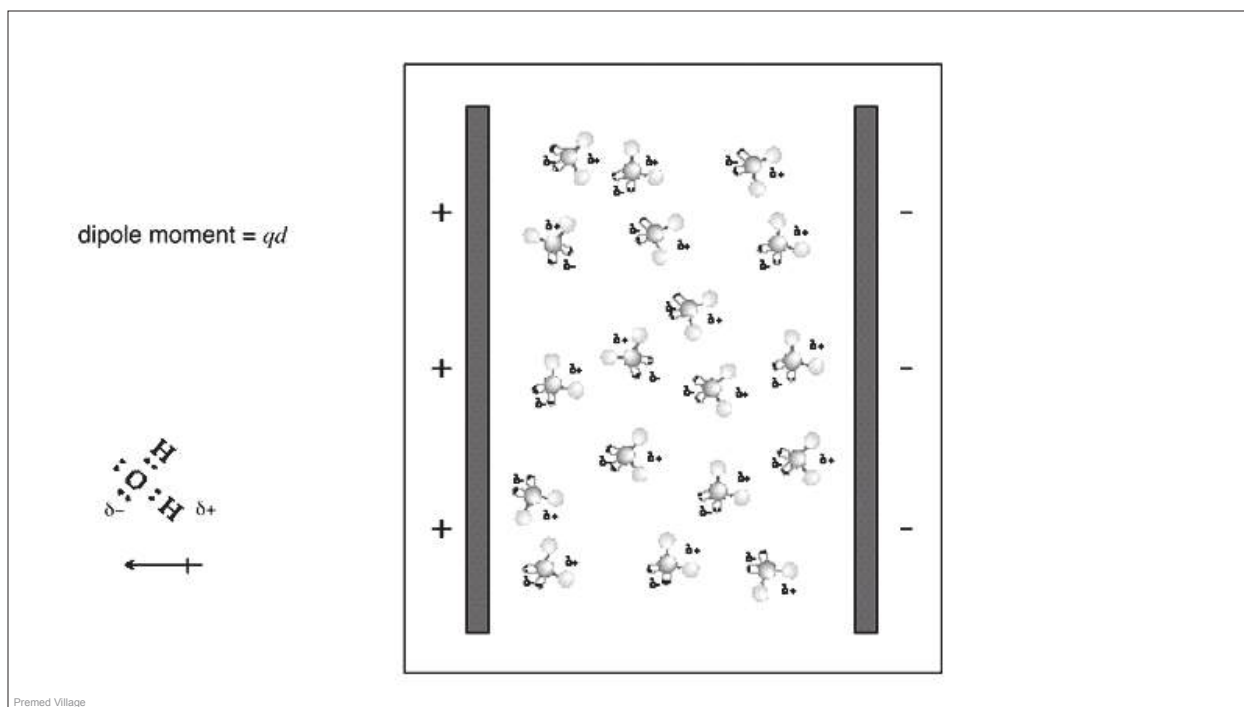


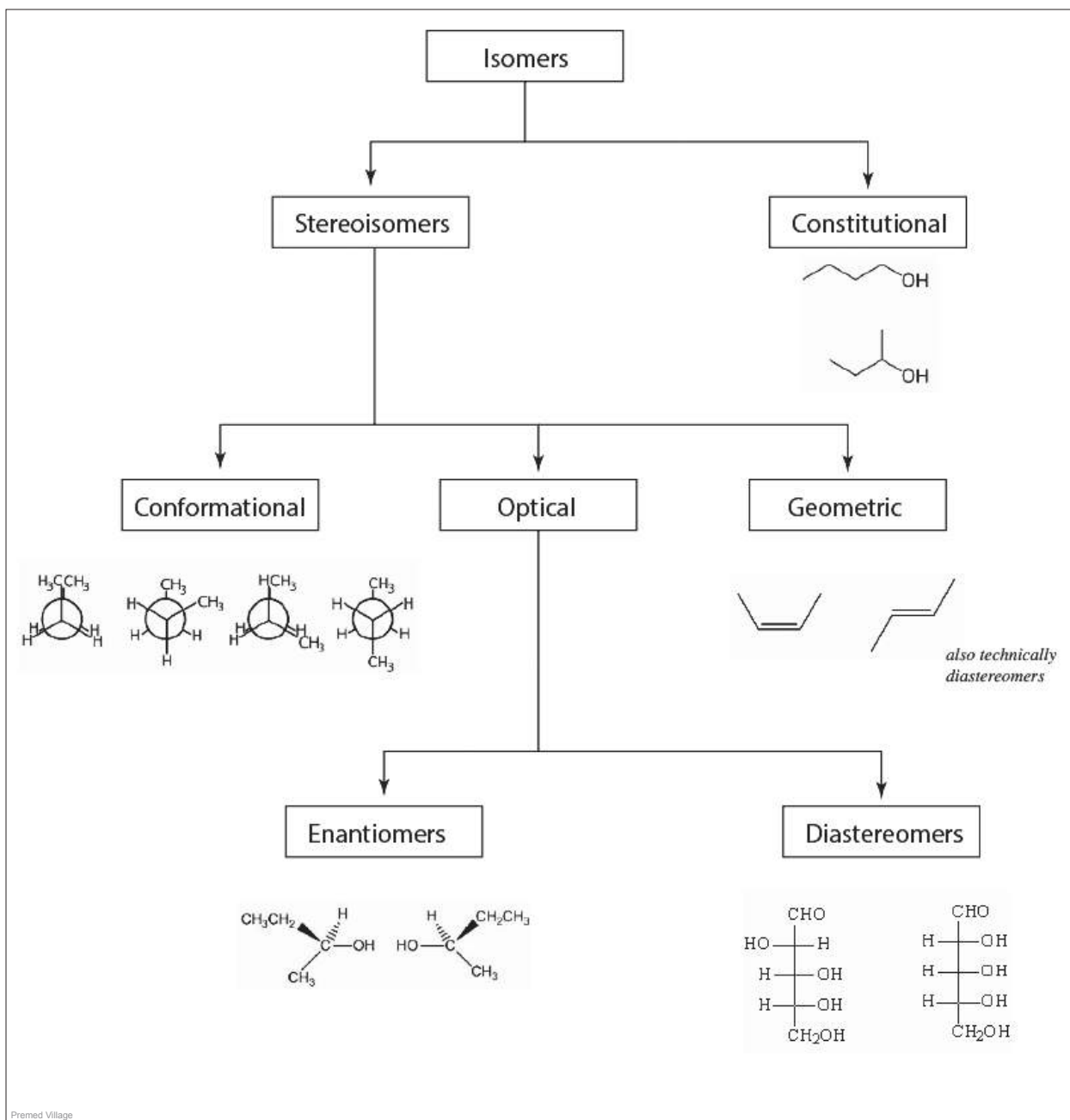
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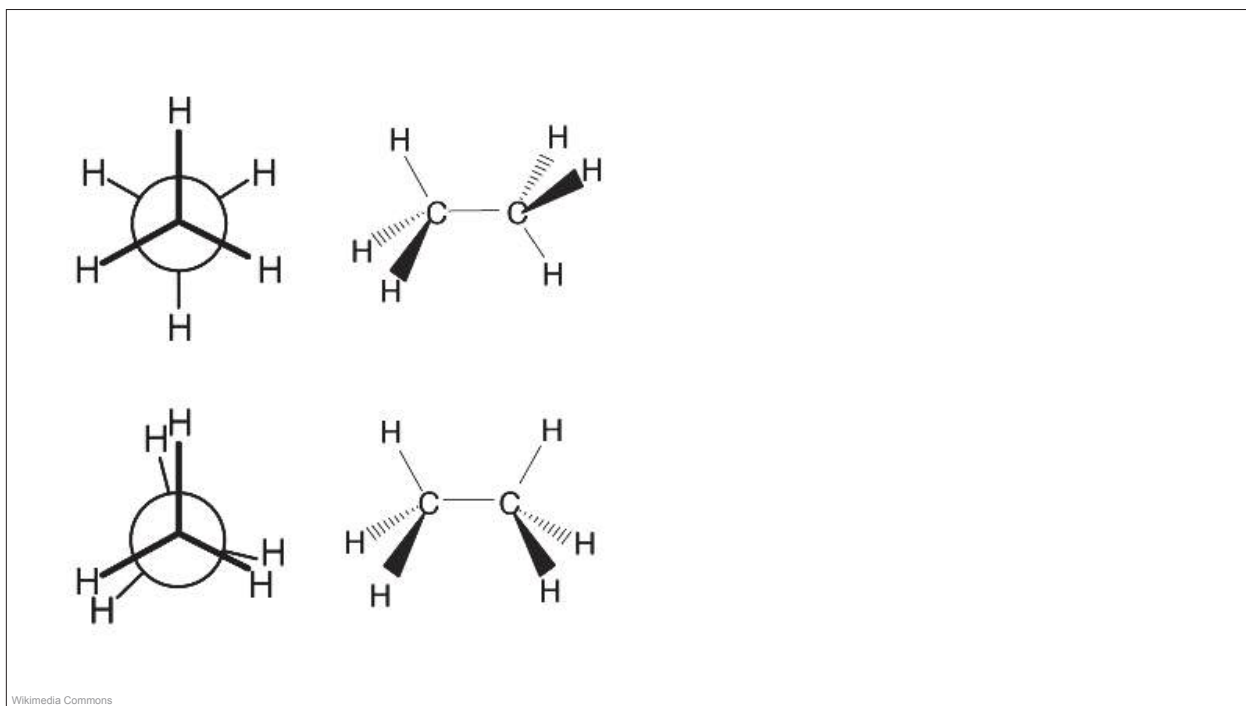
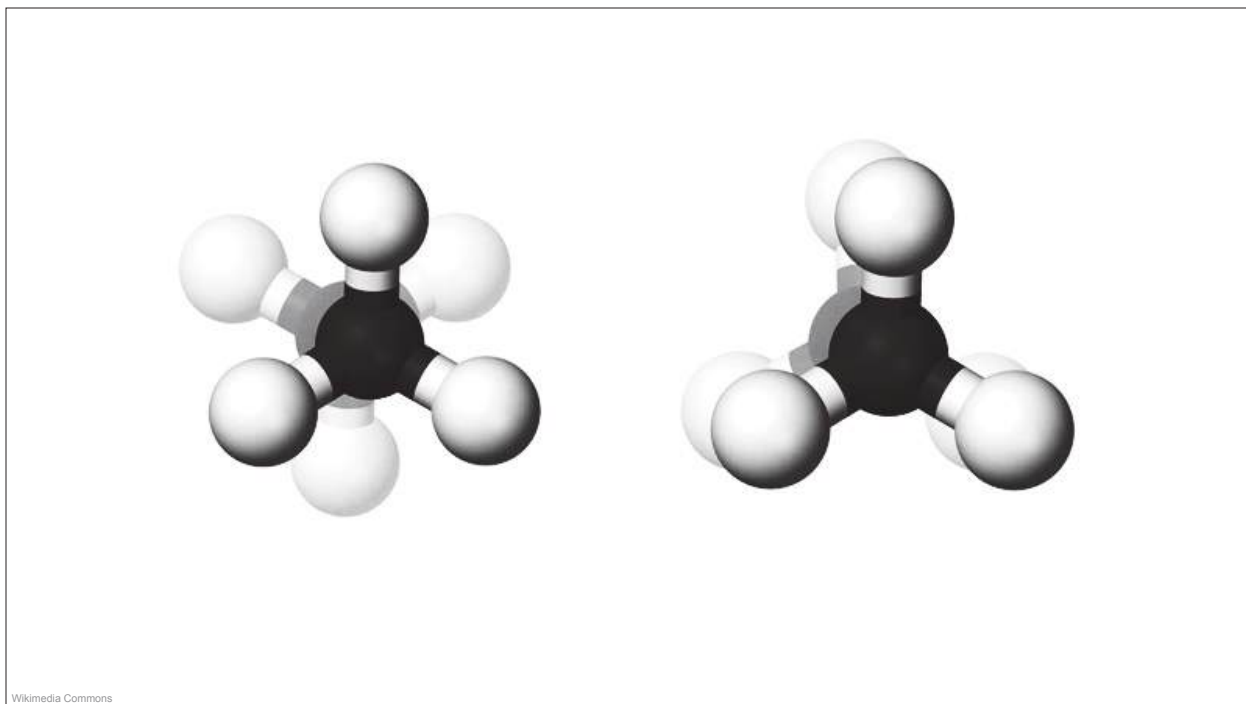


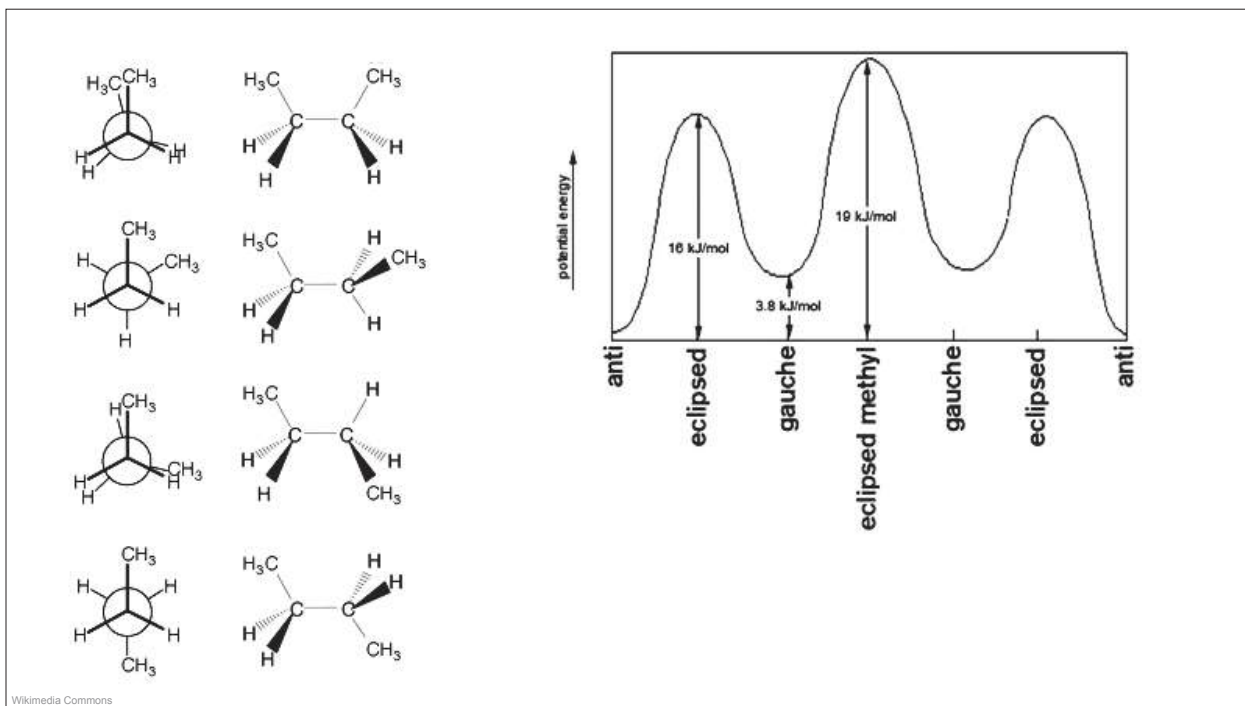
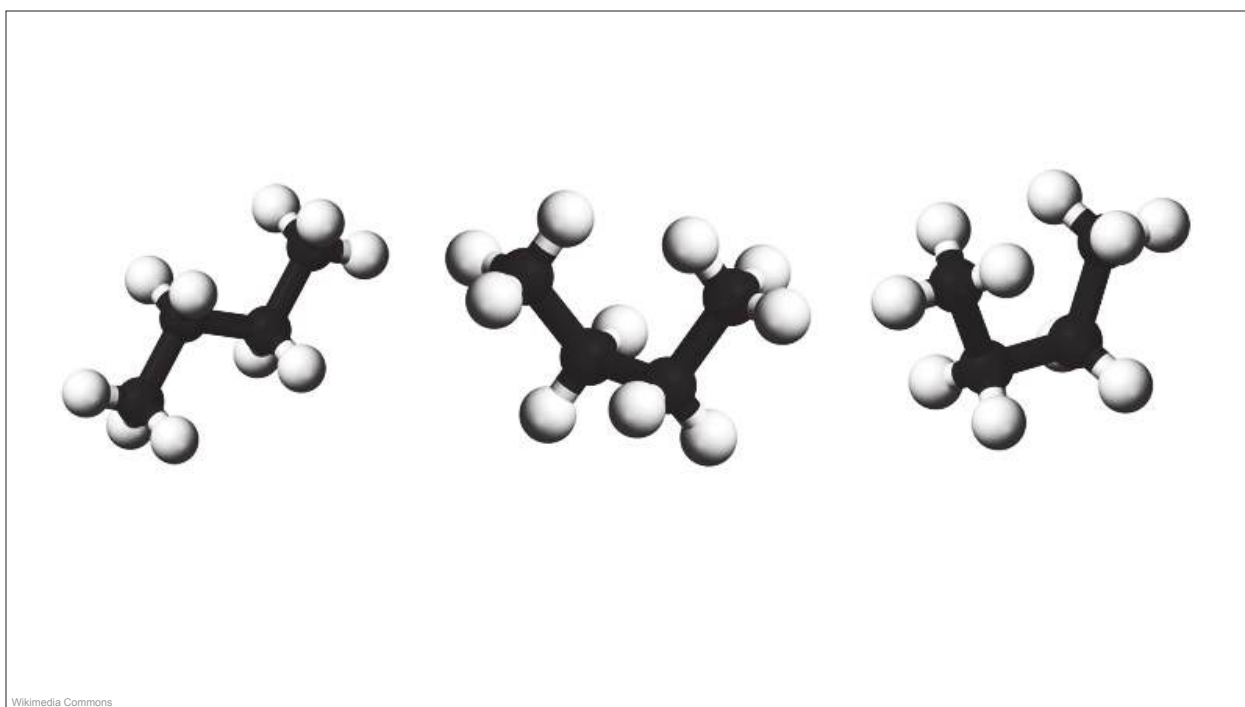
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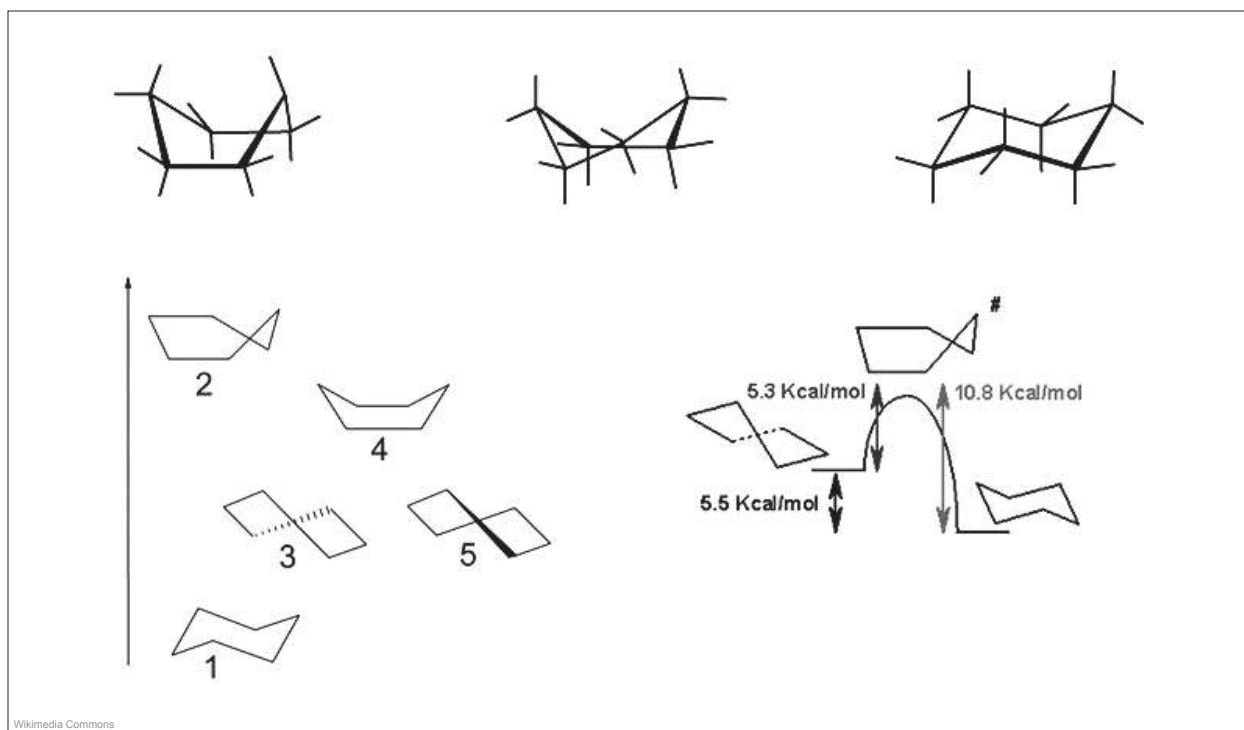




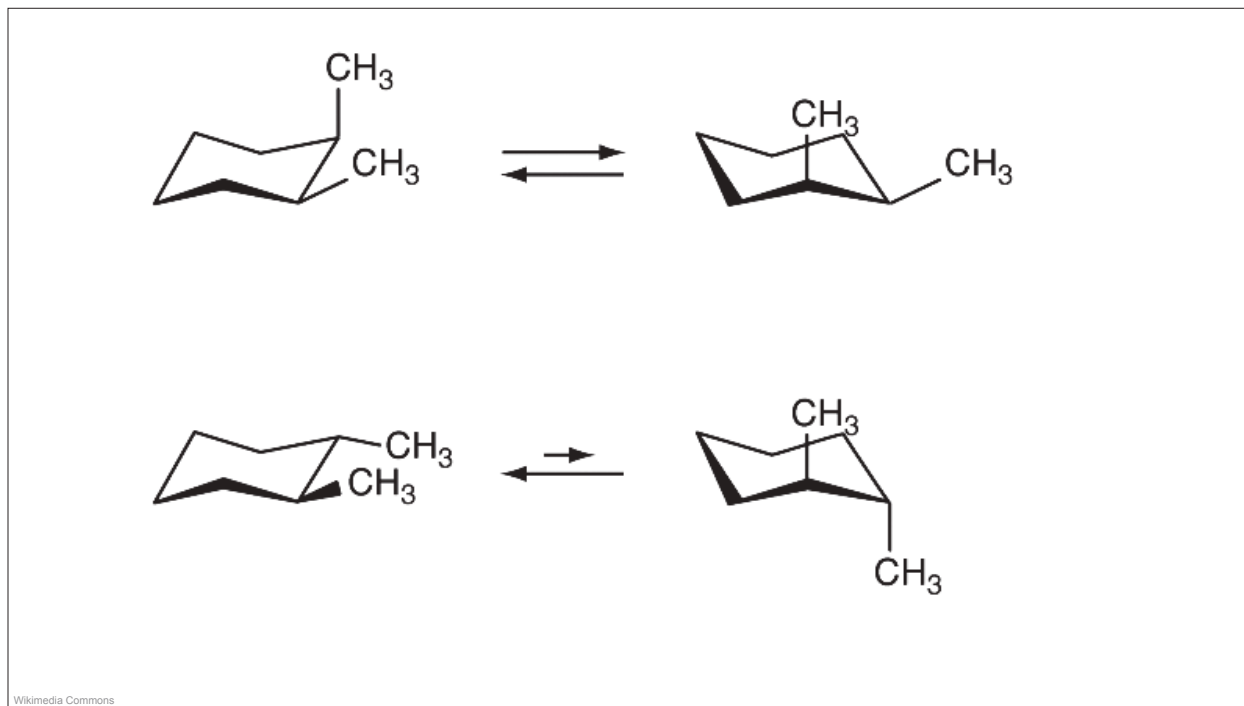




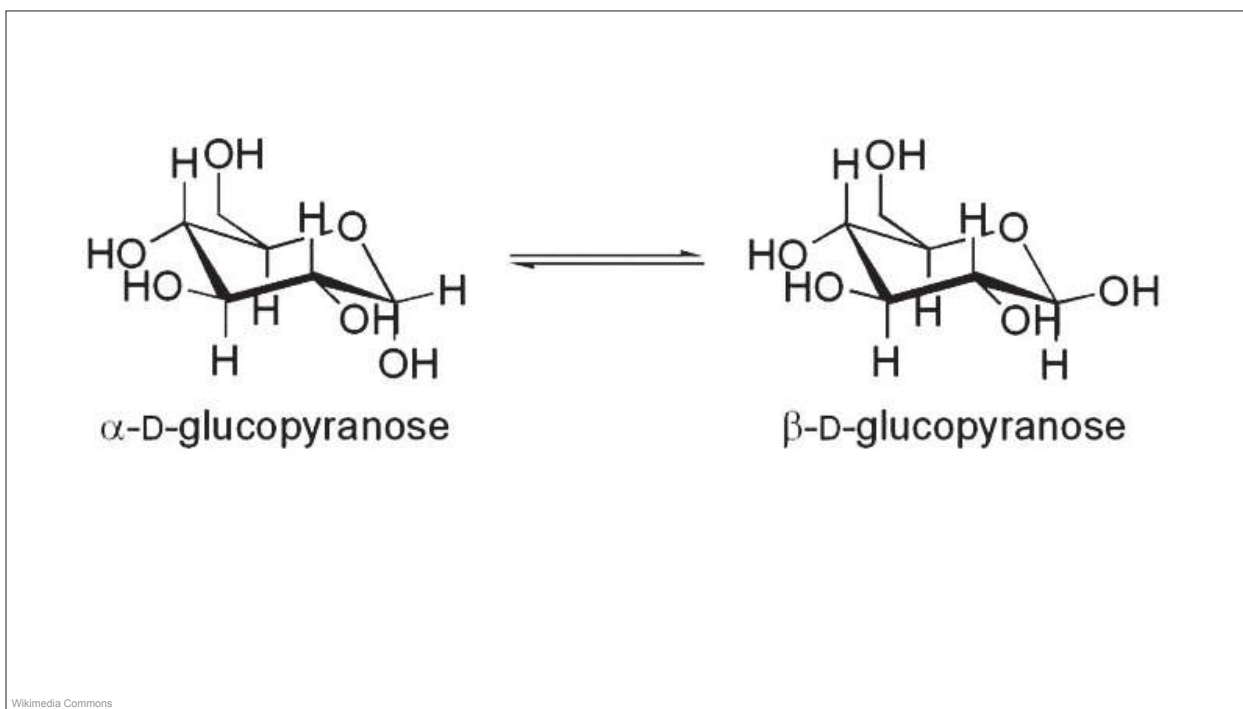
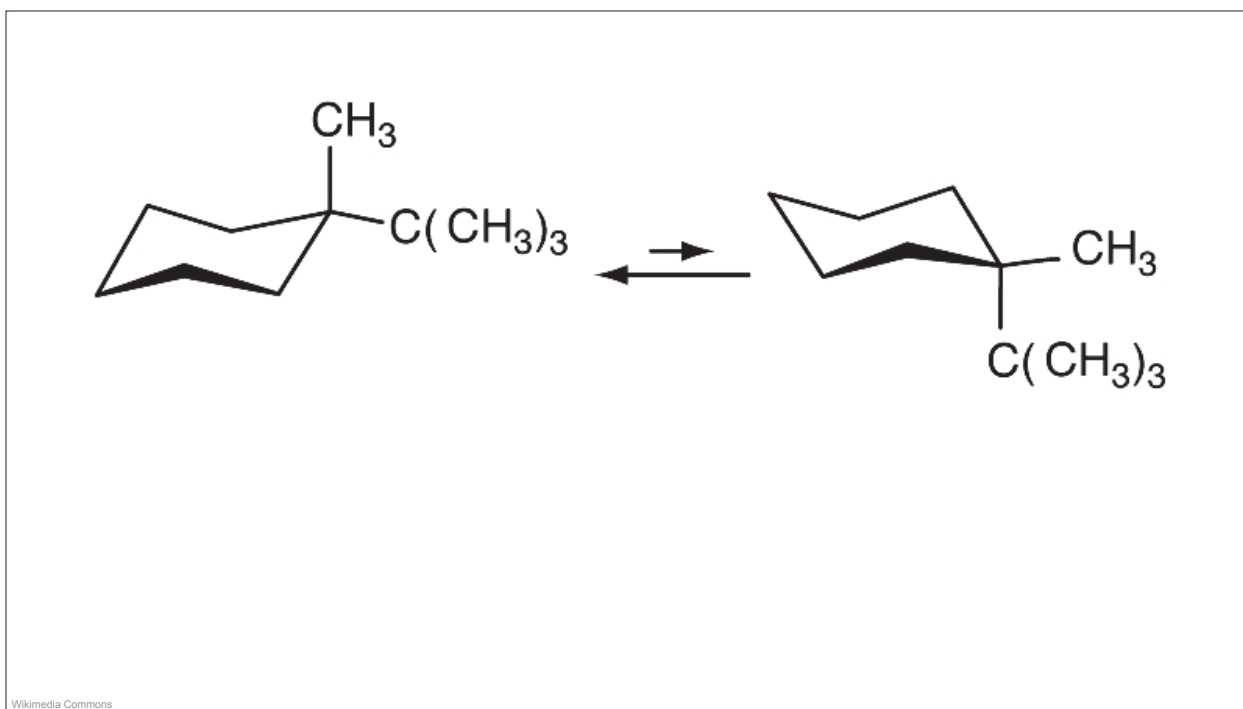


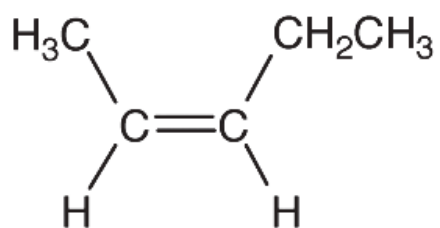
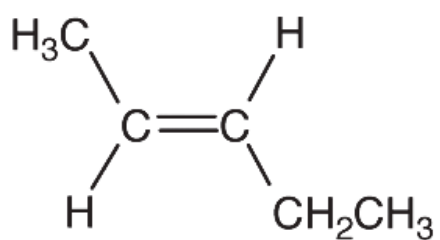


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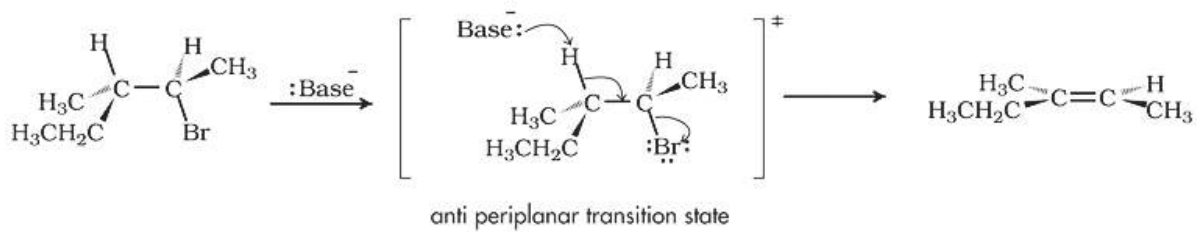
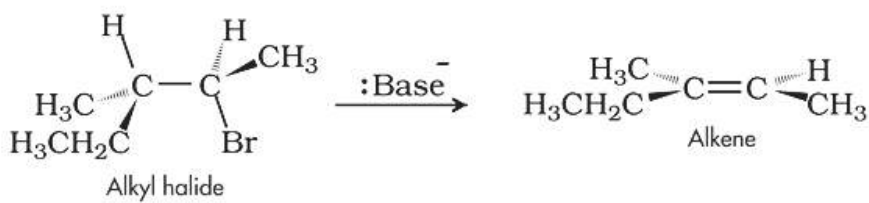


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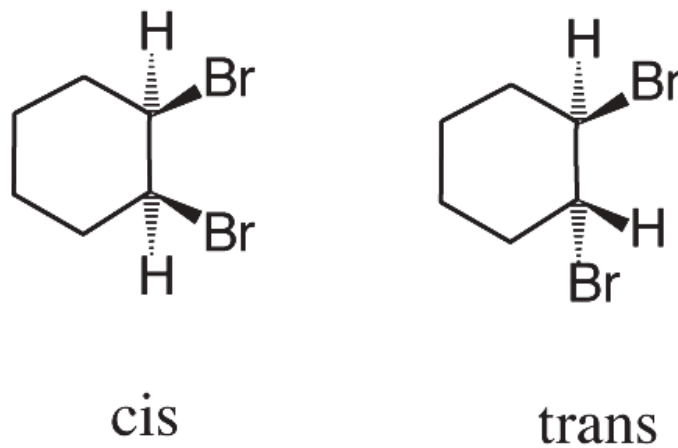


*cis**trans*

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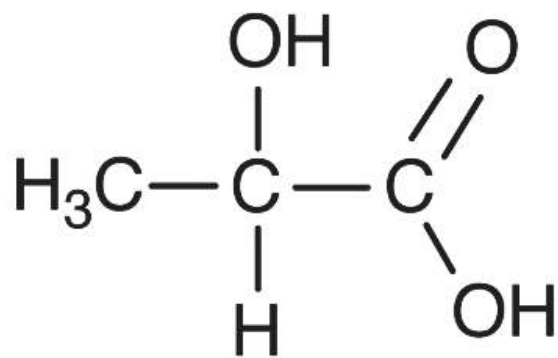
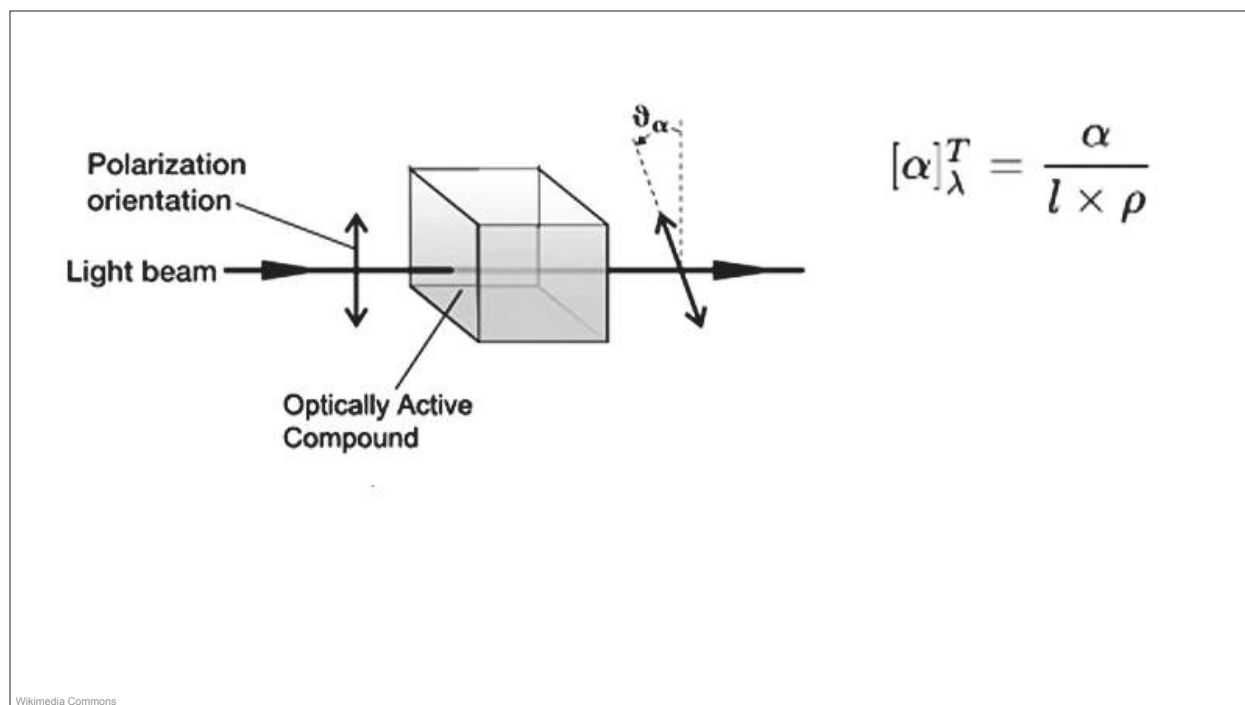
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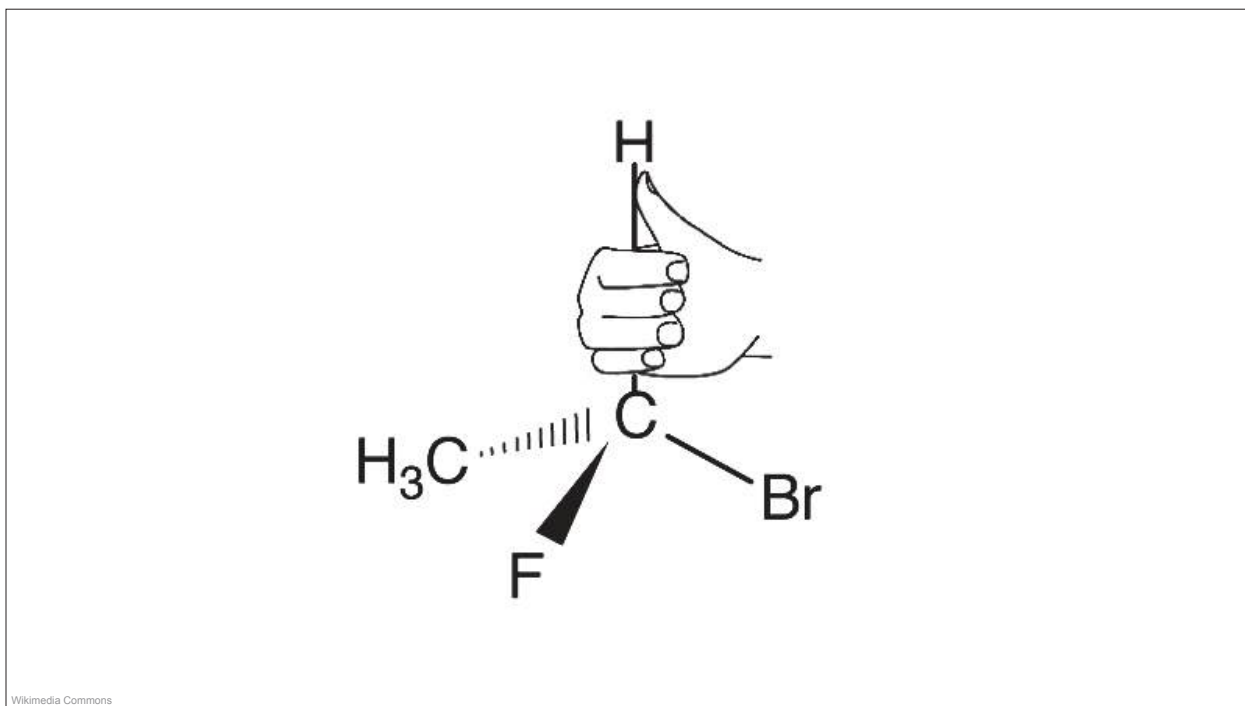
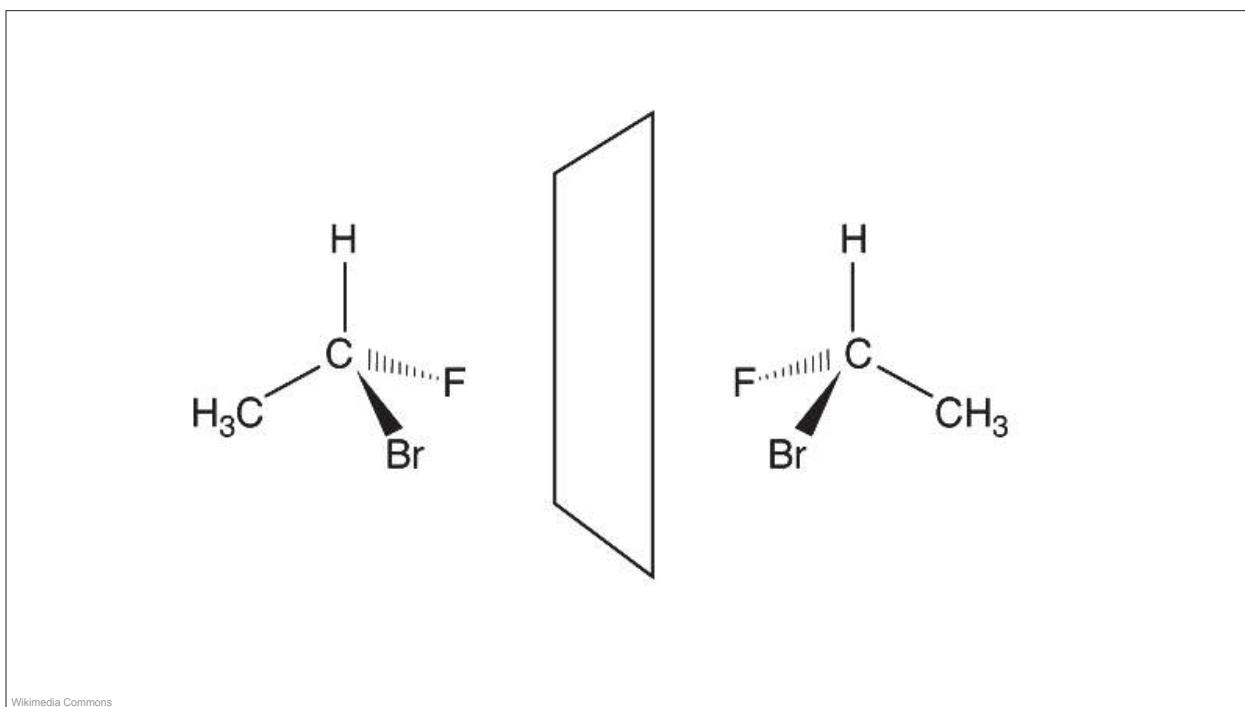


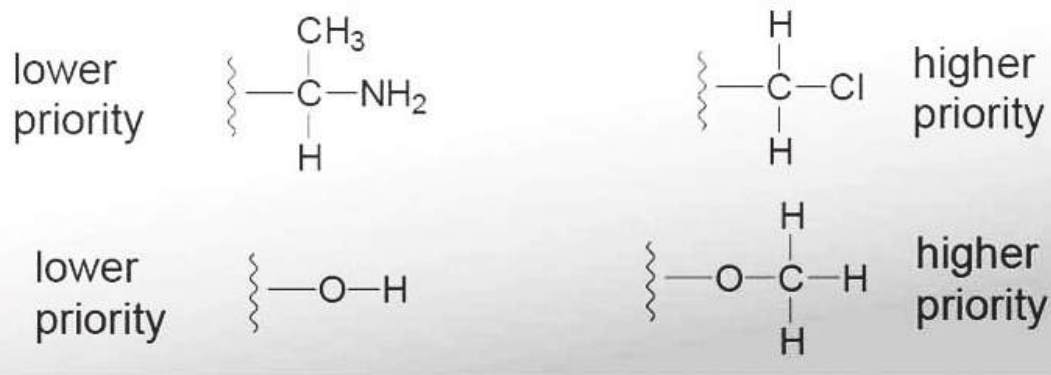
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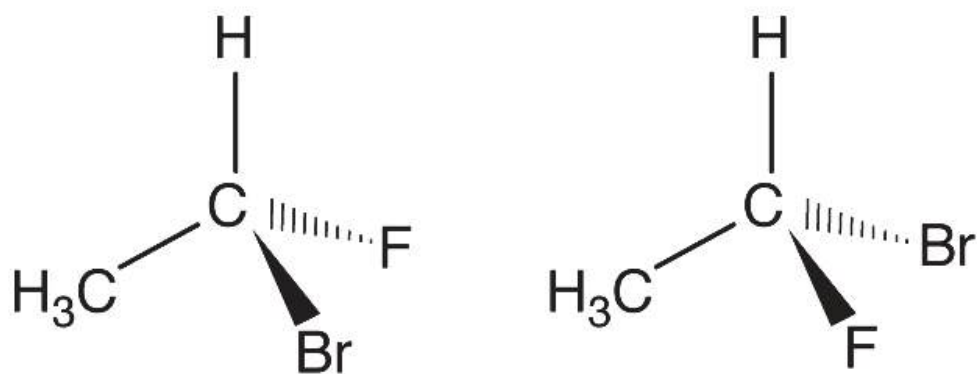
Lactic Acid

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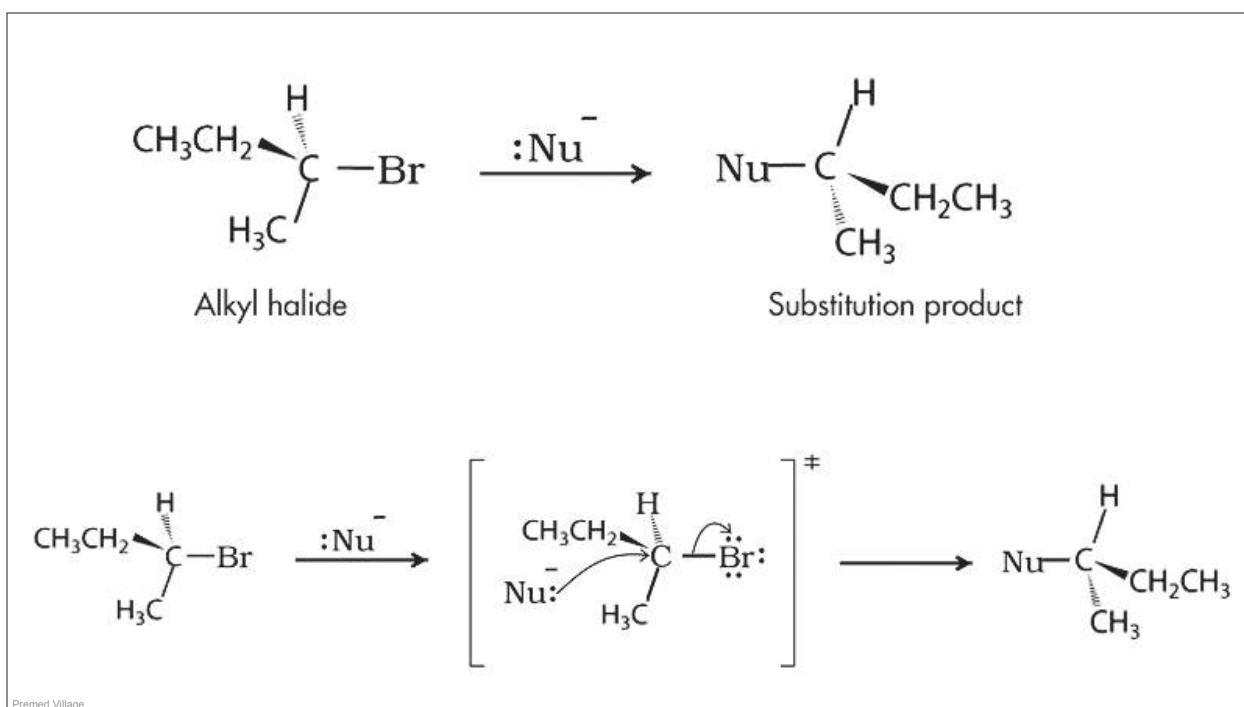


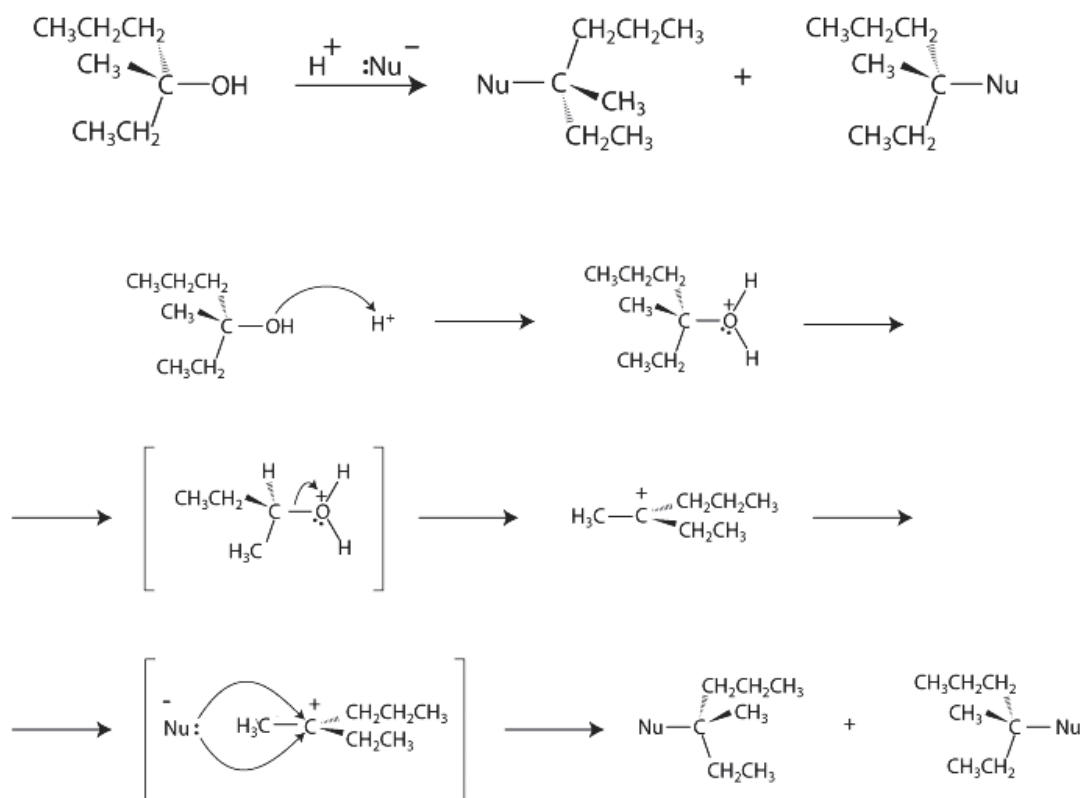


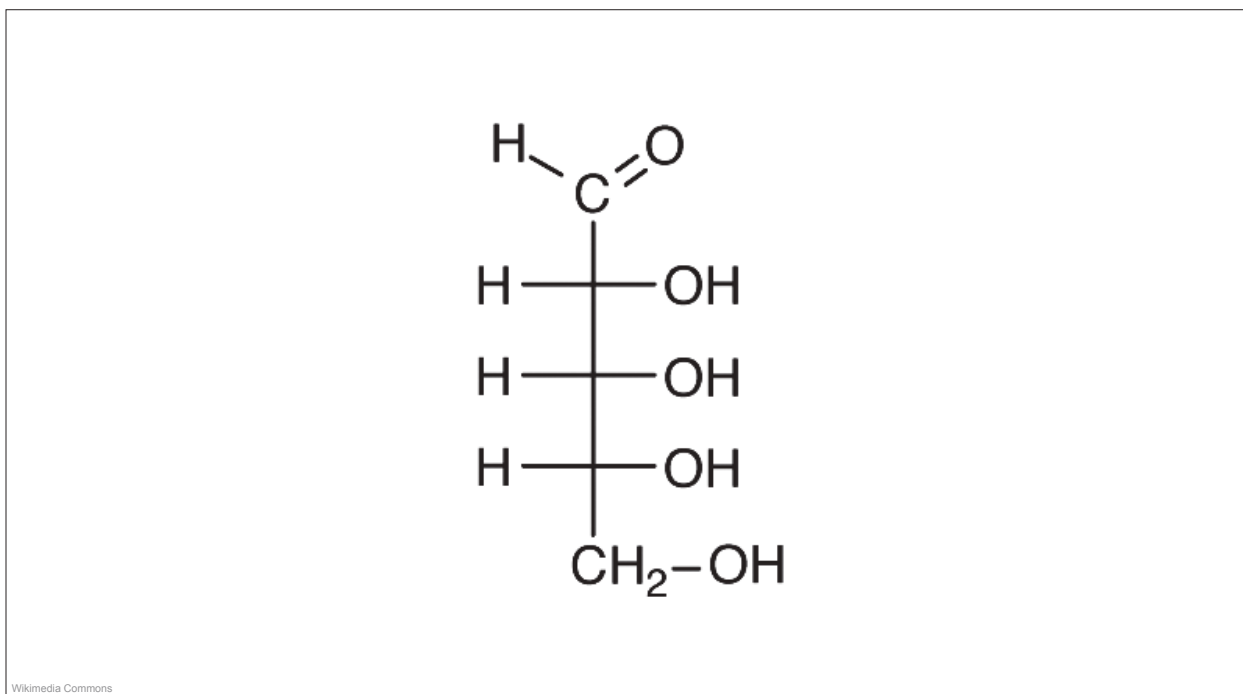
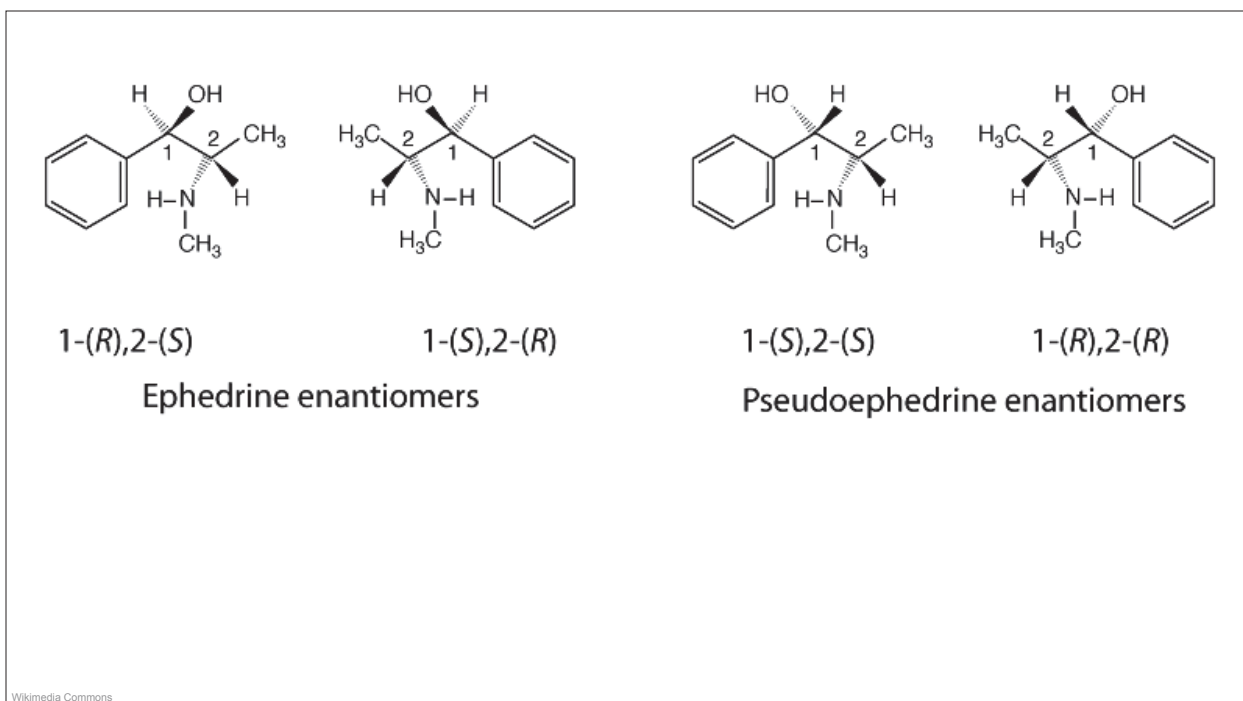
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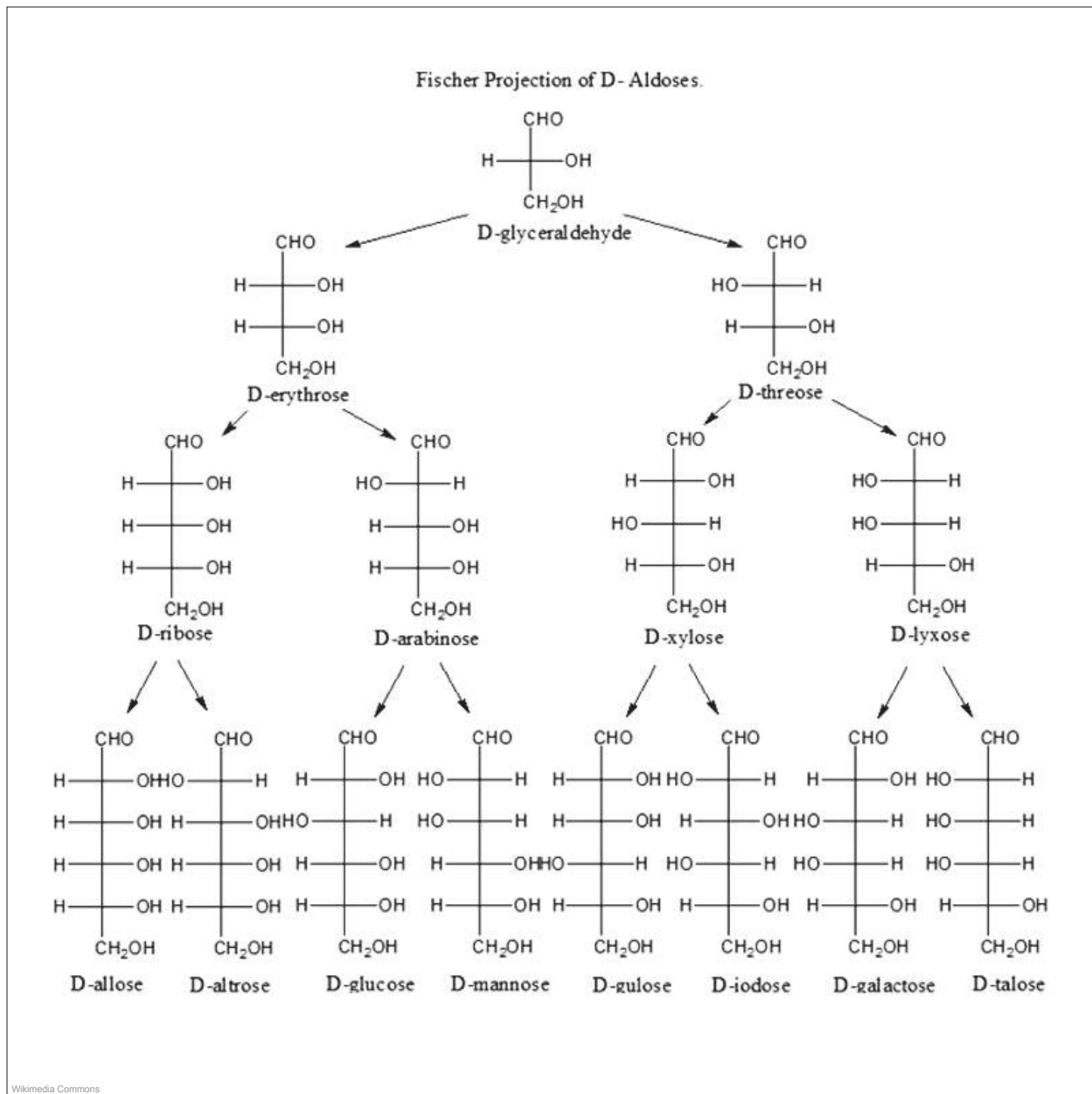


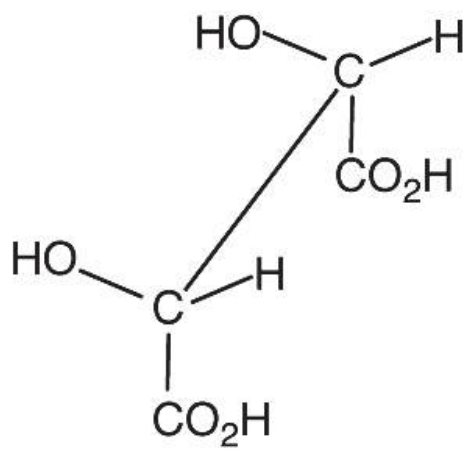
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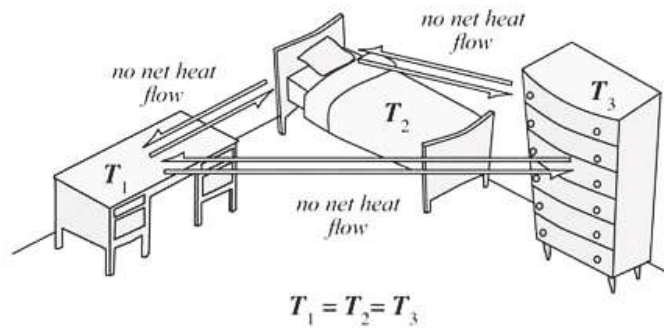




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Zeroth law

If two bodies are each in thermal equilibrium with a third body, then all three bodies are in thermal equilibrium with each other.



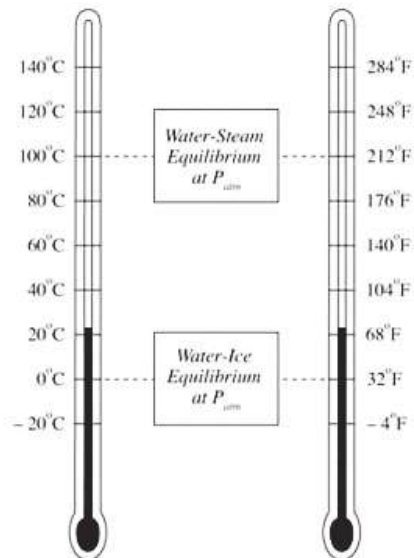
Systems at the same temperature are in thermal equilibrium.

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Converting Celsius and Fahrenheit

$$T_c = \frac{5}{9} (T_f - 32)$$

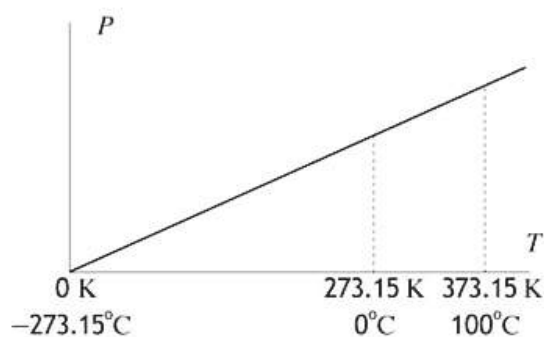
$$T_f = \frac{9}{5} T_c + 32$$



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Kelvin Temperature

$$T = T_c + 273.15$$

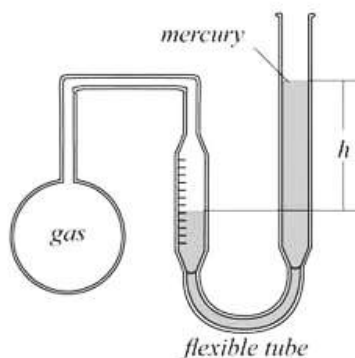


Pressure-Temperature Graph for a Constant Volume Gas Thermometer

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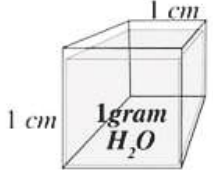
How does the constant volume gas thermometer pictured at right measure temperature?

- It measures the pressure of the gas.
- It measures changes in the volume of the mercury.
- It measures the thermal expansion of the gas.
- It measures the ratio of the density of the mercury to the density of the gas.



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Specific Heat

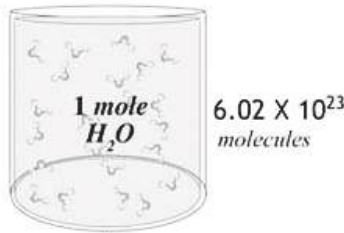


Heat per gram per degree Celsius

$$Q = m c \Delta T$$

Q = heat flow
 m = mass
 c = specific heat
 ΔT = temperature change

Molar Heat Capacity



Heat per mole per degree Celsius

$$Q = n C \Delta T$$

Q = heat flow
 n = number of moles
 C = molar heat capacity
 ΔT = temperature change

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According to the *rule of Dulong and Petit* the molar heat capacity of metals with atomic weight above 35 is relatively constant (about 26 J / mole • °C). From the information presented, which of the metals in the table below has the lowest specific heat?

Element	Atomic Weight	Molar Heat Capacity at STP
Ni	58.70	26.0 J / mole • °C
Ag	107.868	25.5
Cd	112.40	26.0
Pb	207.2	26.8

- a. Ni

b. Ag

c. Cd

d. Pb

The table below gives the heat capacities of ice, liquid water, and steam as well as the heats of transformation for melting and boiling water ($P = 1\text{ atm}$).

C_{ice} (cal/g \cdot $^{\circ}\text{C}$)	Latent Heat of Fusion (cal/g)	C_{water} (cal/g \cdot $^{\circ}\text{C}$)	Latent Heat of Vaporization (cal/g)	C_{steam} (cal/g \cdot $^{\circ}\text{C}$)
0.5	80	1	540	0.48

How much heat must be added to transform 1g of ice at -100°C into steam?

- a. 48 cal c. 621.5 cal
b. 580 cal d. 770 cal

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The easiest path has four steps: 1) heating the ice from -100°C to 0°C ; 2) melting the ice; 3) heating the liquid water from 0°C to 100°C ; and finally, 4) boiling the water. The amount of heat which must be added for temperature change equals the product of the mass, specific heat and temperature change. For the phase changes, the amount of heat equals the product of the mass and the heat of transformation. Here are the computations for each of the four steps:

$$Q_{-100^{\circ}\text{C} \rightarrow 0^{\circ}\text{C}} = (1\text{ g}) \left(.50 \frac{\text{cal}}{\text{g} \cdot ^{\circ}\text{C}} \right) (100^{\circ}\text{C}) = 50\text{ cal}$$

$$Q_{\text{fusion}} = (1\text{ g}) \left(80 \frac{\text{cal}}{\text{g}} \right) = 80\text{ cal}$$

$$Q_{0^{\circ}\text{C} \rightarrow 100^{\circ}\text{C}} = (1\text{ g}) \left(1 \frac{\text{cal}}{\text{g} \cdot ^{\circ}\text{C}} \right) (100^{\circ}\text{C}) = 100\text{ cal}$$

$$Q_{\text{vaporization}} = (1\text{ g}) \left(540 \frac{\text{cal}}{\text{g}} \right) = \underline{540\text{ cal}}$$

$$\text{sum} = 770\text{ cal}$$

THIS IS A VERY COMMONLY OCCURRING TYPE OF PROBLEM. (ALTHOUGH THE COMPUTATIONS HERE ARE SUPPOSED TO BE EASY ENOUGH TO DO IN YOUR HEAD, IT'S A GOOD IDEA IN A TEST ENVIRONMENT TO WRITE THE COMPUTATIONS DOWN TO AVOID MISTAKES.)

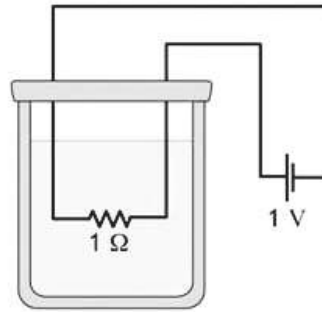


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The Dewar flask at right contains 100ml of water at 25°C.

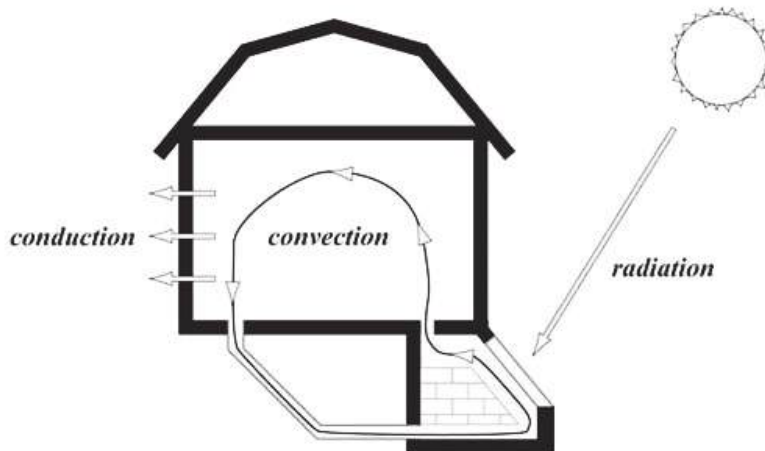
After a 1 volt (1 joule per coulomb) battery begins to deliver 1 ampere (1 coulomb per second) of current through the resistance immersed in the water, approximately how long does it take the water temperature to reach 35°C?



- a. 10 seconds
- b. 32 seconds
- c. 1000 seconds
- d. 4200 seconds

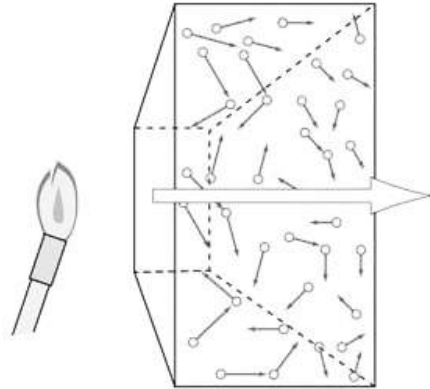
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Three Modes of Heat Transmission



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Transmission of Heat by Conduction



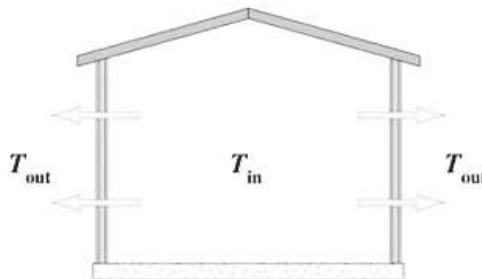
$$\frac{Q}{t} = K A \frac{\Delta T}{\Delta x}$$

- Q = heat flow
- t = time
- K = thermal conductivity of material
- A = cross-sectional area
- ΔT = temperature difference across the conductor ($T_2 - T_1$)
- Δx = conductor thickness

When warmer (faster) molecules collide with cooler (slower) molecules, the warmer molecules transfer part of their energy to the cooler molecules. Conduction of heat is occurring.

Premed Village

Night or day, the interior of a house is maintained at a constant temperature of 27°C . During the day, the outside temperature is 17°C . At night, the outside temperature is 7°C . What is the approximate percentage increase in the rate of heat lost by conduction through the walls of a house at night versus the day?



- a. 3%
- b. 9%
- c. 50%
- d. 100%

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Transmission of Heat by Radiation - Stefan's Law



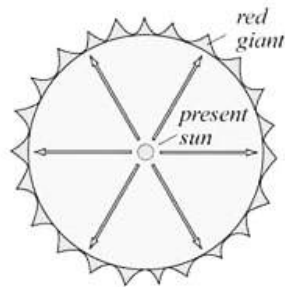
The tungsten filament ($\epsilon = 0.4$) of a typical 100W bulb has a surface area of 40mm^2 and an operating temperature of about 3200K.

$$\frac{Q}{t} = A\epsilon\sigma T^4$$

- Q = heat (light) emitted
- t = time
- A = surface area of emitter
- ϵ = emissivity
- σ = Stefan-Boltzmann constant
($5.7 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^2$)
- T = emitter absolute temperature

Premed Village

Scientists predict that in approximately five billion years the energy from a changing hydrogen fusion dynamic within our sun will push the outermost layers of the star outward. Expanding and cooling, the sun will become a red giant, perhaps even engulfing the earth. If its temperature decreases from 6000K to 3000K and its radius undergoes a 40 fold increase, what will be the resulting change in the luminosity of the Sun? (luminosity is the rate of total light emission)



Growth of the sun into a red giant will occur in approximately five billion years.

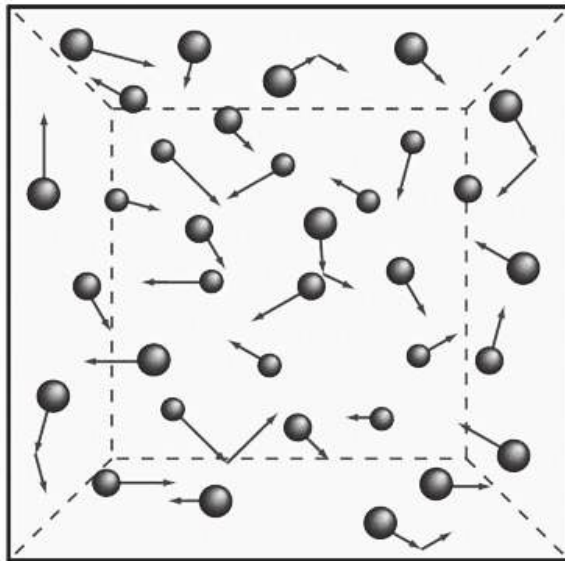
- a. 16 fold decrease
- b. 80 fold decrease
- c. 20 fold increase
- d. 100 fold increase

Premed Village

Engineers designed the Apollo capsule/command module to be constructed with a silvered exterior to control heat exchange with the environment during space travel. Which of the following were among the effects of this design feature on heat exchange?



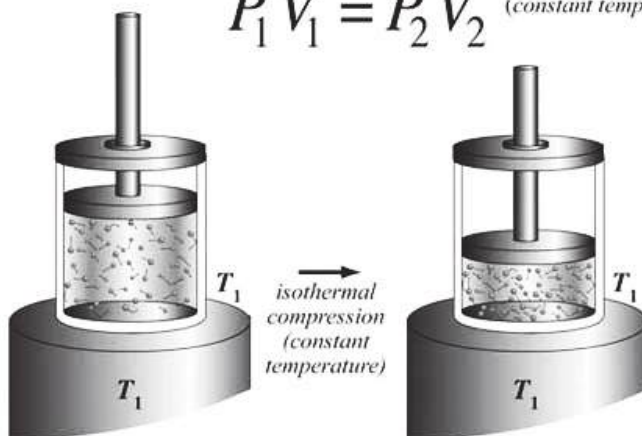
- a. Maximizing the absorption of energy from the surroundings
- b. Minimizing the radiation of energy to the surroundings
- c. Minimizing convection currents within the vehicle
- d. Maximizing conductive diffusion of heat along the vehicle



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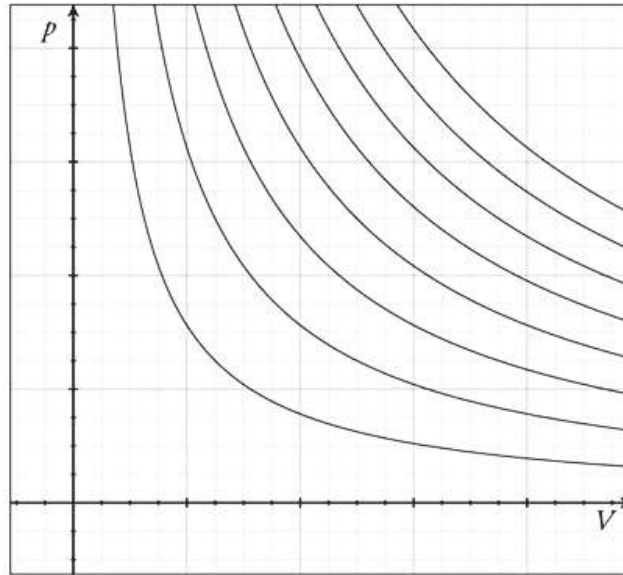
Boyle's Law

$$P_1 V_1 = P_2 V_2 \quad (\text{constant temperature})$$



Thermal equilibrium with the heat sink allows the gas to be compressed at constant temperature, isothermally. With constant temperature, Boyle's Law applies. The pressure and volume are inversely proportional (PV is constant). Pressure increases as volume decreases.

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Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (\text{constant pressure})$$

Weight for pressure regulation



isobaric expansion
(constant pressure)



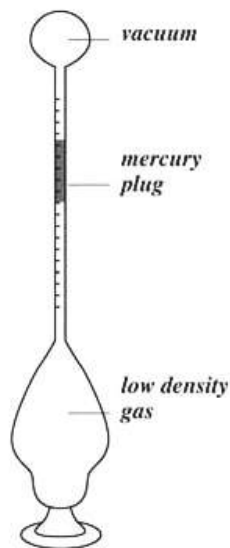
Heat source

Heating a gas makes its particles move faster. Collisions are stronger. Therefore, to exert the same pressure, the particles must be more spread out. The volume must have increased.

Premed Village

How does the thermometer at right measure temperature?

- a. It measures the pressure of the gas.
- b. It measures changes in the volume of the mercury.
- c. It measures the volume of the gas.
- d. It measures the ratio of the density of the mercury to the density of the gas.

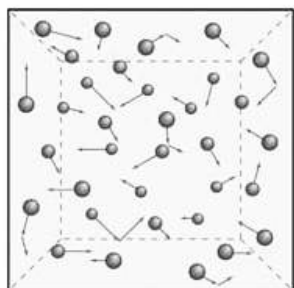


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The Ideal Gas Law

$$PV = nRT$$

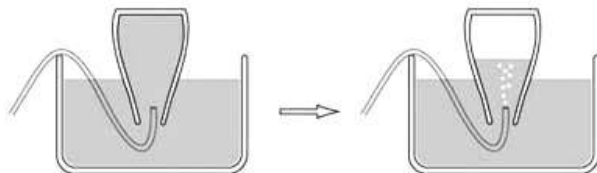
- P = pressure
- V = volume
- T = temperature
- n = # of moles of gas
- R = ideal gas constant
[8.31 J/mole · K]
[0.082 liter · atm/mole · K]



1 mole of an ideal gas occupies 22.4 liters at STP.

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To serve as an apparatus for collecting gaseous substances a flask is completely filled with water and inverted with its mouth submerged within a larger container of water.



Student A collects methane gas (CH_4) in this manner, and student B collects propane gas (C_3H_8). After each has collected one gram of substance:

- the gaseous phase in student A's flask has greater volume
- the gaseous phase in student B's flask has greater volume
- the volume of the gaseous phases of both flasks are equal
- the gaseous phase in student B's flask has greater pressure

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The Temperature of an Ideal Gas Depends on the Average Translational Kinetic Energy of the Particles

$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$$

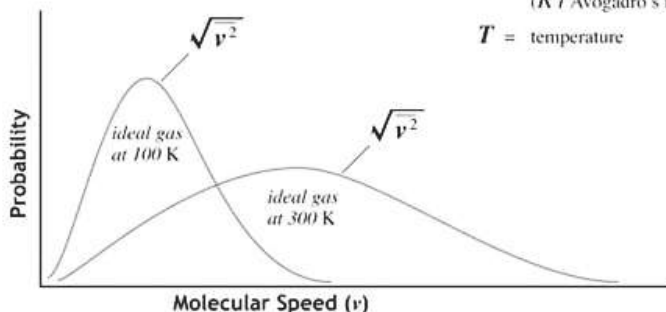
m = mass

$\overline{v^2}$ = average square speed

k = Boltzmann's constant

(R / Avogadro's number)

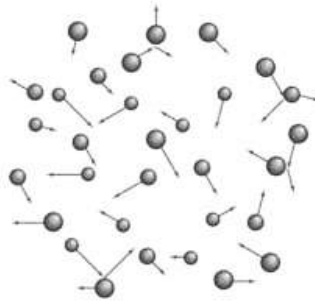
T = temperature



The difference in the velocity distribution curves for ideal gas particles at 100 K and 300 K shows the dependence of the average translational kinetic energy of the particles on temperature.

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The Internal Energy of an Ideal Gas Depends on Temperature



$$U = \frac{3}{2}NkT$$

U = internal energy
 N = number of molecules
 k = Boltzmann's constant
 = R / Avogadro's number
 T = temperature

$$U = \frac{3}{2}nRT$$

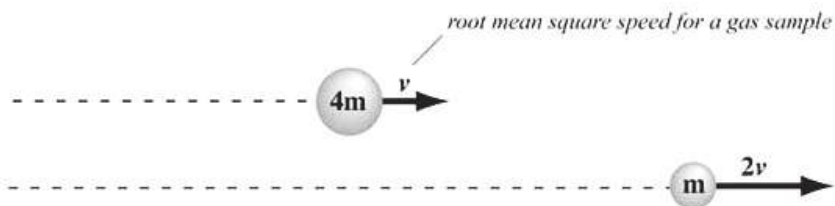
n = moles of gas
 R = ideal gas constant

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RMS Particle Speed Is Inversely Proportional to the Square Root of Particle Mass (for a given temperature)

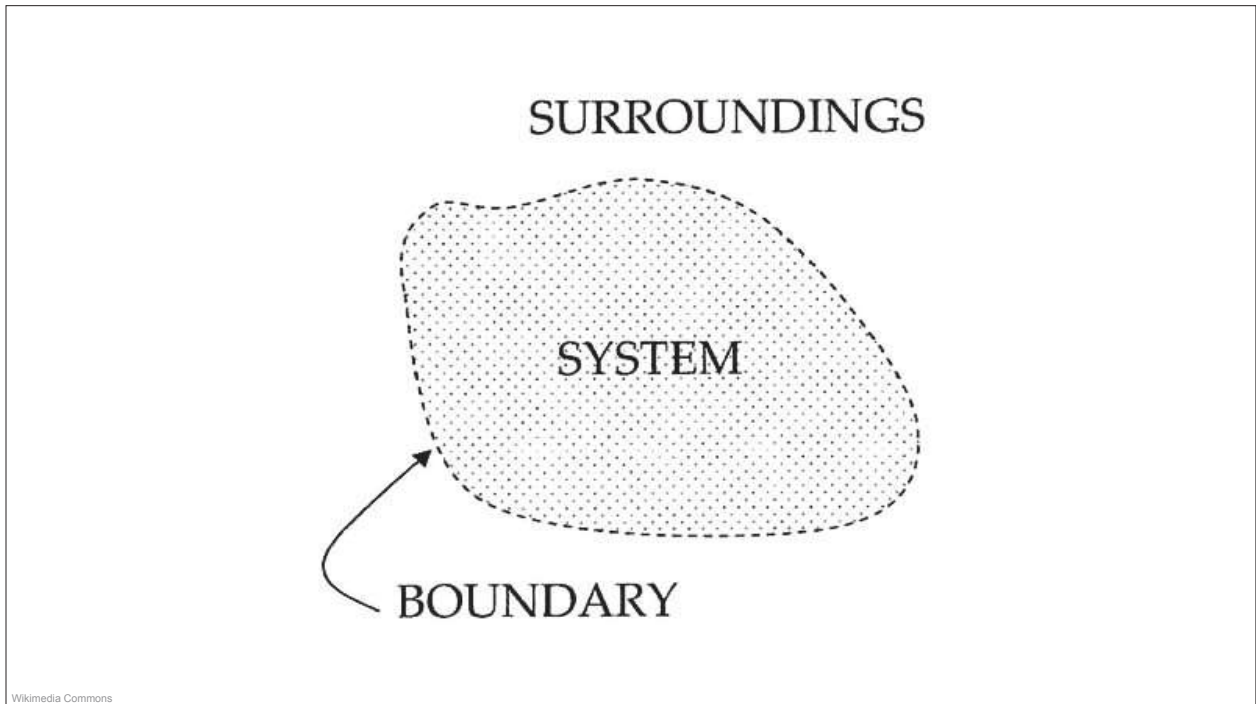
$$\frac{\bar{v}_A}{\bar{v}_B} = \frac{\sqrt{m_B}}{\sqrt{m_A}}$$

m = mass
 \bar{v} = root mean square speed
 (square root of average square speed)



'Average' (root mean square) speed is inversely proportional to the square root of molecular mass. For two samples of ideal gas at the same temperature, if the molecules of one gas are four times larger, the root mean square speed is half as great.

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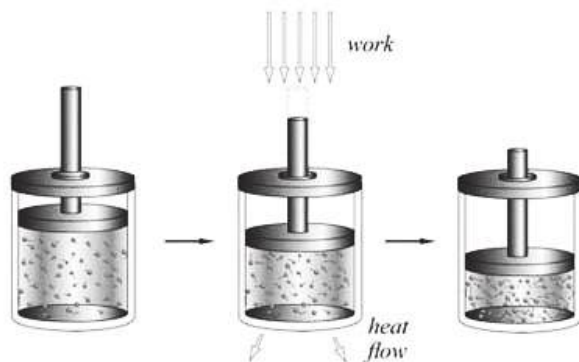


The First Law of Thermodynamics

$$\Delta U = Q - W$$

$$= Q - P^* \Delta V$$

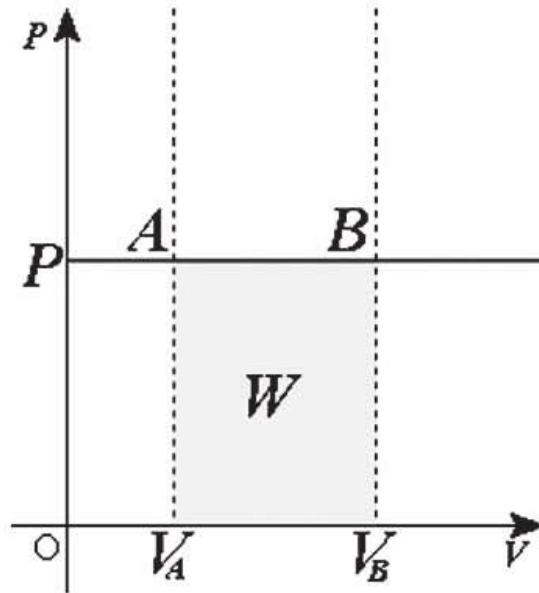
- ΔU = internal energy change
- Q = heat flow
- W = macroscopic work
- P^* = constant pressure
- ΔV = volume change



Internal energy change results from the combination of heat flow and work between the system and its surroundings. In this example, the internal energy of our ideal gas system became greater (the particles are moving faster in the final state) because more energy entered the system through work than departed the system as heat flow.

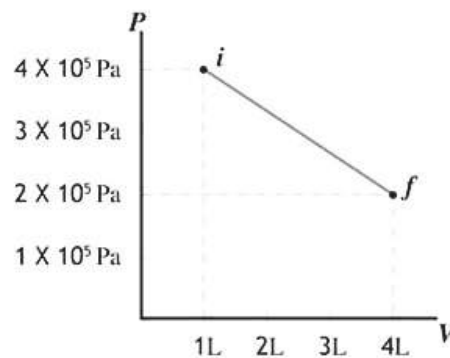
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Ideal Gas and the 1st Law of Thermodynamics



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The straight line on the graph shows the path between the initial and final states in the expansion of a gas. How much work is performed by the gas during the expansion?



- a. 900 J
- b. 1150 J
- c. 90,000 J
- d. $9 \times 10^5 \text{ J}$

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An ideal gas is taken from the same initial state and same final state by the three alternative pathways:

(1) (2) (3)

Which of the following are equal for all three pathways.

I. work done by the gas	a. II only
II. heat flow between the gas and the surroundings	b. II and IV
III. internal energy change	c. III and IV
IV. temperature change	d. I, II, III, and IV

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Adiabatic Process

Insulated Piston

No Heat Flow

$$Q = 0$$

$$\Delta U = -W$$

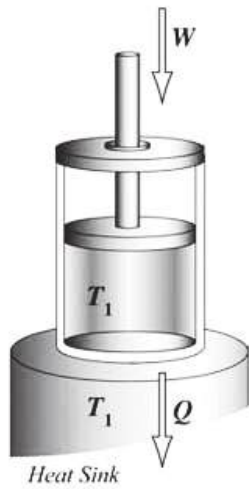
First law of thermodynamics for an adiabatic process

Q = heat flow
 ΔU = internal energy change
 W = macroscopic work

In an adiabatic process, no heat flow occurs, so internal energy change directly corresponds to the work performed.

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Isothermal Process



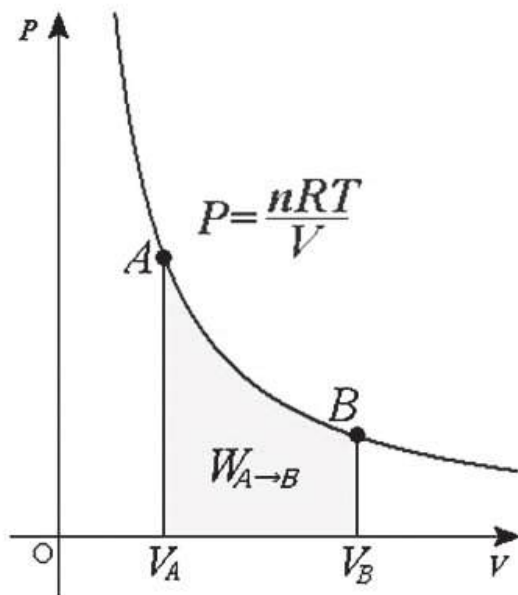
$$\Delta U = 0$$
$$Q = W$$

*First law of thermodynamics
for an isothermal process*

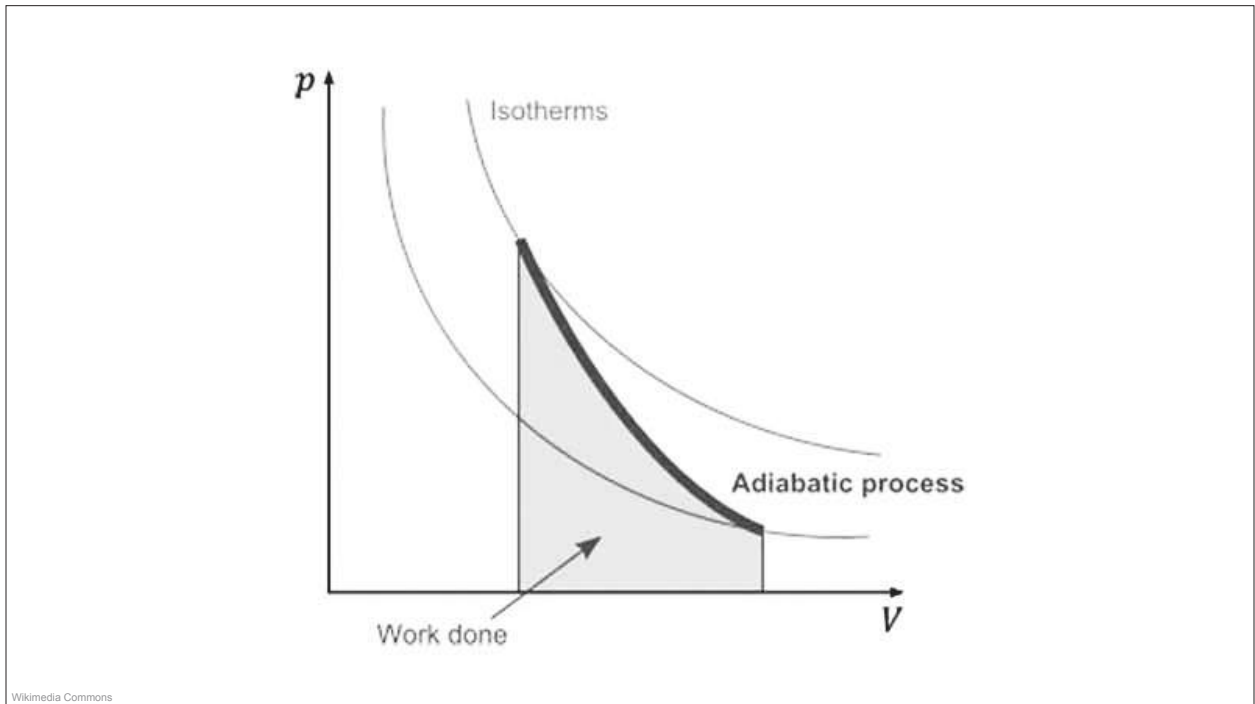
- ΔU = internal energy change
- Q = heat flow
- W = macroscopic work

In an isothermal process on an ideal gas, the temperature is constant. Because temperature is constant, internal energy must be constant. If internal energy is constant, any work that occurs must be balanced by heat flow.

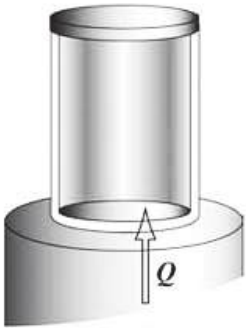
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Isovolumetric Process



$$W = 0$$

$$\Delta U = Q$$

*First law of thermodynamics
for an isovolumetric process*

W = macroscopic work
 ΔU = internal energy change
 Q = heat flow

In an isovolumetric process, no thermodynamic work occurs. The only way internal energy changes is through heat flow.

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The First Law of Thermodynamics

$$\Delta U = Q - W$$

$$= Q - P^* \Delta V$$

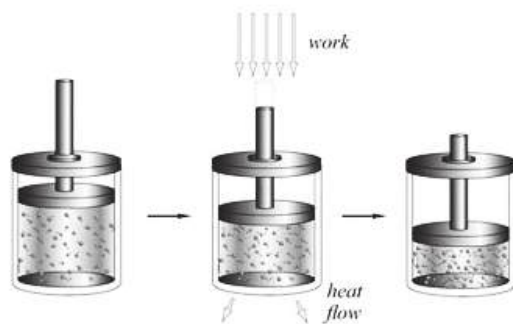
ΔU = internal energy change

Q = heat flow

W = macroscopic work

P^* = constant pressure

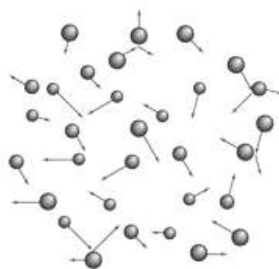
ΔV = volume change



Internal energy change results from the combination of heat flow and work between the system and its surroundings. In this example, the internal energy of our ideal gas system became greater (the particles are moving faster in the final state) because more energy entered the system through work than departed the system as heat flow.

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The Internal Energy of an Ideal Gas Depends on Temperature



$$U = \frac{3}{2} N k T$$

U = internal energy
 N = number of molecules
 k = Boltzmann's constant
 = R / Avogadro's number
 T = temperature

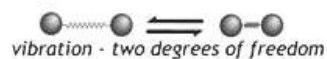
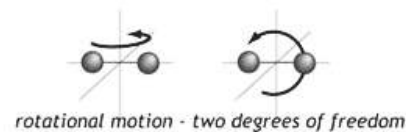
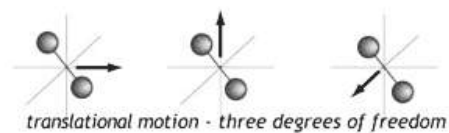
$$U = \frac{3}{2} n R T$$

n = moles of gas
 R = ideal gas constant

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Molar Heat Capacities ($\text{J mol}^{-1} \text{K}^{-1}$)

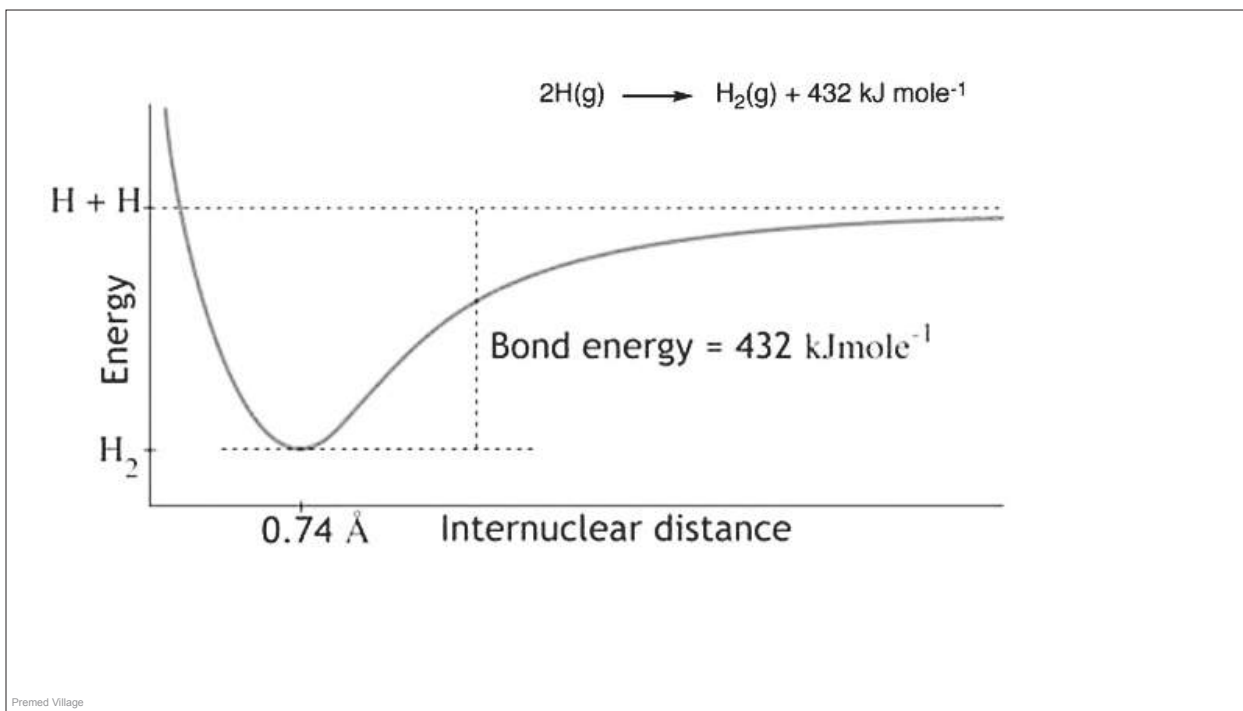
He	20.5	N ₂	29.5	H ₂ O	33.5
Ar	20.5	F ₂	31.4	CO ₂	37.2

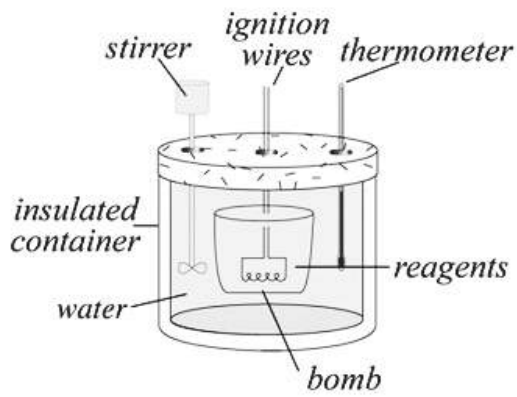


$$KE_{total} = KE_{trans} + KE_{rot} + KE_{vib}$$

$$U = KE_{total} + PE_{total}$$

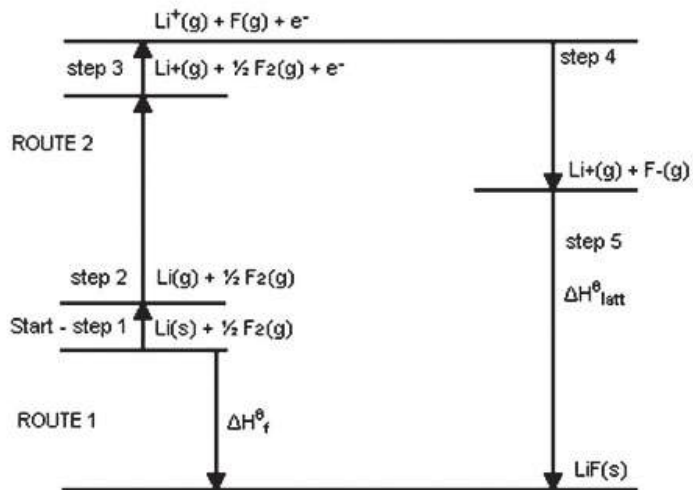
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$$\Delta U = Q \quad (\text{constant volume, } W = 0)$$

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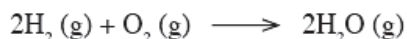
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A positive value of ΔH for a reaction means that:

- A. The internal energy of the substance has increased.
- B. Heat is given off to the environment during the reaction.
- C. Heat is absorbed from the environment during the reaction.
- D. The reaction is exothermic.

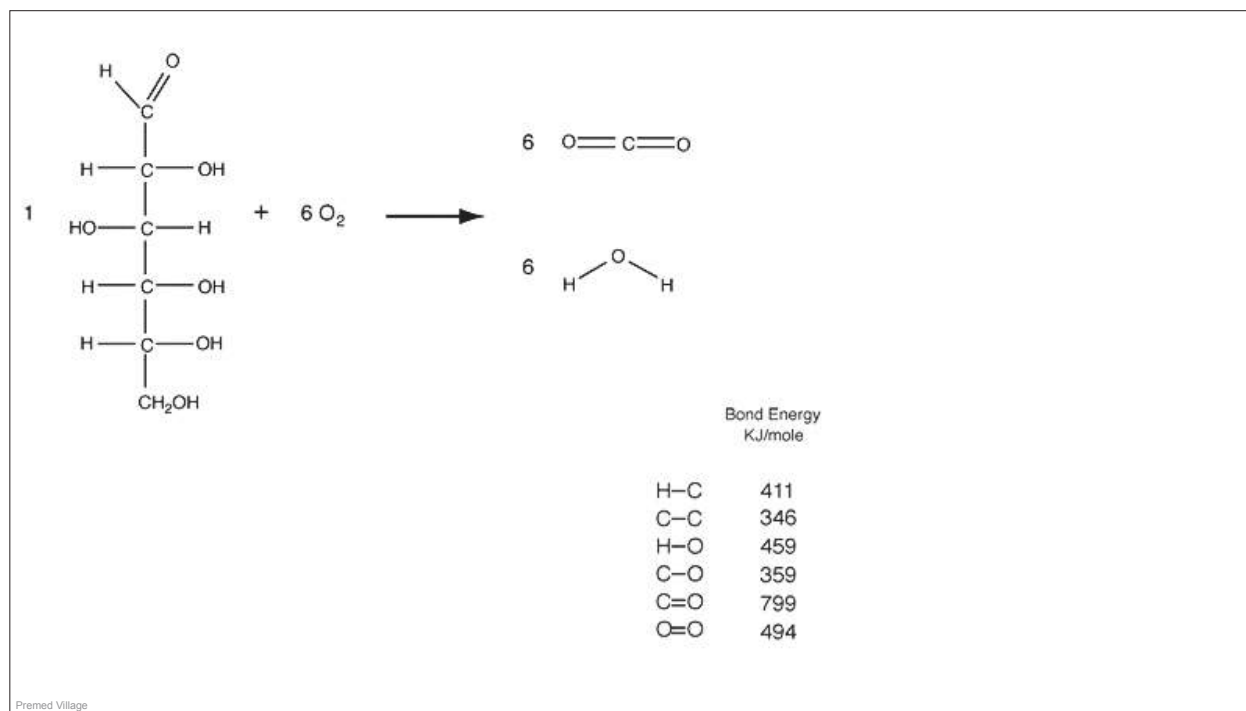
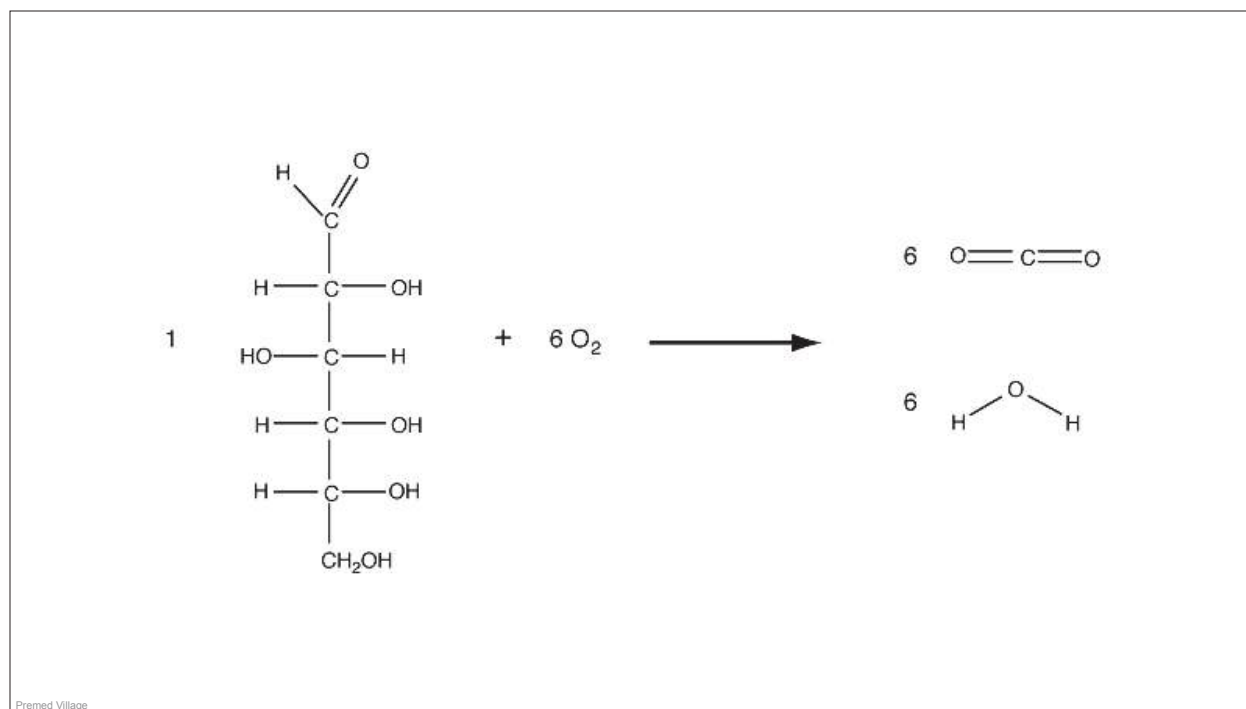
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Which of the following statements is true about the following exothermic reaction, when carried out at constant temperature and pressure?

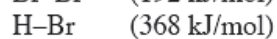
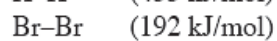
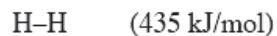


- A. The magnitude of the change in internal energy over the reaction is greater than the magnitude of the enthalpy change.
- B. The magnitude of the change in internal energy over the reaction is less than the magnitude of the enthalpy change.
- C. The magnitude of the change in internal energy over reaction is equal to the magnitude of the enthalpy change.
- D. Impossible to determine any of the above from given information.

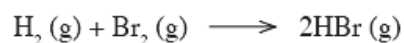
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Given these bond energies:

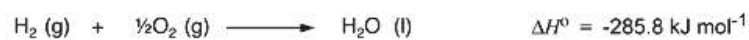
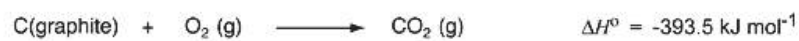


Which of the following would be the best estimate of the enthalpy change of the following reaction?



- A. -26 kJ
- B. -109 kJ
- C. 259 kJ
- D. 109 kJ

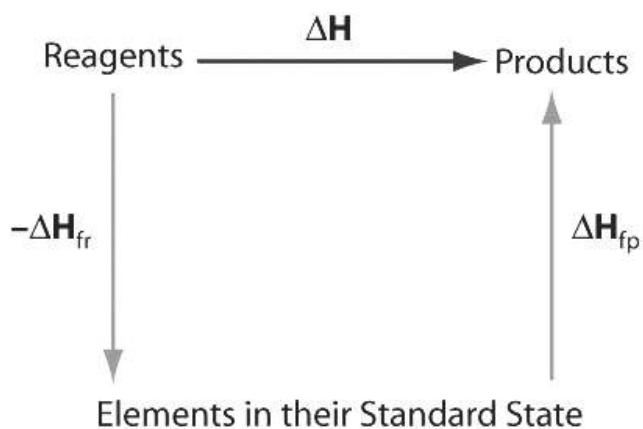
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Chemical Compound	Phase (matter)	Chemical formula	ΔH_f° in kJ/mol
Ammonia (Ammonium Hydroxide)	aq	NH ₃ (NH ₄ OH)	-80.8
Ammonia	g	NH ₃	-46.1
Copper (II) sulfate	aq	CuSO ₄	-769.98
Sodium carbonate	s	Na ₂ CO ₃	-1131
Sodium chloride (table salt)	s	NaCl	-411.12
Sodium hydroxide	aq	NaOH	-469.6
Sodium hydroxide	s	NaOH	-426.7
Sodium nitrate	s	NaNO ₃	-424.8
Sulfur dioxide	g	SO ₂	-297
Sulfuric acid	l	H ₂ SO ₄	-814
Silica	s	SiO ₂	-911

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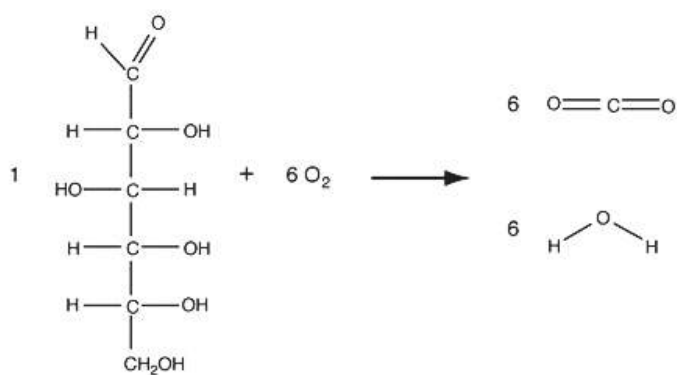


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$$\Delta H = H_{\text{products}} - H_{\text{reactants}}$$

$$\Delta H = \sum \Delta H_f^{\circ} \text{products} - \sum \Delta H_f^{\circ} \text{reactants}$$

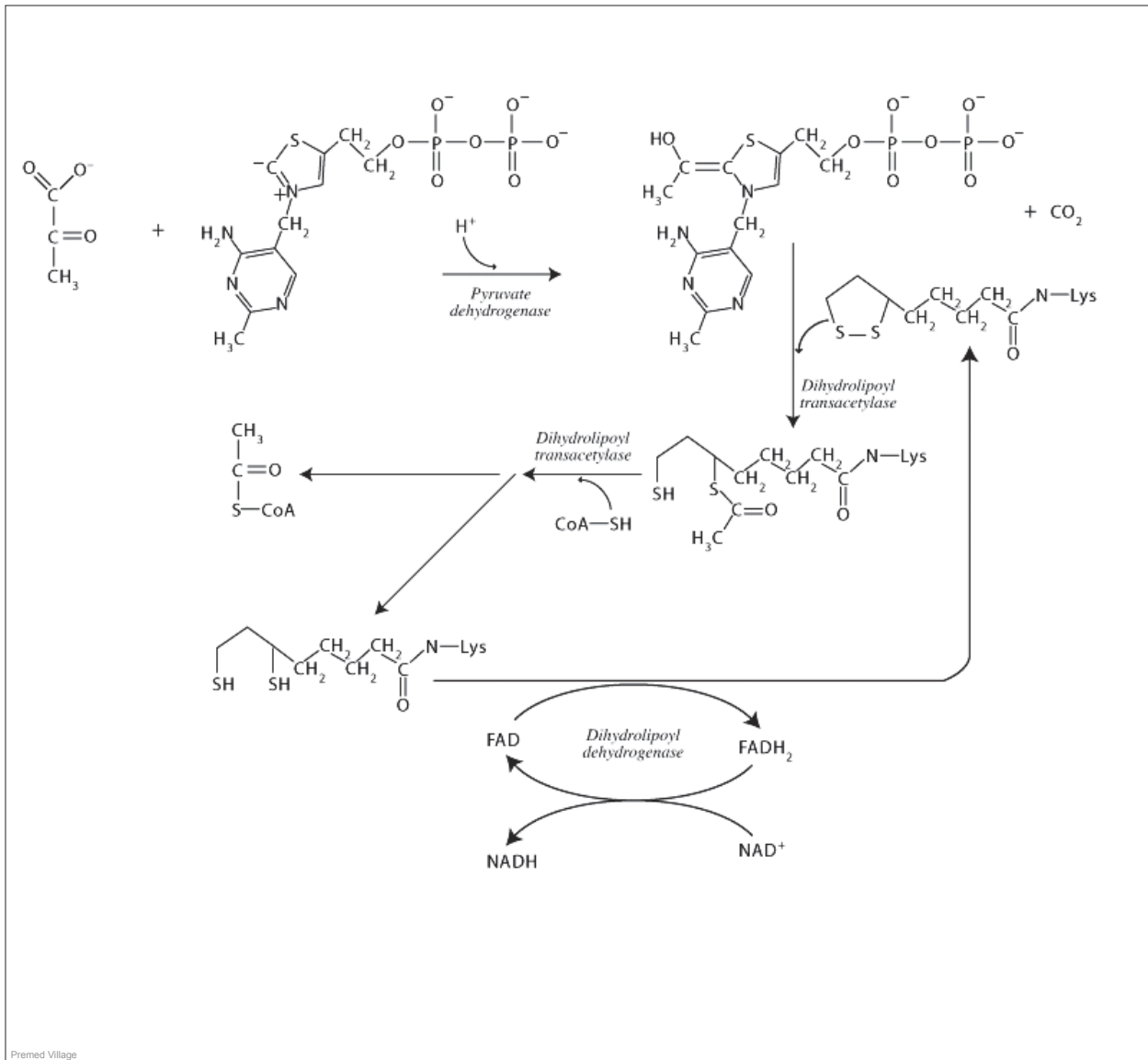
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Standard Enthalpies
KJ/mole

Glucose	-1274
O ₂	0
CO ₂	-286
H ₂ O	-394

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Thermochemistry



Entropy

An isolated system tends toward disorder (greater entropy) because disordered states are more probable. Possible disordered states outnumber ordered states.

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What is the relationship between a microstate and a macrostate of a thermodynamic system?

- A. A microstate is a point in phase space, whereas a macrostate specifies the relationship of the system to its surroundings.
- B. A microstate corresponds to the quantum electrodynamic parameters of the system, whereas a macrostate describes the system as measured in the laboratory.
- C. A macrostate corresponds to the macroscopic properties of a statistical ensemble of systems comprised of the accessible microstates.
- D. A microstate defined by specifying external parameters, such as volume and temperature, whereas a macrostate is defined as a state for which the motions of the individual particles are completely specified.

- In the system below, two bulbs are connected by a tube and stopcock. In the initial state, all of the gas (N particles) is constrained to occupy a single bulb. When the stopcock is opened, the gas spontaneously moves to occupy both bulbs. In this example, with the stopcock opened, the probability of the second state is 2^N times that of the initial state.



- Entropy rises with the multiplicity of the system (the number of possible internal configurations that correspond to a particular macrostate).

$$S = k \ln X$$

S = entropy
 k = Boltzmann's constant
 X = multiplicity

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Free expansion is an irreversible process in which a gas expands into an insulated evacuated chamber. During a free expansion

- I. the temperature remains constant
 - II. the entropy of the gas increases
 - III. the internal energy of the gas remains constant
- A. I
 - B. I and III
 - C. II and III
 - D. I, II, and III

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Carbon monoxide is a linear molecule. The carbon and oxygen atoms are roughly the same size and the dipole moment of the molecule is relatively small. This means that at temperatures just below its freezing point (74K), the molecules of this substance can flip easily in the crystal and assume one of two orientations with equal probability. The probability of flipping vanishes at even lower temperatures, though, as the temperature approaches absolute zero, where motion ceases and only one quantum energy state is available to each molecule. At absolute zero, the theoretical entropy of pure carbon monoxide crystal would be:

- a. zero
- b. a small positive value
- c. a small negative value
- d. absolute zero is impossible to attain



carbon monoxide

Premed Village

Entropy Change Due to Heat Flow

$$\Delta S = \frac{\Delta Q_r}{T}$$

ΔS = entropy change
 Q_r = heat flow (in reversible process)
 T = temperature

Premed Village

When a hot stone is dropped into a cool water bath and heat flows from the stone into the bath

- A. More entropy is lost in the stone than gained by the water.
- B. More entropy is gained by the stone than lost by the water.
- C. Less entropy is lost by the stone than gained by the water.
- D. The change in entropy in the stone is balanced by an equal and opposite change in entropy in the water.

Premed Village

Which of the following does NOT change for a sample of ideal gas undergoing an adiabatic compression?

- A. entropy
- B. internal energy
- C. pressure
- D. volume

Which of the following does NOT change for a sample of ideal gas undergoing an isothermal compression?

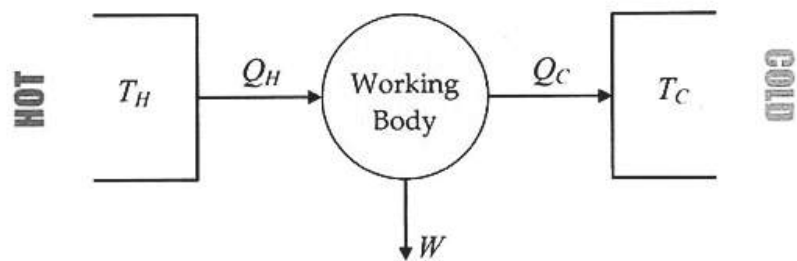
- A. entropy
- B. internal energy
- C. pressure
- D. volume

Premed Village

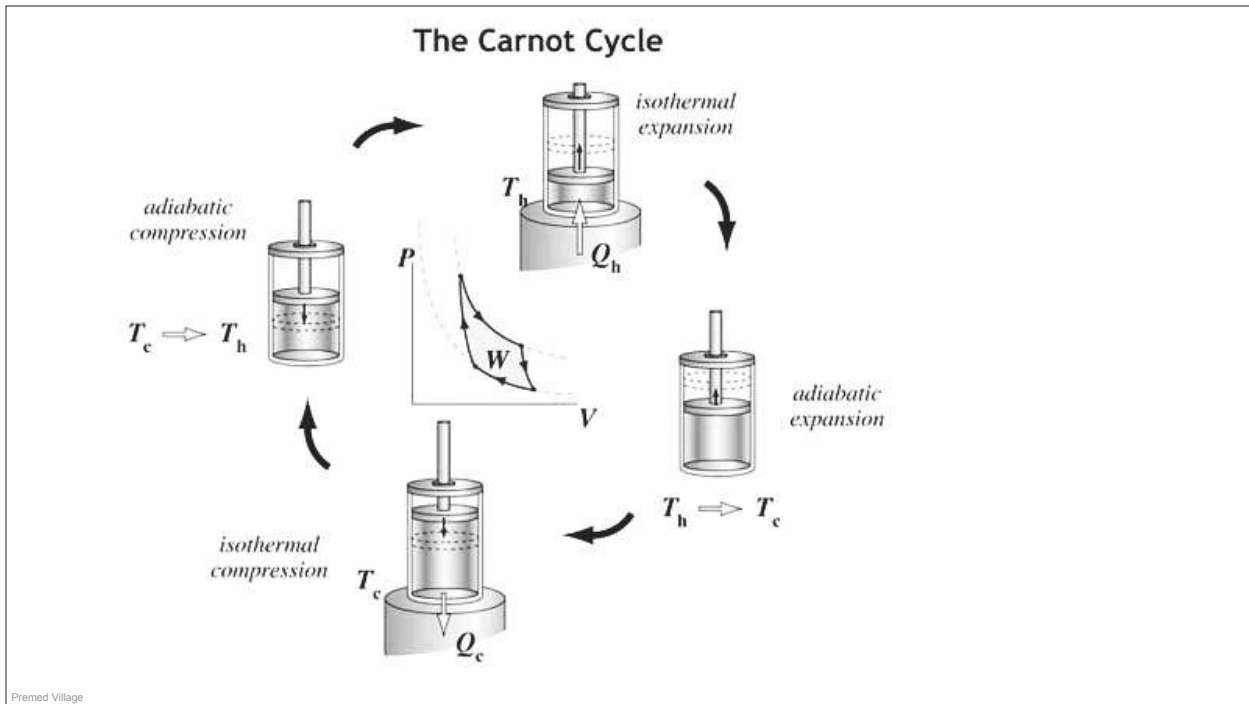
A sealed container holds 1-L of hydrogen gas (H_2) at STP. A second sealed container holds 1-L of helium gas (He) at STP. Both containers are heated isochorically to 100°C . Which gas experiences the greatest change in entropy?

- A. the hydrogen gas
- B. the helium gas
- C. both have equal changes in entropy
- D. the entropy of neither gas changes

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The Thermal Efficiency of a Heat Engine

$$\epsilon = \frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

$$\epsilon = \frac{T_h - T_c}{T_h} = 1 - \frac{T_c}{T_h}$$

(with heat input and output occurring at fixed temperatures)

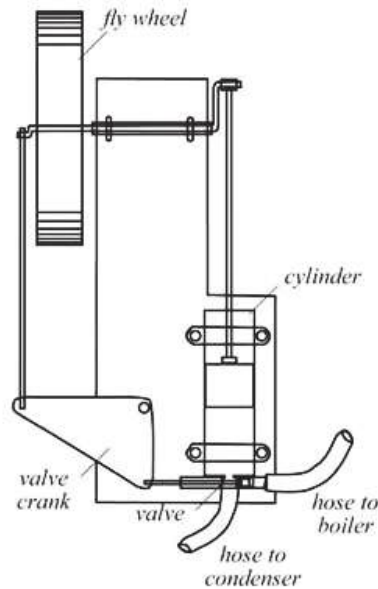
ϵ = thermal efficiency
 W = net work
 Q_h = heat flow in
 Q_c = heat flow out
 T_h = hot sink temperature
 T_c = cold sink temperature

Premed Village

Which of the following would tend to increase the thermal efficiency of the single stroke steam engine at right?

- I. Increasing boiler temperature
- II. Decreasing boiler temperature
- III. Increasing condenser temperature
- IV. Decreasing condenser temperature

- a. I only
- b. I and IV
- c. II only
- d. II and III



Premed Village

What is the maximum efficiency of an engine operating between $177\text{ }^{\circ}\text{C}$ and $27\text{ }^{\circ}\text{C}$?

- A. 33%
- B. 85%
- C. 50%
- D. 15%

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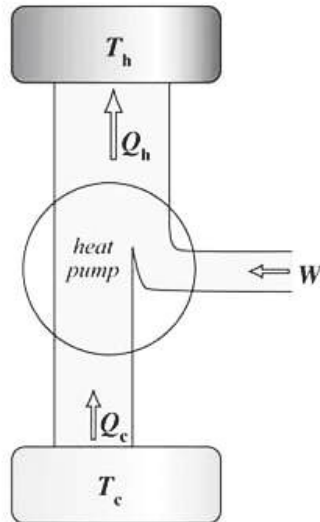
Coefficient of Performance

$$\text{COP} = \frac{Q_h}{W}$$

$$= \frac{T_h}{T_h - T_c}$$

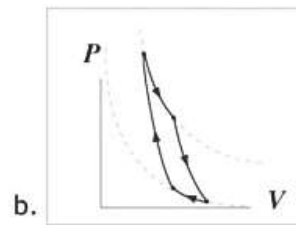
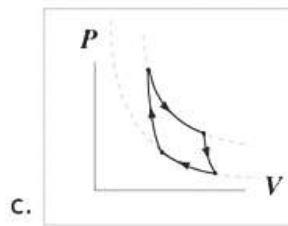
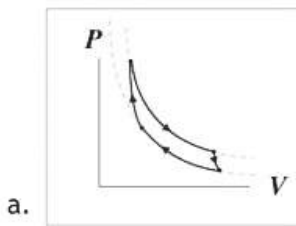
(with heat input and output occurring at fixed temperatures)

- ϵ = thermal efficiency
- W = net work
- Q_h = heat flow in
- Q_c = heat flow out
- T_h = hot sink temperature
- T_c = cold sink temperature



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Which of the pressure-volume graphs below depicts the most efficient Carnot cycle?



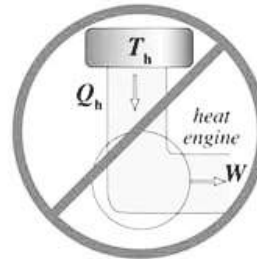
d. All three are equally efficient.

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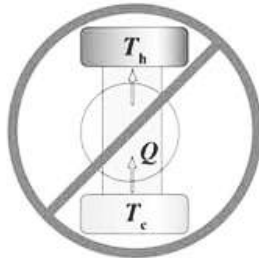
The Second Law of Thermodynamics

The entropy of the universe increases for all real processes.

No heat engine operating on a cycle can be 100% efficient (Kelvin's formulation).



Kelvin's formulation of the second law of thermodynamics

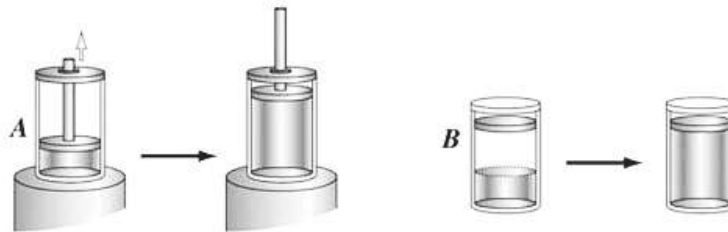


Clausius' formulation

An engine cannot transfer heat continuously from a colder to a hotter body and produce no other effects (Clausius' formulation).

Premed Village

With identical initial pressure, volume and temperature, ideal gas A occupies a piston in thermal equilibrium with a hot sink. Thermally insulated, ideal gas B occupies the volume beneath a membrane and the vacuum compartment above. Gas A is expanded isothermally. For gas B the membrane is broken, and gas B expands to occupy a volume identical to the final volume of A . Which of the following are equal?



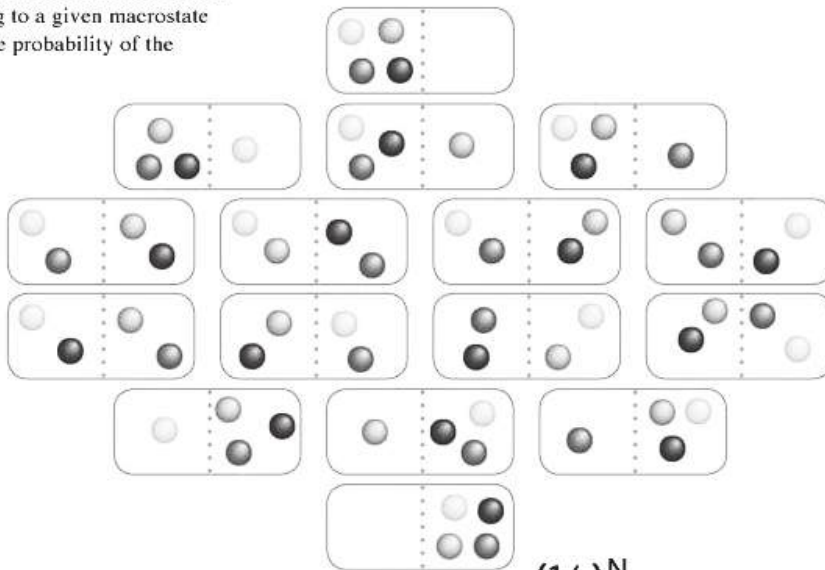
- work performed during each expansion
- heat flow during each expansion
- the entropy change due to heat flow during each expansion
- the final entropy of the gases

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The entropy of the world
only increases.
It never decreases.

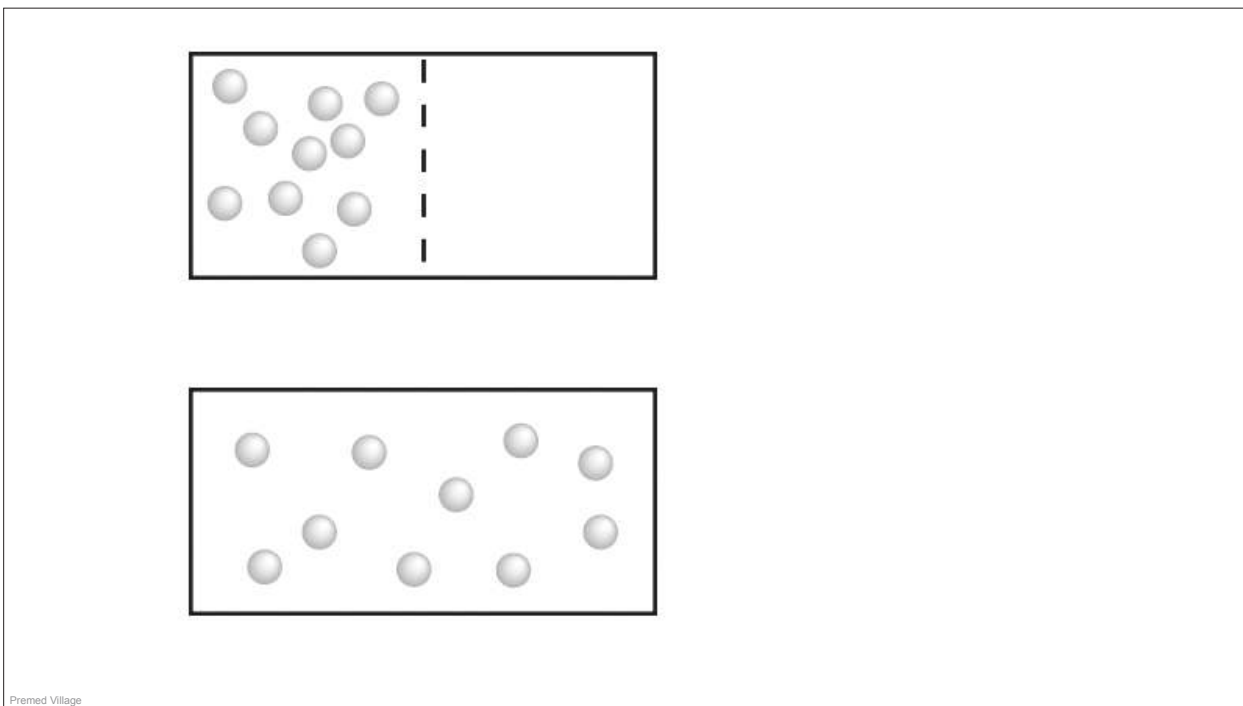
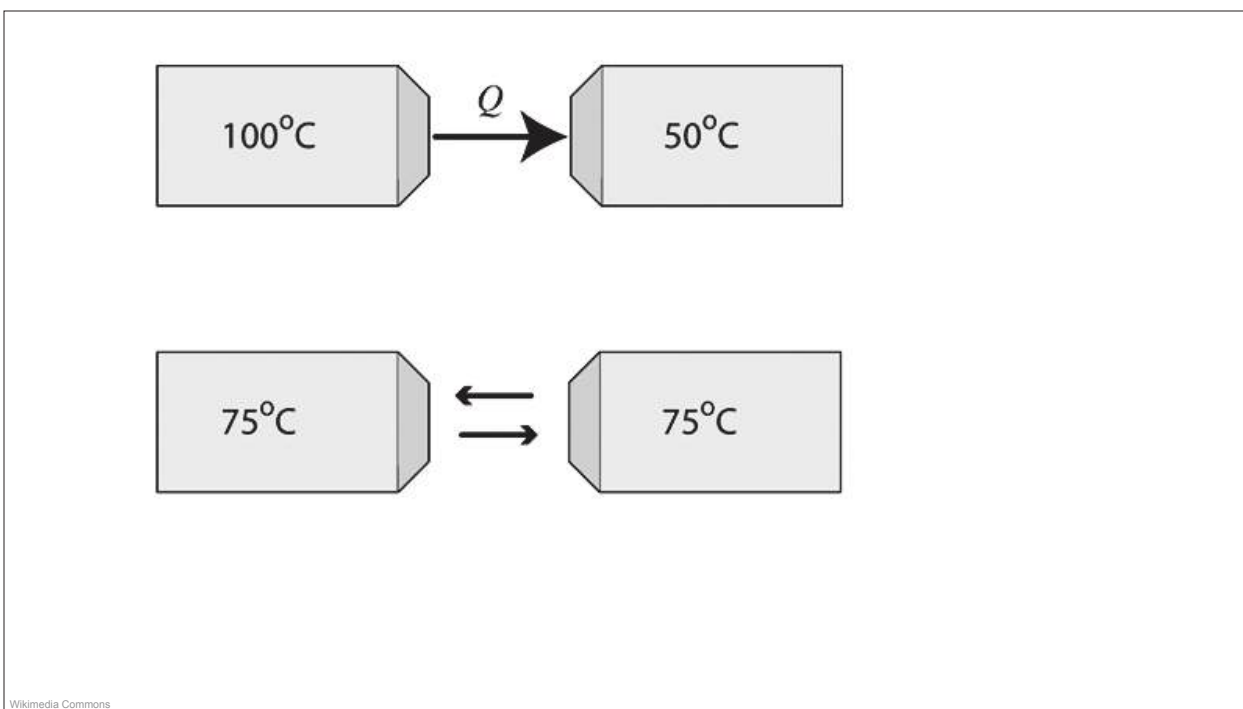
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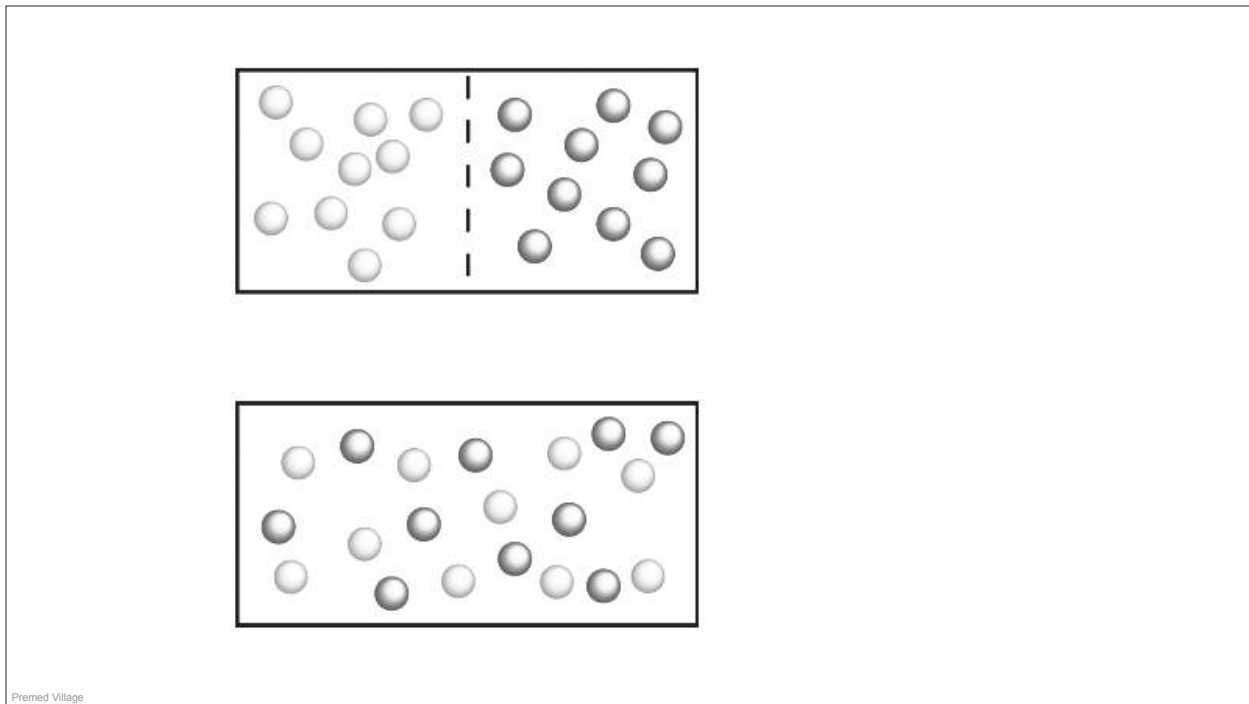
The greater the number of microstates
corresponding to a given macrostate
the greater the probability of the
macrostate.



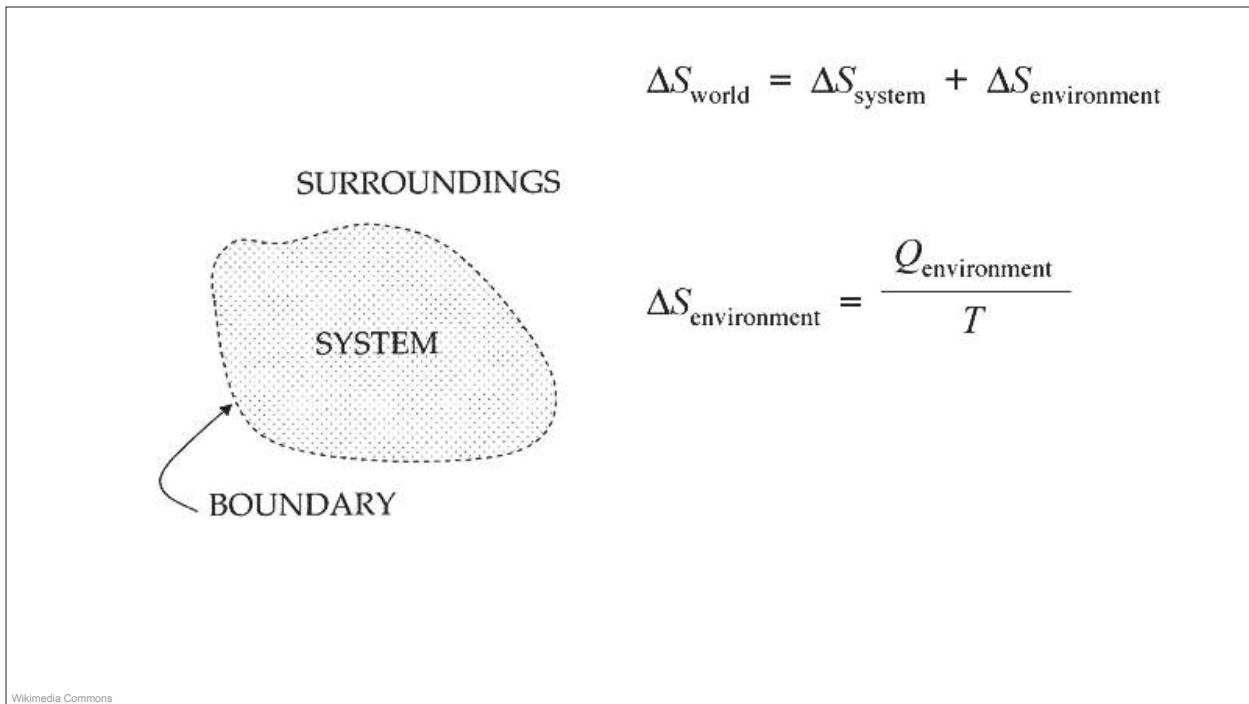
probability of all particles being in half the container $(1/2)^N$

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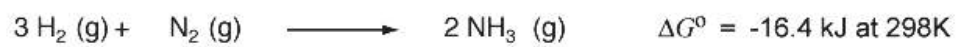


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$$G = H - TS$$

$$\Delta G = \Delta H - T \Delta S$$

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$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = -RT \ln K_{eq}$$

$$K_{eq} = e^{\left(\frac{-\Delta G^\circ}{RT}\right)}$$

Premed Village

Which of the following statements about the relationship between ΔG° , the standard free energy change, and K , the thermodynamic equilibrium constant, is untrue?

- A. If ΔG° is large and positive, K is very small.
- B. If ΔG° is large and negative, K is very large.
- C. If ΔG° is zero, $K = 1$.
- D. All of the above are true.

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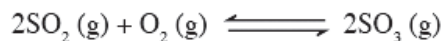
Which of the following is the proper expression of K_c for the following reaction?



- A. $\frac{[\text{NH}_3][\text{O}_2]}{[\text{NO}][\text{H}_2\text{O}]}$
- B. $\frac{4[\text{NO}]6[\text{H}_2\text{O}]}{4[\text{NH}_3]5[\text{O}_2]}$
- C. $\frac{[\text{NO}]^4[\text{H}_2\text{O}]^6}{[\text{NH}_3]^4[\text{O}_2]^5}$
- D. $\frac{[\text{NH}_3]^4[\text{O}_2]^5}{[\text{NO}]^4[\text{H}_2\text{O}]^6}$

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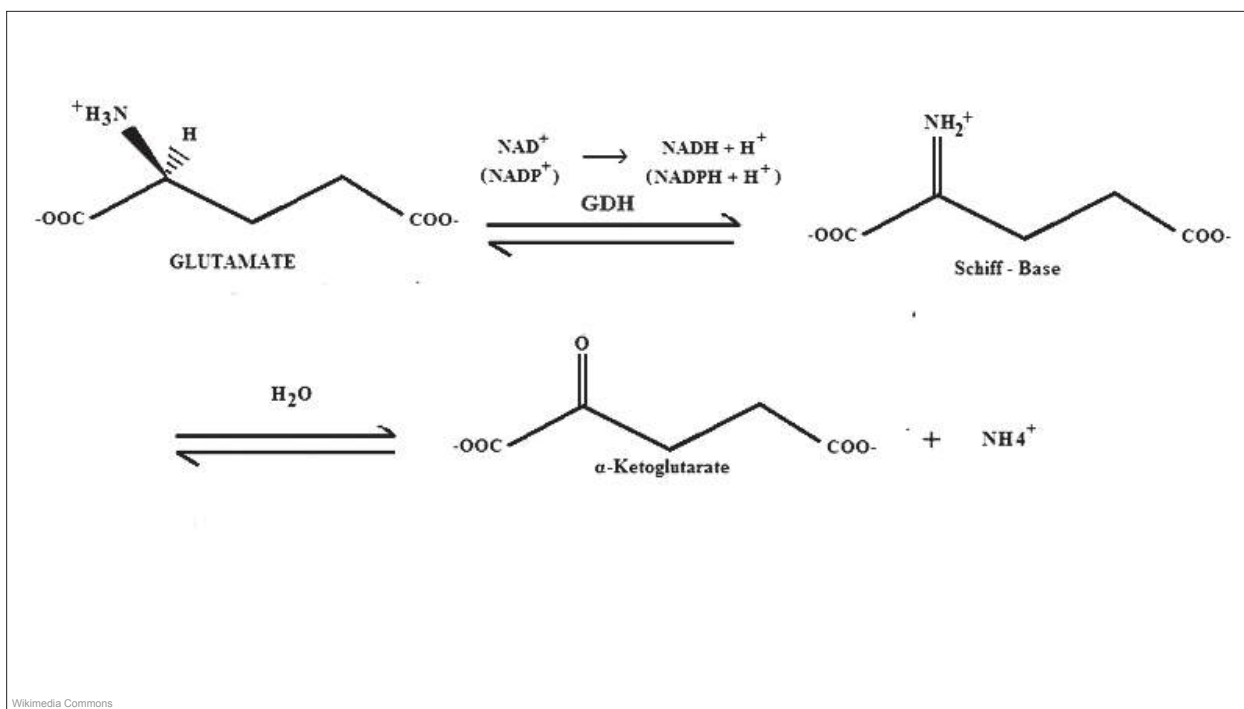
The equilibrium constant under standard conditions for the reaction of SO_2 with O_2 to form SO_3 , $K_c = 1.5 \times 10^{-1}$

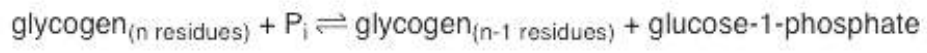


If 0.01 mol of each of the three gases are present along with argon in a 1 liter container at STP, which of the following is occurring?

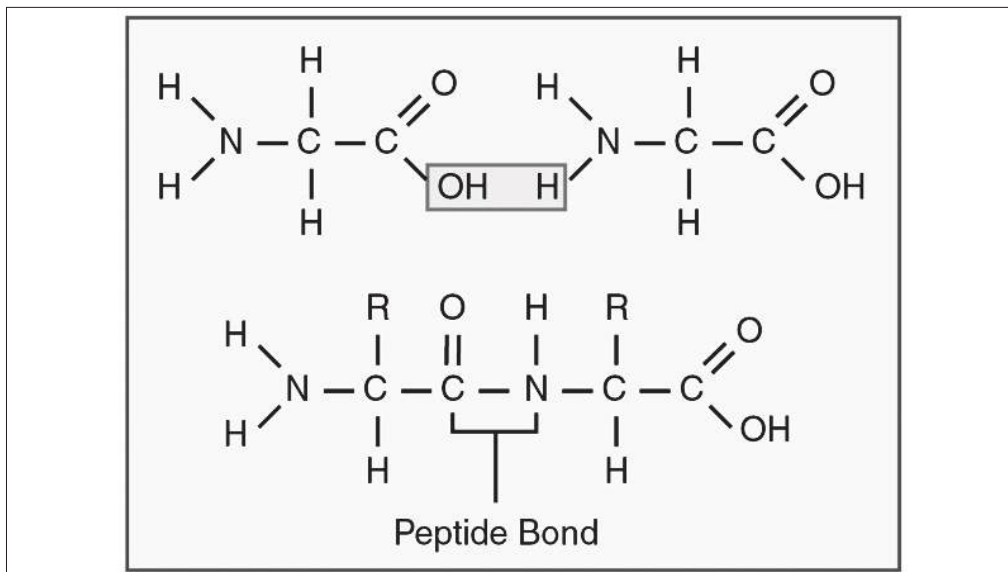
- A. The forward reaction occurs at a higher rate than the reverse reaction.
- B. The reverse reaction occurs at a higher rate than the forward reaction.
- C. The reaction is at equilibrium.
- D. Pressure is increasing in the container.

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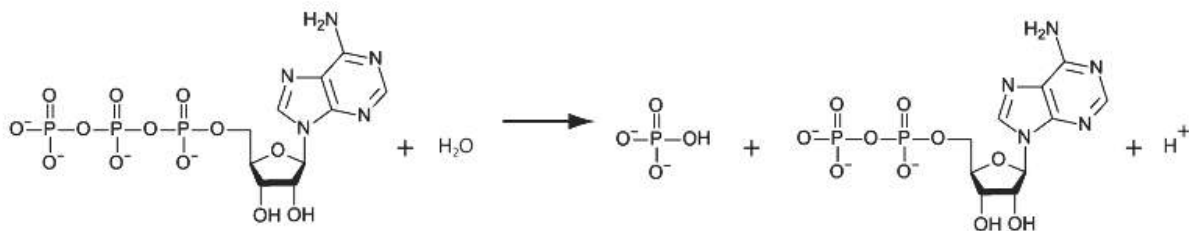


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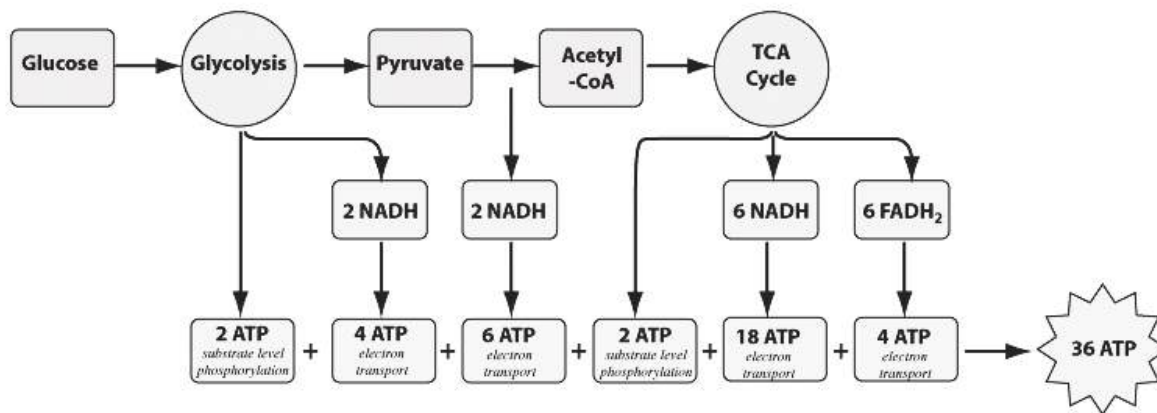


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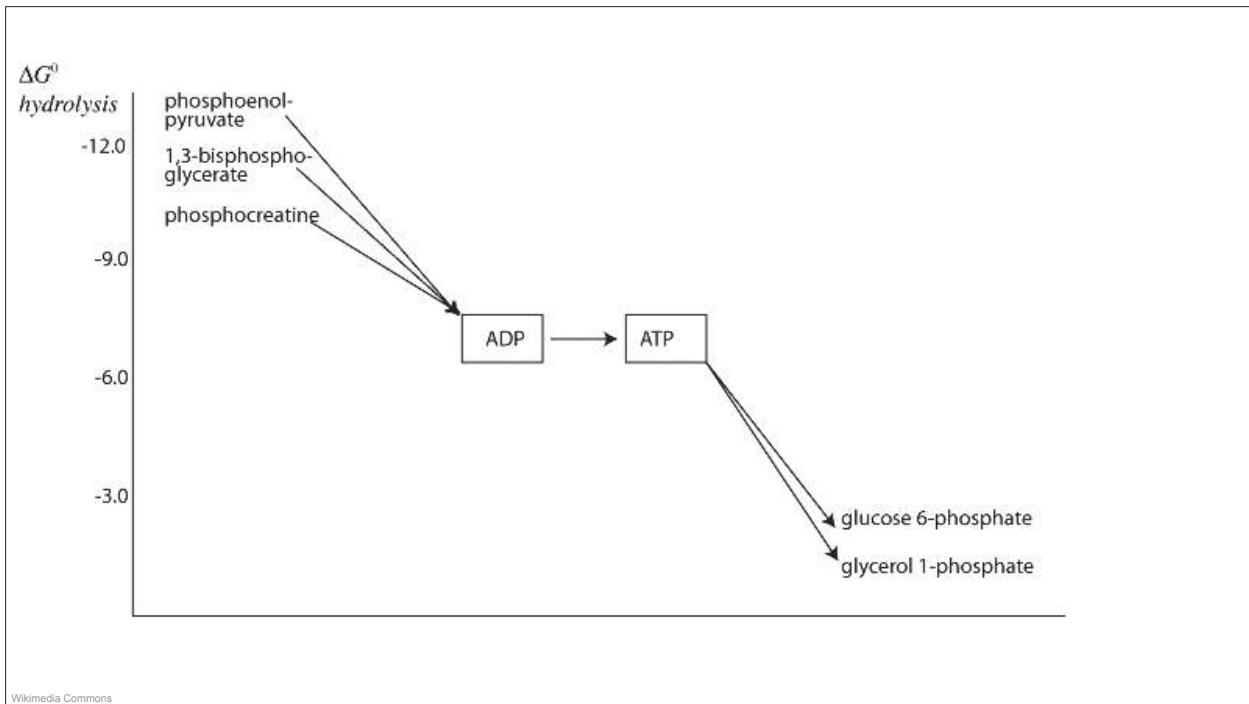
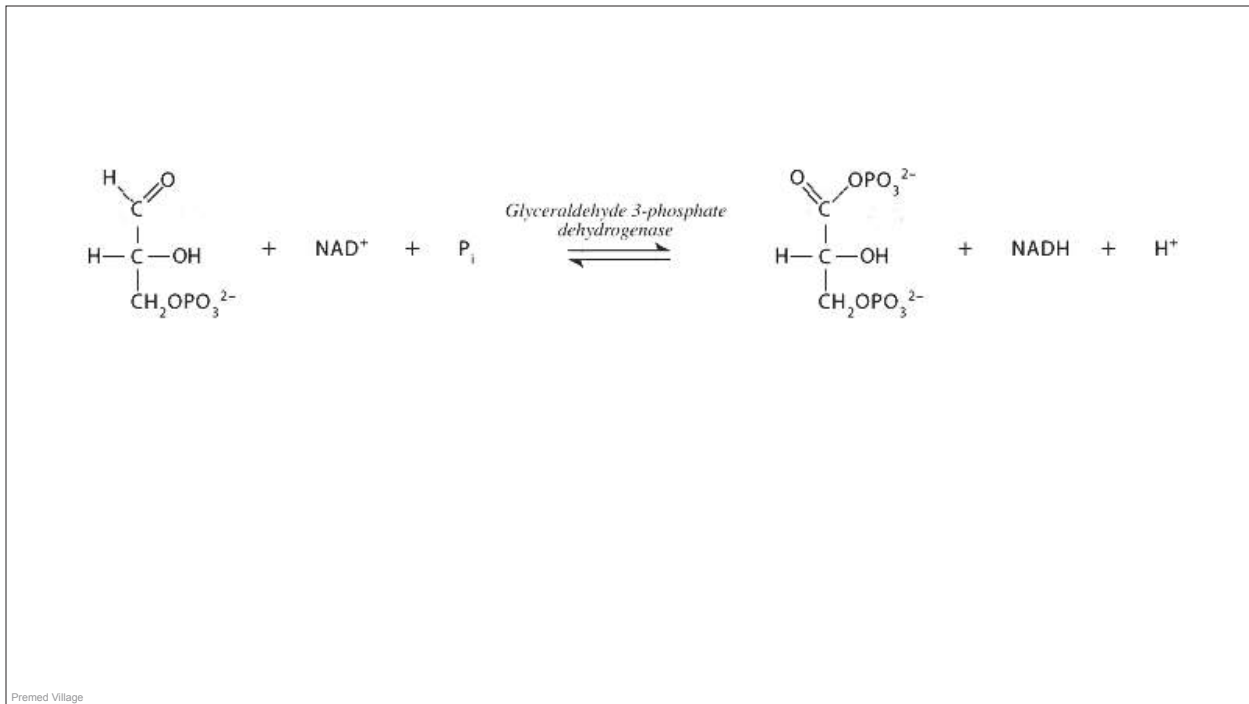
Hydrolysis of ATP

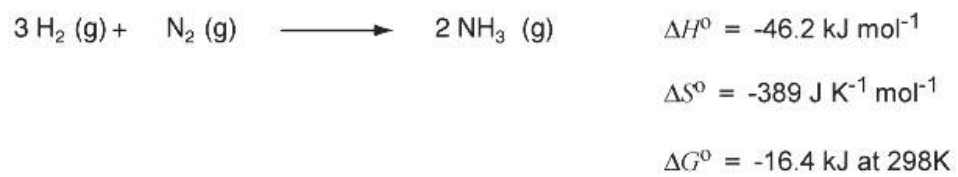
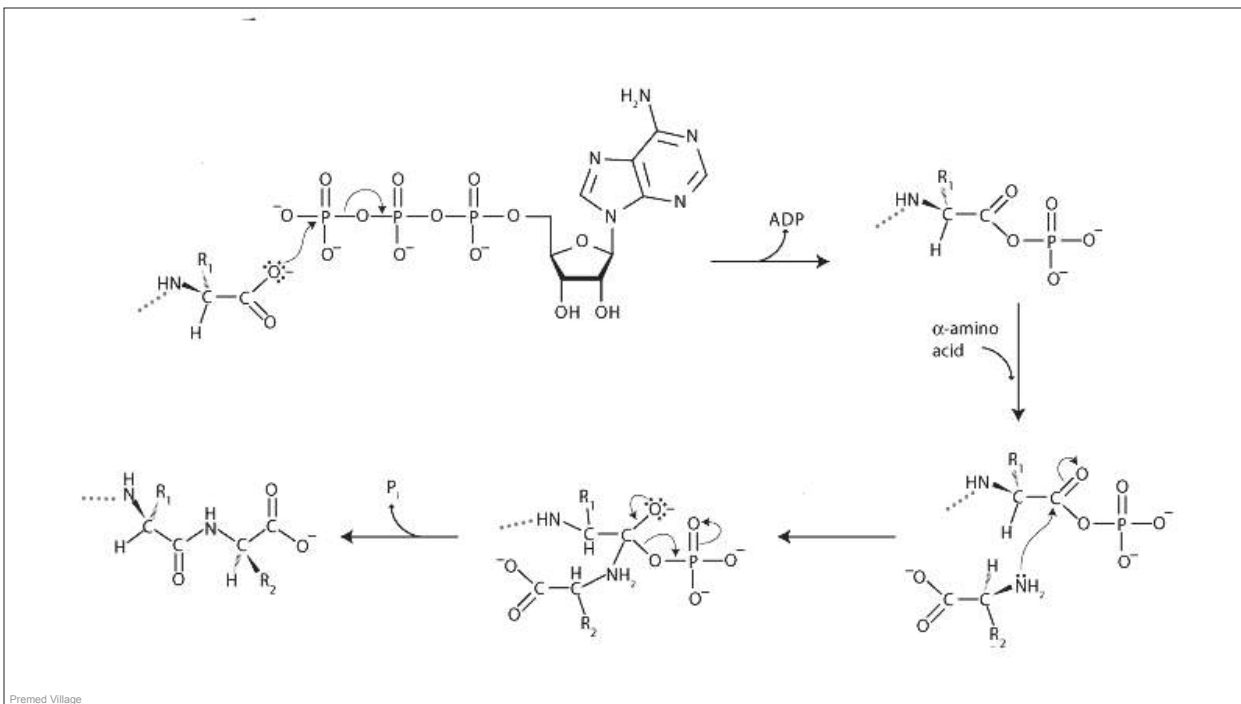


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$$\ln \frac{K_1}{K_2} = - \frac{\Delta H^\circ}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

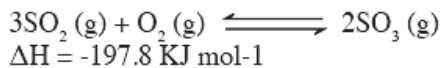


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If a chemical system at equilibrium experiences a change in concentration, temperature, volume, or partial pressure, then the equilibrium shifts to counter-act the imposed change.

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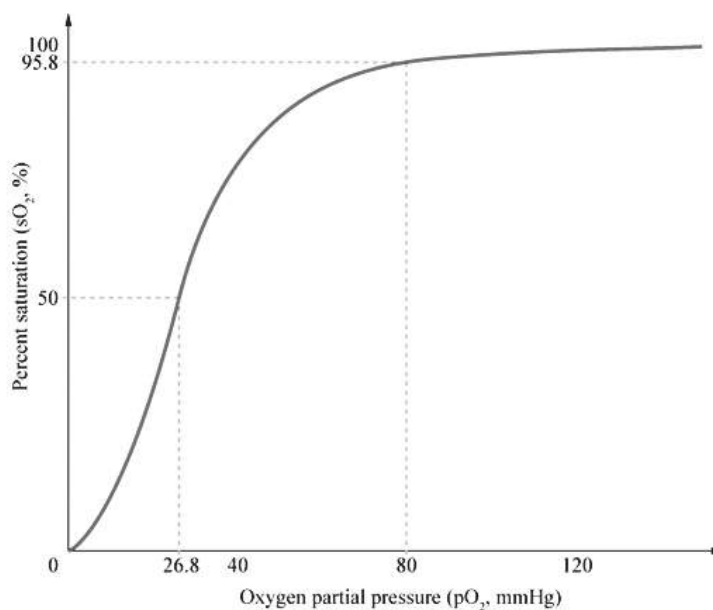
The reaction of sulfur dioxide with oxygen is as follows:



At 1000°C and 0.3 atm , the equilibrium constant, K_p , is equal to 3.42 . Which of the following strategies would increase the yield of sulfur trioxide?

- I. Increasing the pressure of the reaction vessel
 - II. Introducing a catalyst
 - III. Heating the reaction vessel further
- A. I
 - B. I and III
 - C. II and III
 - D. I, II and III

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Solvent**Solute**

gas

gas

liquid

gas

liquid

liquid

liquid

solid

solid

solid

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$$\text{Concentration} = \frac{\text{amount of solute}}{\text{amount of solvent or solution}}$$

Mole fraction:

$$X_A = \frac{n_A}{n_A + n_B + \dots}$$

Molarity

$$M = \frac{\text{moles of solute}}{\text{liter of solution}}$$

400mL of 0.2 M NaOH solution
How many moles?

6.0 g NaCl (MW 58.4) in water
makes 250mL of solution. Molarity?

Percent by mass and volume:

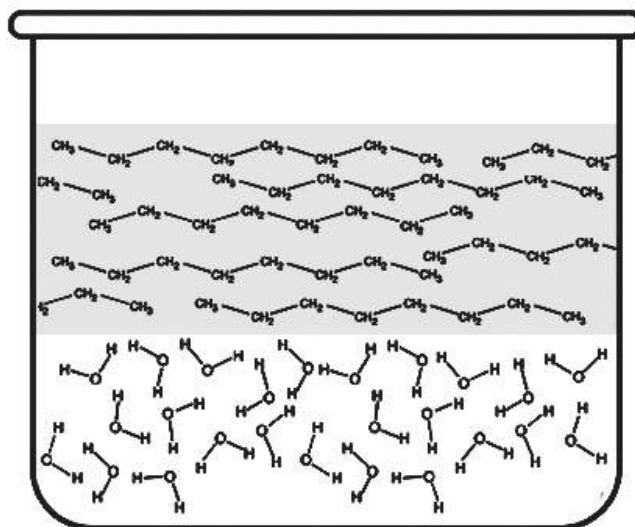
$$\text{mass \%} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

$$\text{vol \%} = \frac{\text{vol of solute}}{\text{vol of solution}} \times 100\%$$

Molality

$$m = \frac{\text{moles of solute}}{\text{kilograms of solvent}}$$

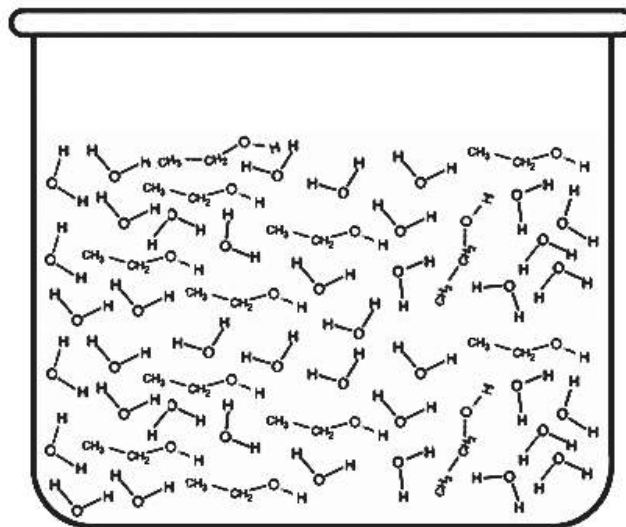
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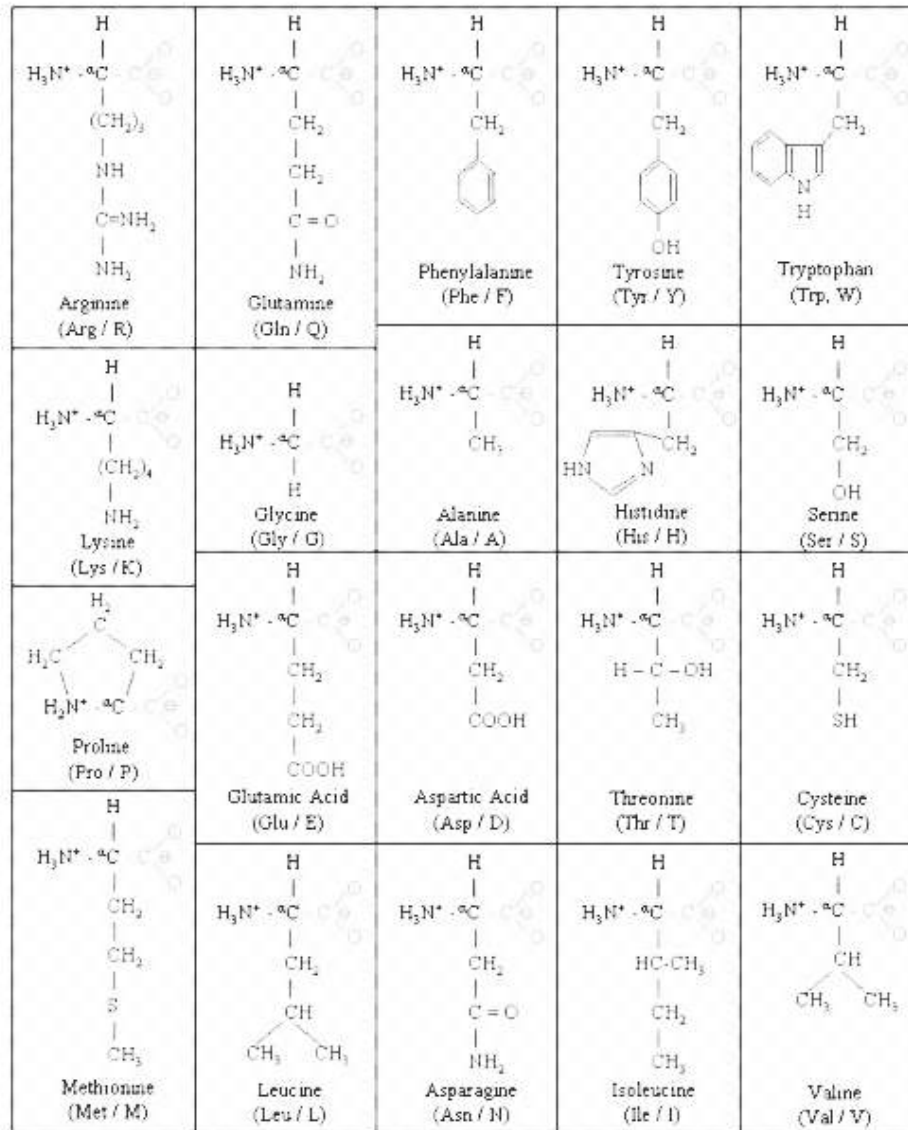
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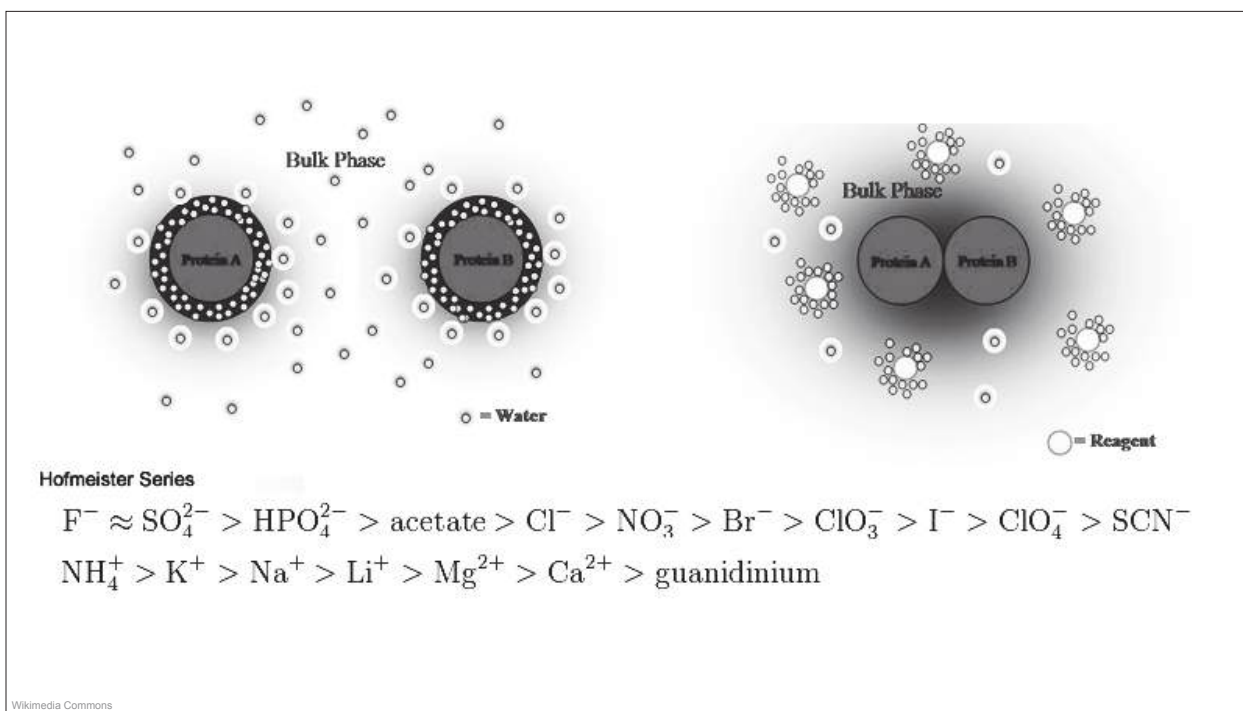
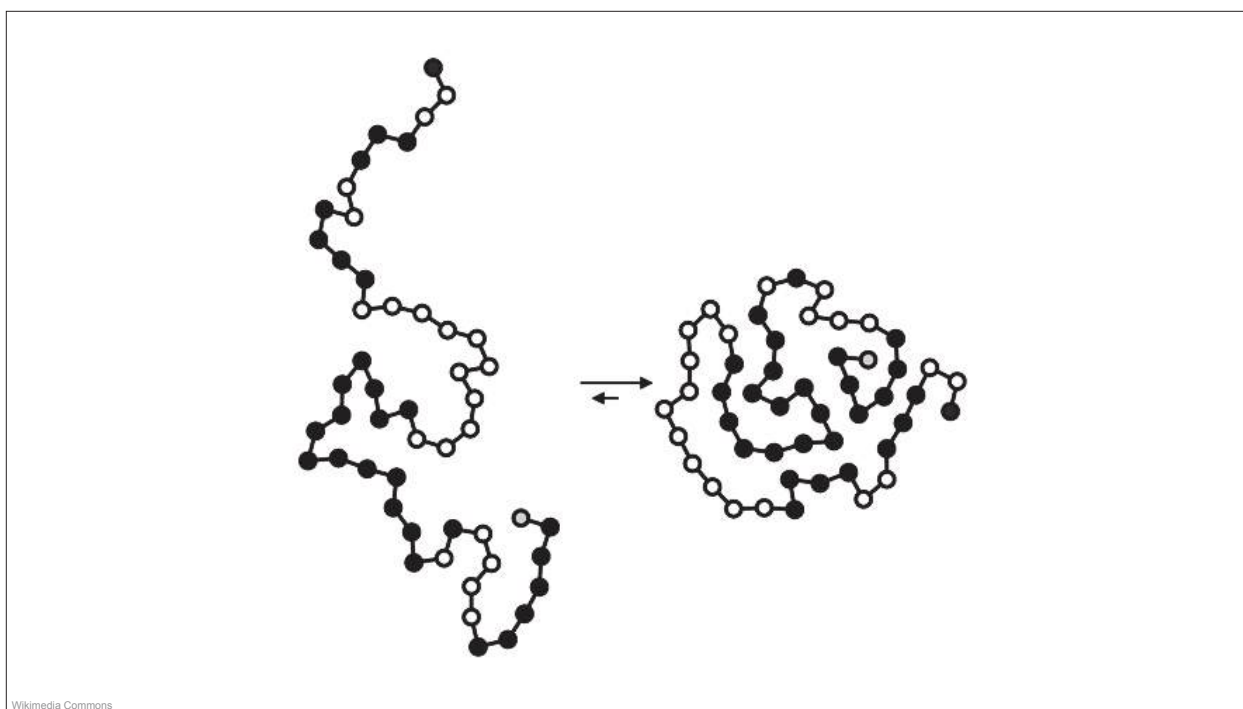
Solubility in Water

Methanol	infinite
Ethanol	infinite
Propanol	infinite
Butanol	90g/kg
Pentanol	2.7g/kg



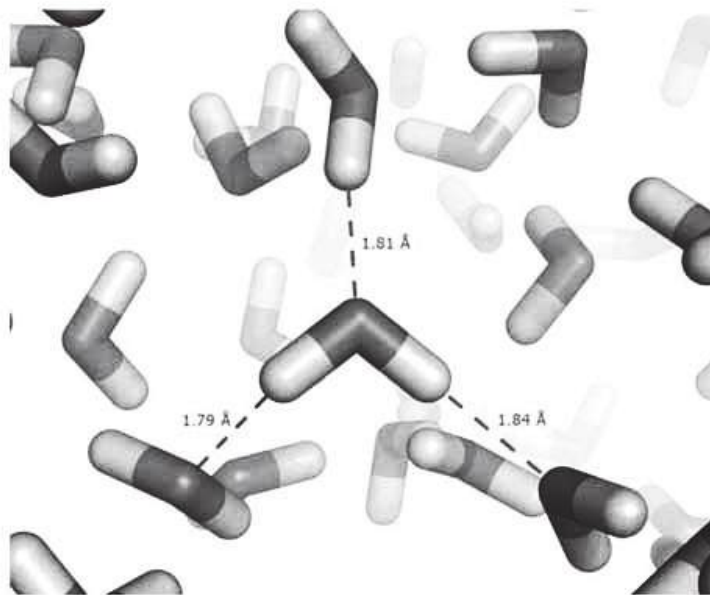
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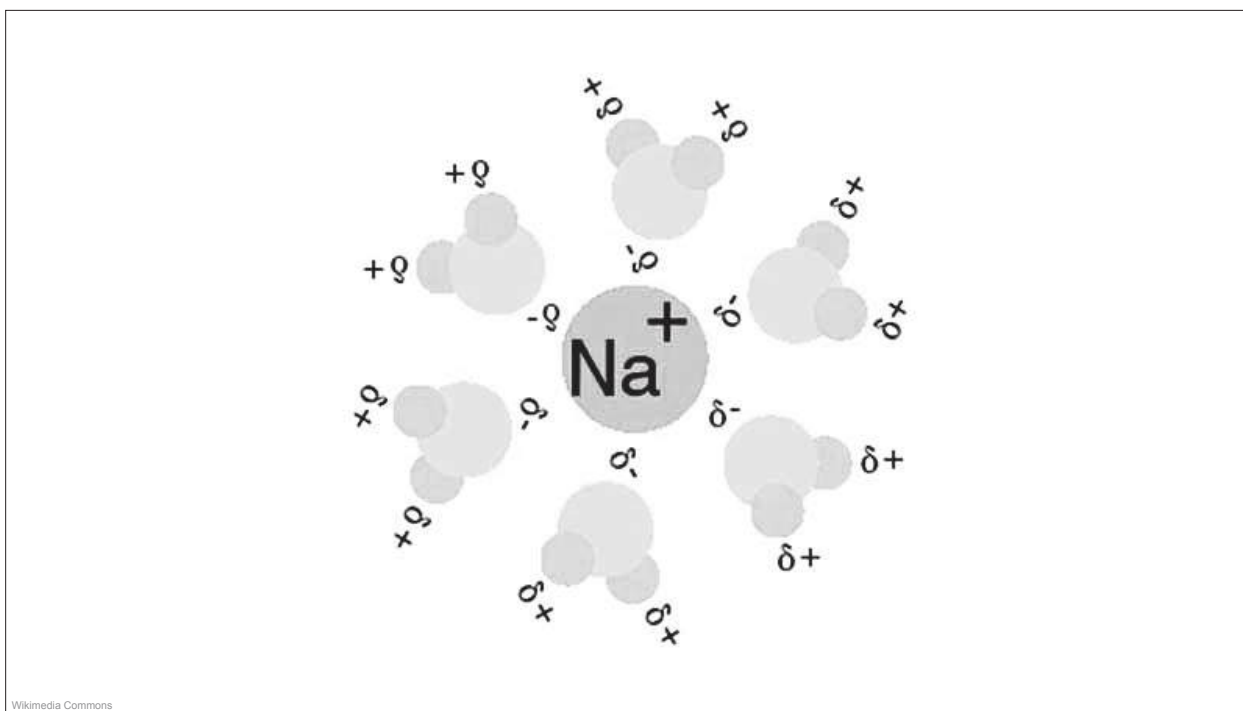
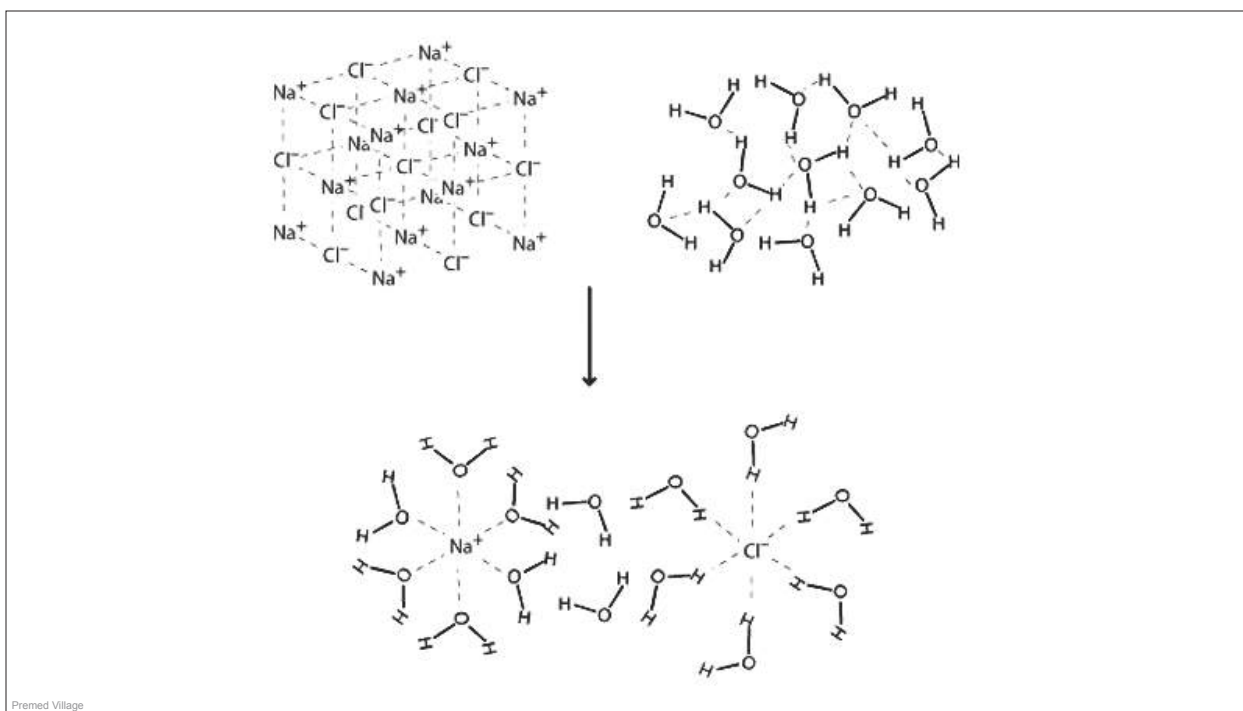


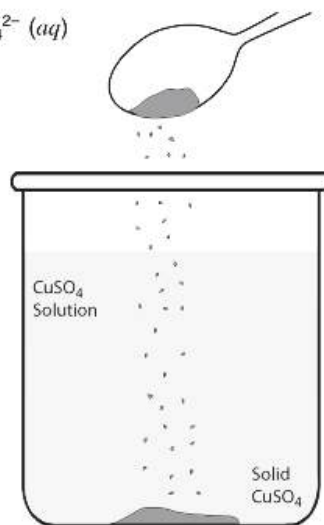
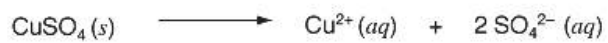


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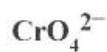
Endothermic solution process - positive ΔH



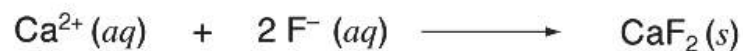
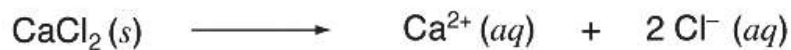
Exothermic solution process - negative ΔH



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SOLUBLE(except with Pb^{2+} , Hg_2^{2+} , Ag^+ & Cu^+)(except with Ba^{2+} , Sr^{2+} , Pb^{2+} , Hg_2^{2+} , Ca^{2+} & Ag_2^{2+})**INSOLUBLE**(except with Na^+ , K^+ , NH_4^+ , Mg^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+})(except with Na^+ , K^+ , Ba^{2+} , Sr^{2+})(except with Na^+ , K^+ , Ca^{2+} , Ba^{2+} , Sr^{2+})(except with Na^+ , K^+ , Mg^{2+} , NH_4^+)(except with Na^+ , K^+ , NH_4^+)

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Testing an Aqueous Solution for the Presence of Fluoride

Premed Village



$$K = \frac{[\text{Pb}^{2+}][\text{SO}_4^{2-}]}{[\text{PbSO}_4]}$$

$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{SO}_4^{2-}]$$

$$= 2.53 \times 10^{-8}$$

Premed Village

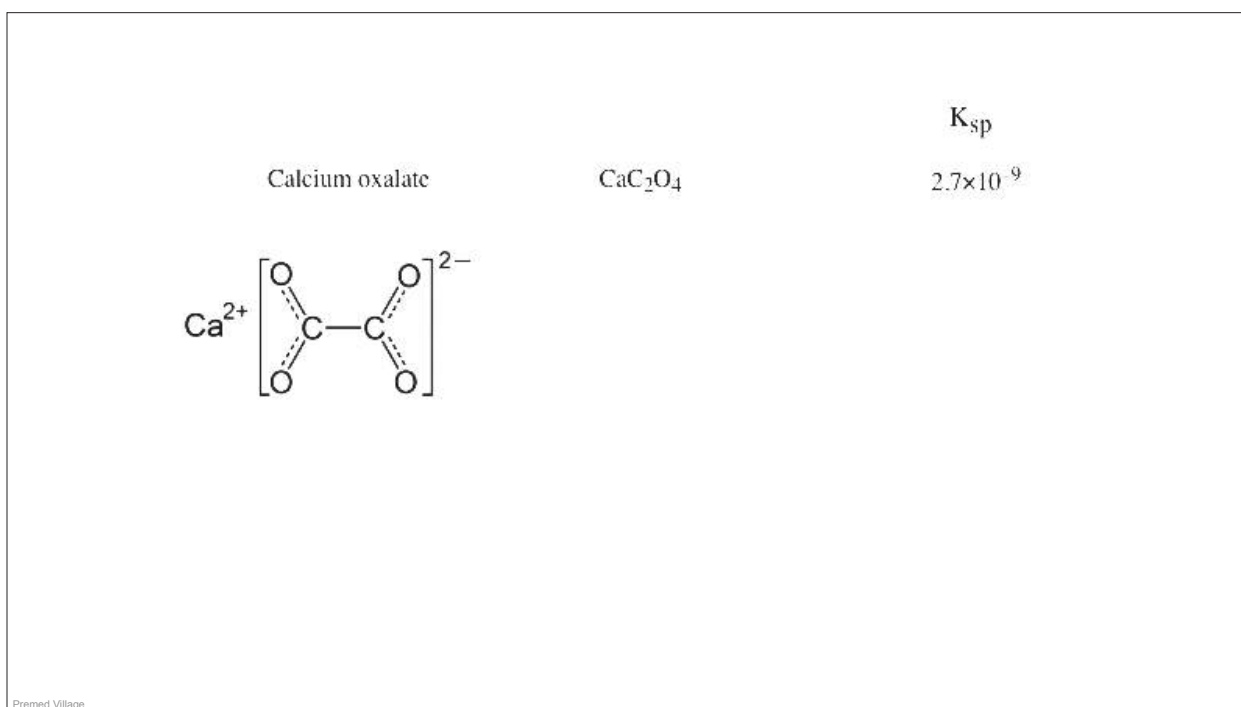


$$K_{\text{sp}} = [\text{A}^{x+}]^P [\text{B}^{y-}]^Q$$

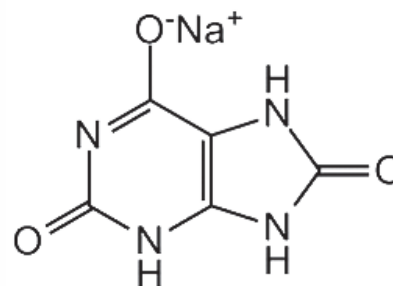


$$K_{\text{sp}} = [\text{Ca}^{2+}][\text{F}^{-}]^2$$

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Gout is associated with the appearance of crystals of monosodium urate monohydrate (hereafter called sodium urate) in the synovial fluid, causing an inflammatory reaction. There is a good correlation between the incidence of gout and raised serum uric acid concentrations. In particular the occurrence of gout increases rapidly with concentration above the saturation solubility of sodium urate in physiological saline, about 0.4 mmol/l (7 mg/100 ml). Apparently we can view the development of gout as stemming simply from the process of precipitation from a supersaturated solution.



What is the K_{sp} of sodium urate?

(Concentration of physiological saline: 150mM NaCl)



$$K_{sp} = [A^{x+}]^P [B^{y-}]^Q$$

$$\Delta G = \Delta G^\circ + RT \ln Q_{sp}$$

$$\Delta G^\circ = -RT \ln K_{sp}$$

$Q_{sp} < K_{sp}$: ΔG of the solution process is negative and all ions are present in solution

$Q_{sp} = K_{sp}$: ΔG of the solution process is zero and the solution is saturated

$Q_{sp} > K_{sp}$: ΔG of the solution process is positive. The solution is supersaturated and is precipitating

Premed Village



$$K_{sp} = 2.53 \times 10^{-8}$$

What is the molar solubility of $PbSO_4$ in a 0.1 M solution of Na_2SO_4 ?

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1 liter of saturated CaF_2 solution was evaporated at room temperature, leaving 0.017 g (2.2×10^{-4} mol) which was collected as a residue. Calculate the K_{sp} of CaF_2 at room temperature.

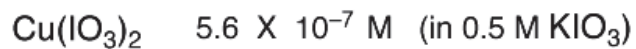
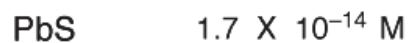
Premed Village



The solubility product of CaF_2 is 3.5×10^{-11} , calculate the molar solubility of CaF_2 at room temperature.

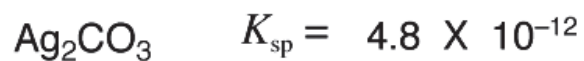
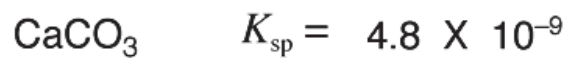
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Use the following solubilities to determine the solubility product constant:



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Which is more soluble in water?



Which precipitates first when concentrated Na_2CO_3 is added to a solution 0.1M for both Ca^{2+} and Ag^+ ?

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The solubility product constants of AgCl, AgBr, and AgI are, respectively, 1.7×10^{-10} , 4.1×10^{-13} , and 1.5×10^{-16} . If a concentrated solution containing KBr is stirred with solid AgCl

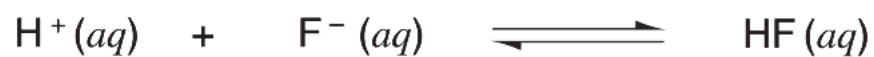
- A. silver will be oxidized
- B. AgCl will dissolve and solid AgBr will precipitate
- C. no reaction will occur
- D. silver will be reduced

Premed Village

The K_{sp} of FeS is 8×10^{-19} . The K_{sp} of PbS is 3×10^{-28} . In a solution containing 0.1 mM concentrations of both Fe^{2+} and Pb^{2+} , which will precipitate first upon dropwise addition of 0.01mM Na_2S ?

What is the lowest concentration of Pb^{2+} obtainable before FeS begins to precipitate?

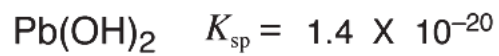
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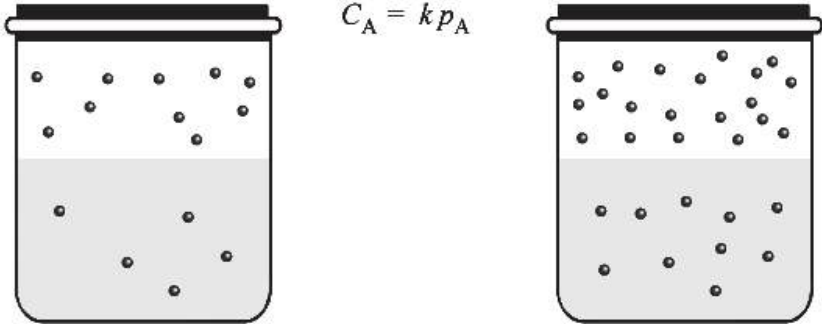
Many hydroxide salts are insoluble.

What effect will changing pH have on Lead(II) solubility ?

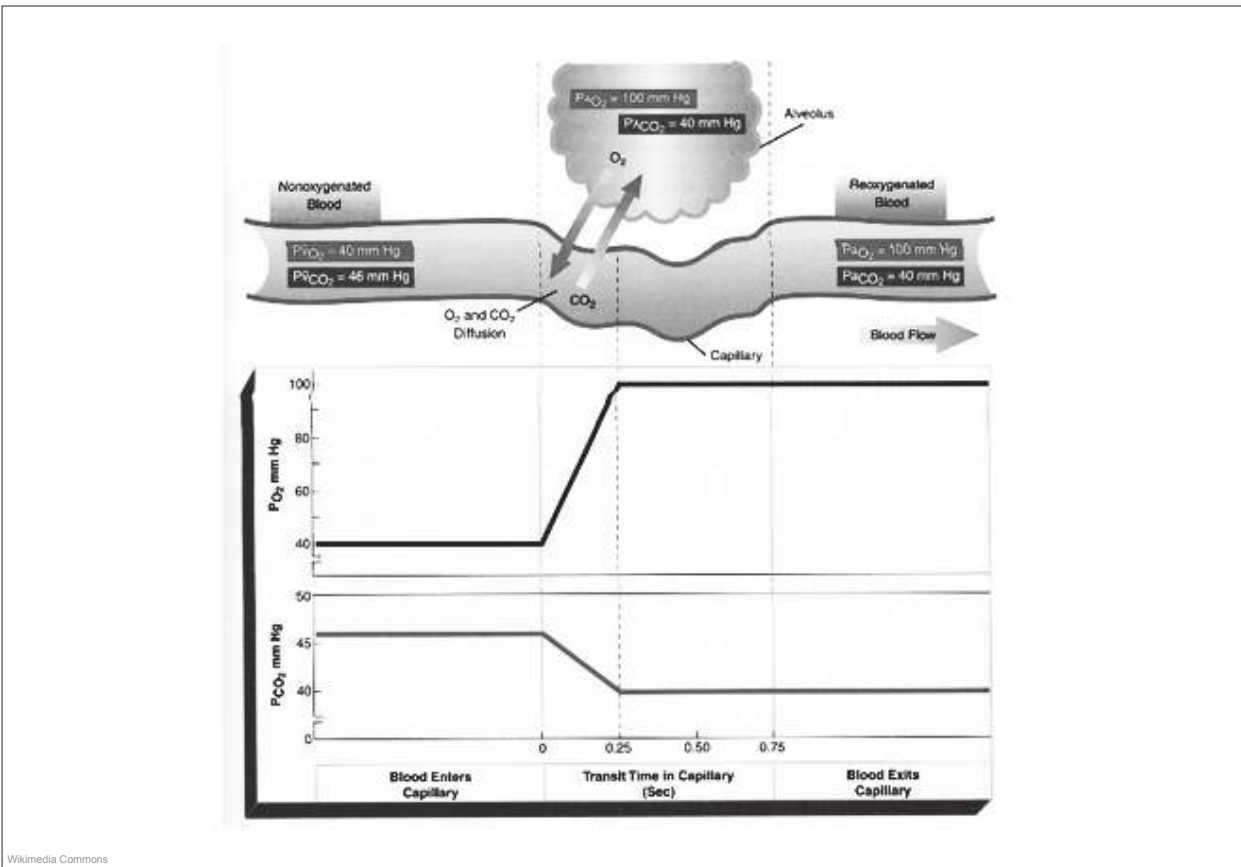


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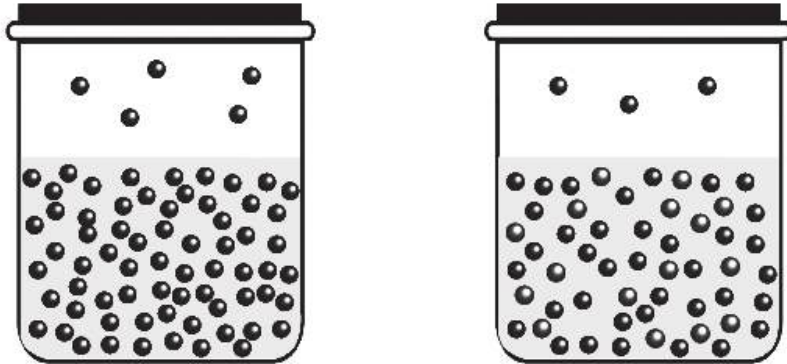
Henry's Law

$$C_A = k p_A$$


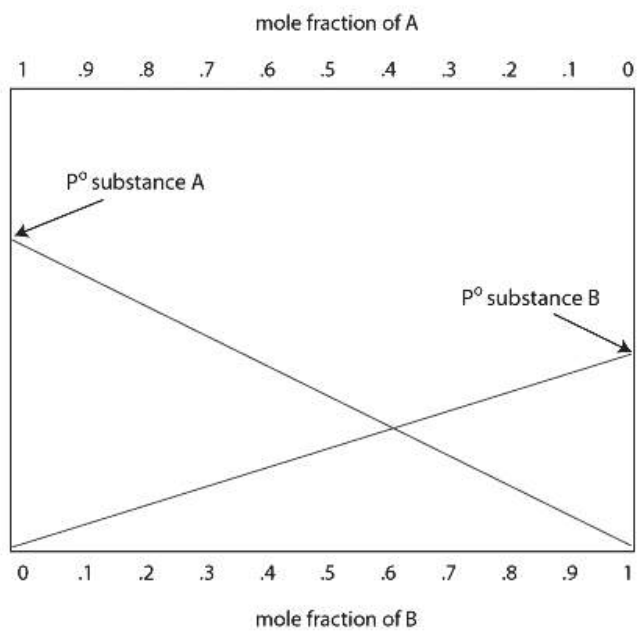
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$$p_A = X_A p_A^{\circ}$$



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Freezing Point Depression and Boiling Point Elevation

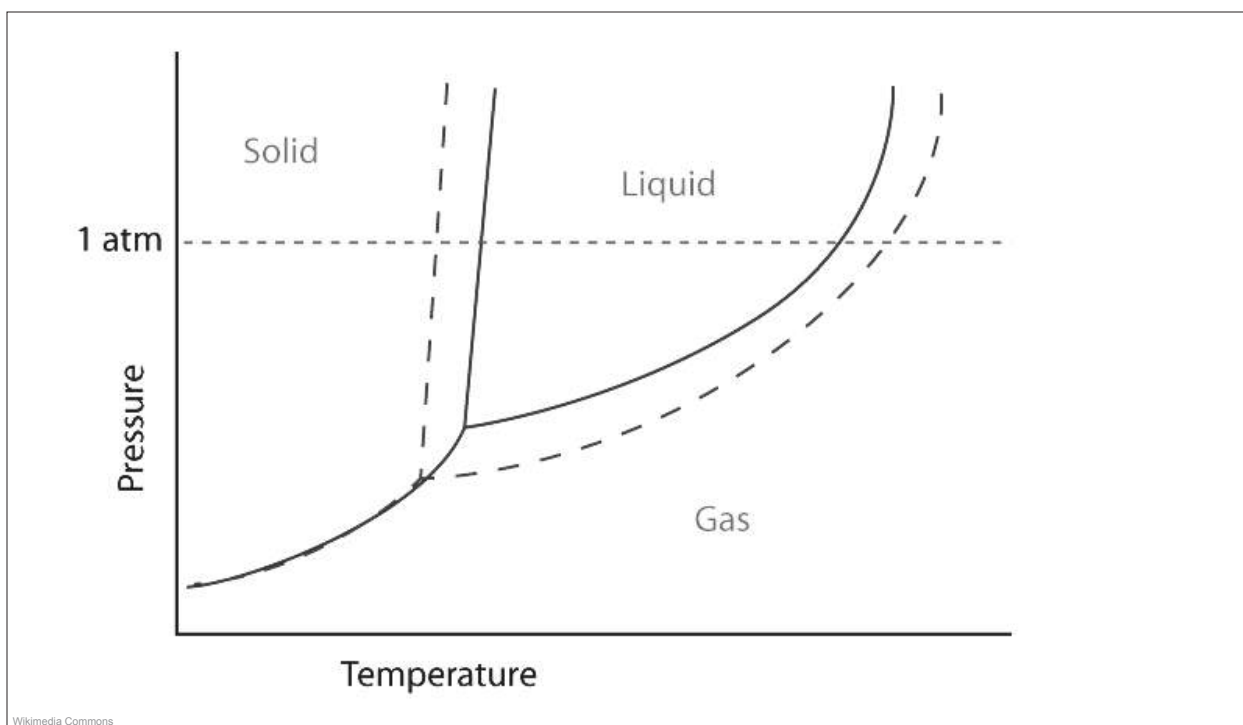
$$\Delta T_{FP} = k_f (i) m$$

$$\Delta T_{BP} = k_b (i) m$$

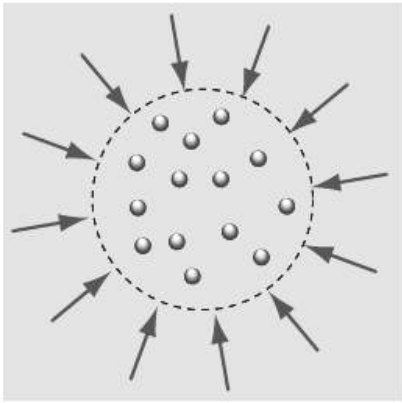
For water, $k_f = -1.85 \text{ K L}^{-1} \text{ mol}^{-1}$

For water, $k_b = 0.51 \text{ K L}^{-1} \text{ mol}^{-1}$

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The osmotic pressure Π in a solution of volume V liters containing n moles of solvent is given by the *van't Hoff* equation:

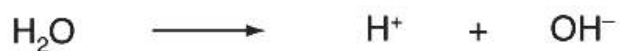


$$\Pi V = nRT$$

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Brønsted–Lowry Acids & Bases

An Brønsted–Lowry acid is a proton (H^+) donor.



An Brønsted–Lowry base is a proton (H^+) receiver.



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1 Bonded hydrogen ions dissociate from the water molecules ($2\text{H}_2\text{O}$)

2 Hydroxide ion (OH^-) forms the conjugate base

3 Oxonium ion forms a conjugate acid by accepting H^+ ion



$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = [\text{H}^+][\text{OH}^-]$$

$$= 1.00 \times 10^{-14}$$

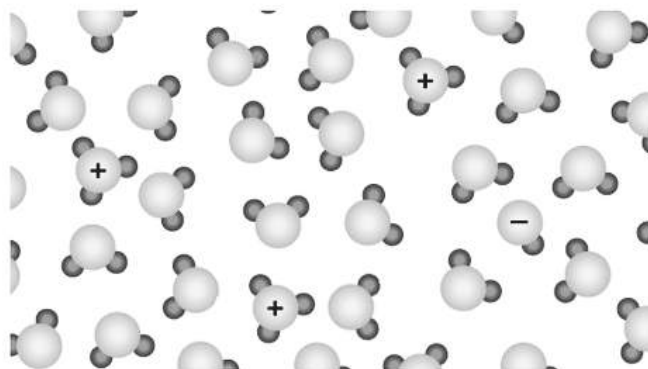
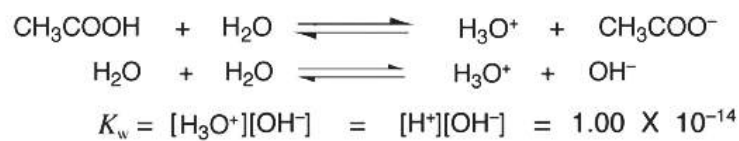
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At 25°C the autoprotolysis of pure water, shown below, attains equilibrium hydronium and hydroxide ion concentrations of about 1×10^{-7} moles per liter for each. The equilibrium concentrations vary somewhat with temperature, however. At 0°C , the concentrations are about 8×10^{-8} moles per liter, and at 100°C the concentrations are about 7×10^{-7} moles per liter. What does this directly imply about the autoprotolysis of water?



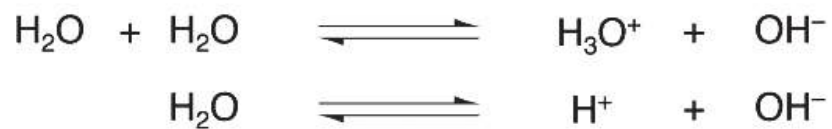
- Autoprotolysis of water is a second order reaction.
- Autoprotolysis of water is an endothermic process.
- Autoprotolysis of water is spontaneous.
- Water is a strong electrolyte.

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$$\text{pH} = -\log [\text{H}^+]$$

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$$K_w = [\text{H}^+][\text{OH}^-]$$

$$= 1.00 \times 10^{-14}$$

Calculate the pH of a 0.001M solution of NaOH.

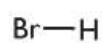
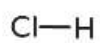
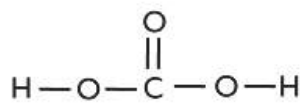
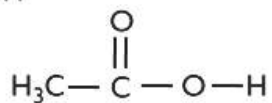
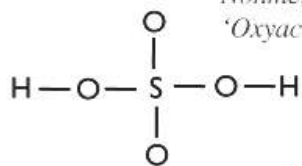
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Use the following relationship to calculate the pH of a 0.001M solution of NaOH

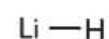
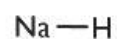
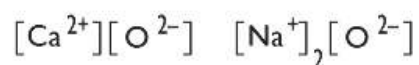
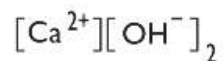
$$\text{pH} + \text{pOH} = \text{p}K_w = 14$$

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Acids

*Nonmetal
Hydrides**Nonmetal Hydroxides
'Oxyacids'*

Bases

*Metal
Hydrides**Metal
Oxides**Metal
Hydroxides*

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$$K_a = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]} \quad \text{or} \quad \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$\text{p}K_a = -\log[K_a]$$

EXAMPLE

$$\frac{[\text{HCO}_3^-][\text{H}^+]}{[\text{H}_2\text{CO}_3]}$$

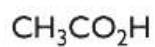
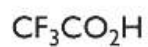
Determine the $\text{p}K_a$:

$$K_a \text{ of HNO}_2 : 7 \times 10^{-4}$$

$$K_a \text{ of CH}_3\text{CO}_2\text{H} : 1.8 \times 10^{-5}$$

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Which is the stronger acid?



$$K_a : 5.9 \times 10^{-1}$$

$$K_a : 1.8 \times 10^{-5}$$

$$K_a : 1.3 \times 10^{-16}$$

True or false?: The larger the $\text{p}K_a$ the weaker the acid.

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$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$

$$\text{p}K_b = -\log[K_b]$$

EXAMPLE

$$\frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

Determine the $\text{p}K_b$:

$$K_b \text{ of } \text{CH}_3\text{NH}_2 : 4.4 \times 10^{-4}$$

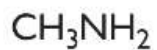
$$K_a \text{ of } \text{CN}^- : 1.6 \times 10^{-5}$$

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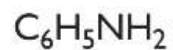
Which is the stronger base?



$$K_b : 1.8 \times 10^{-5}$$



$$K_b : 4.4 \times 10^{-4}$$



$$K_b : 4.3 \times 10^{-10}$$

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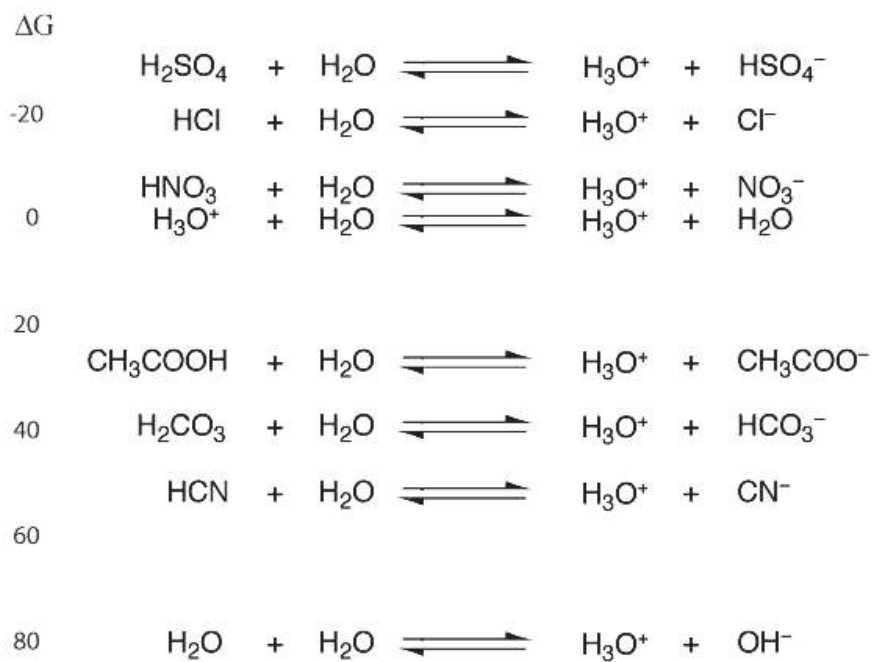


$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \quad K_b = \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]}$$

$$K_a \times K_b = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} \times \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]} = [\text{H}^+][\text{OH}^-] = K_w$$

$$K_a \times K_b = K_w$$

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Acid		pK _a	Base	pK _b
H ₂ SO ₄	sulfuric acid	-3	HSO ₄ ⁻	17
HCl	hydrochloric acid	-3	Cl ⁻	17
HNO ₃	nitric acid	-1	NO ₃ ⁻	15
H ₃ O ⁺	hydronium ion	0	H ₂ O	14
HSO ₄ ⁻	bisulfate	1.8	SO ₄ ²⁻	12.1
H ₃ PO ₄	phosphoric acid	2.1	H ₂ PO ₄ ⁻	11.9
HF	hydrofluoric acid	3.2	F ⁻	10.8
CH ₃ COOH	acetic acid	4.7	CH ₃ COO ⁻	9.3
H ₂ CO ₃	carbonic acid : CO ₂ (aq)	6.3	HCO ₃ ⁻	7.7
H ₂ PO ₄ ⁻	dihydrogen phosphate	7.2	HPO ₄ ²⁻	11.9
HCN	hydrogen cyanide	9.2	CN ⁻	4.8
NH ₄ ⁺	ammonium ion	9.25	NH ₃	4.75
HCO ₃ ⁻	bicarbonate	10.3	CO ₃ ²⁻	3.7
HPO ₄ ²⁻	hydrogen phosphate	12.3	PO ₄ ³⁻	1.7
H ₂ O	water	14	OH ⁻	0
NH ₃	ammonia	23	NH ₂ ⁻	-9

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What is the pH of a 0.1M CH₃CO₂H solution? $K_a : 1.8 \times 10^{-5}$

$$K_a = \frac{[H^+][CH_3CO_2^-]}{[CH_3CO_2H]} = 1.8 \times 10^{-5}$$

$$[H^+] \approx [CH_3CO_2^-] \text{ so approximate } [H^+] = [CH_3CO_2^-]$$

$$[CH_3CO_2H] \approx 0.1M \text{ so approximate } [CH_3CO_2H] = 0.1M$$

$$K_a = \frac{[H^+]^2}{0.1} = 1.8 \times 10^{-5}$$

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Henderson-Hasselbach Equation

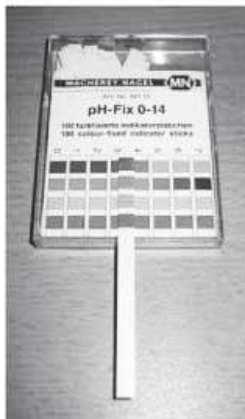


$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$[\text{H}^+] = \frac{[\text{HA}]}{[\text{A}^-]} \times K_a$$

$$\log [\text{H}^+] = \log K_a + \log \left(\frac{[\text{HA}]}{[\text{A}^-]} \right)$$

$$\text{pH} = \text{p}K_a + \log \left(\frac{[\text{A}^-]}{[\text{HA}]} \right)$$



$$\text{pH} = \text{p}K_{\text{ind}} + \log \left(\frac{[\text{A}^-]}{[\text{HA}]}\right)$$

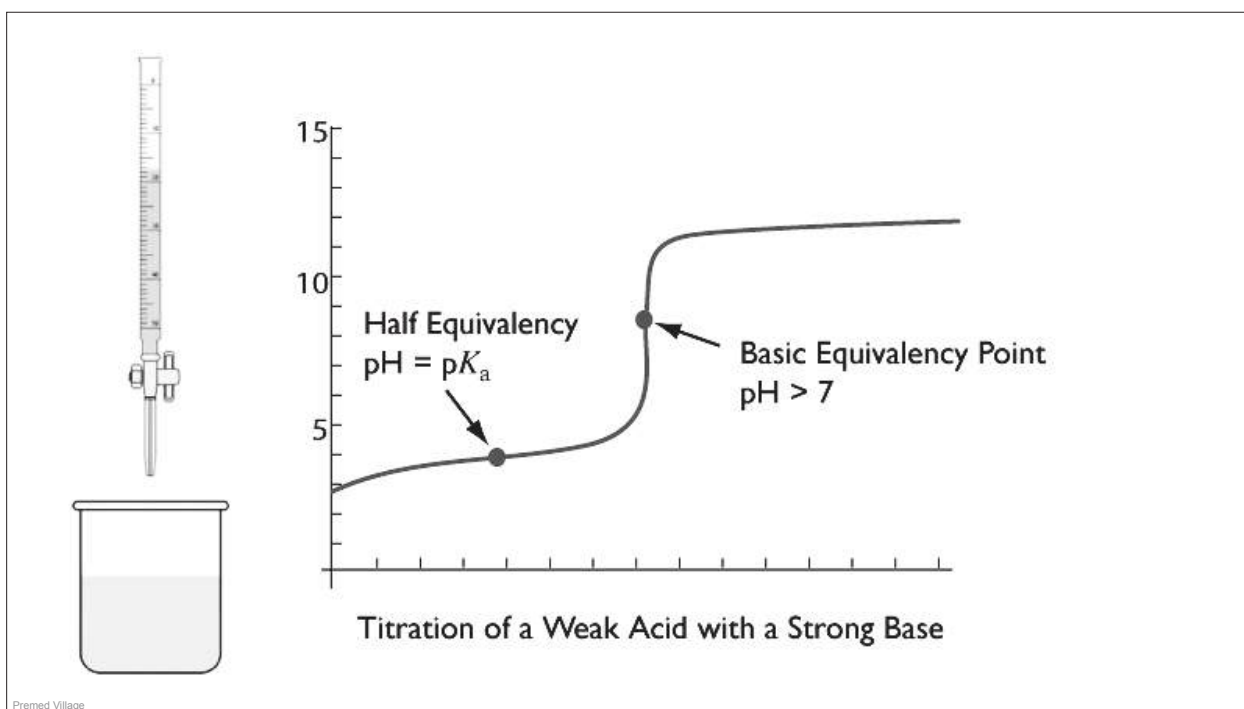
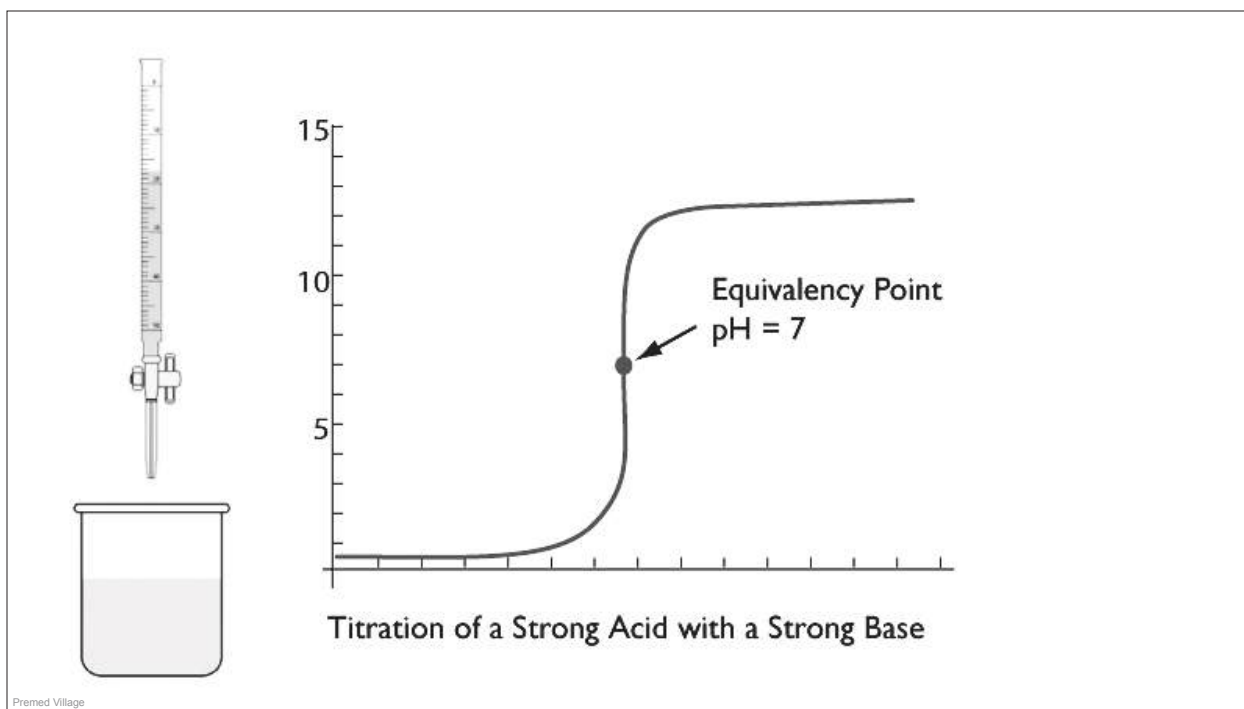
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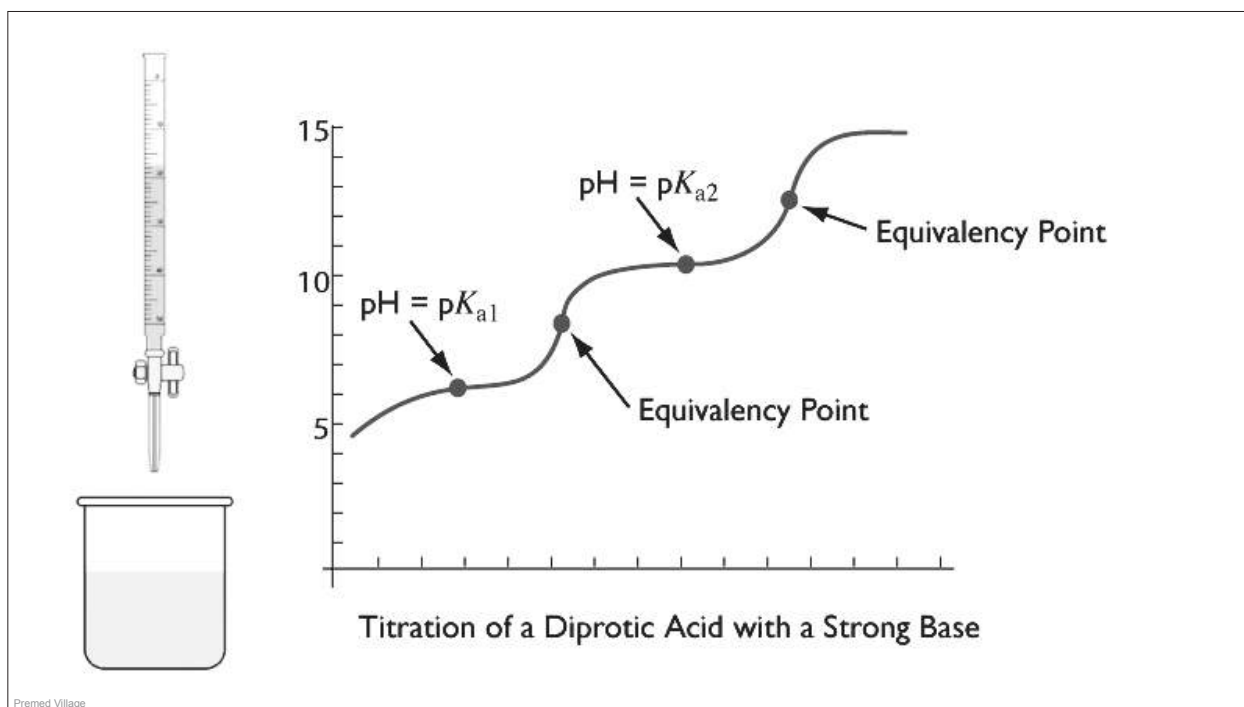
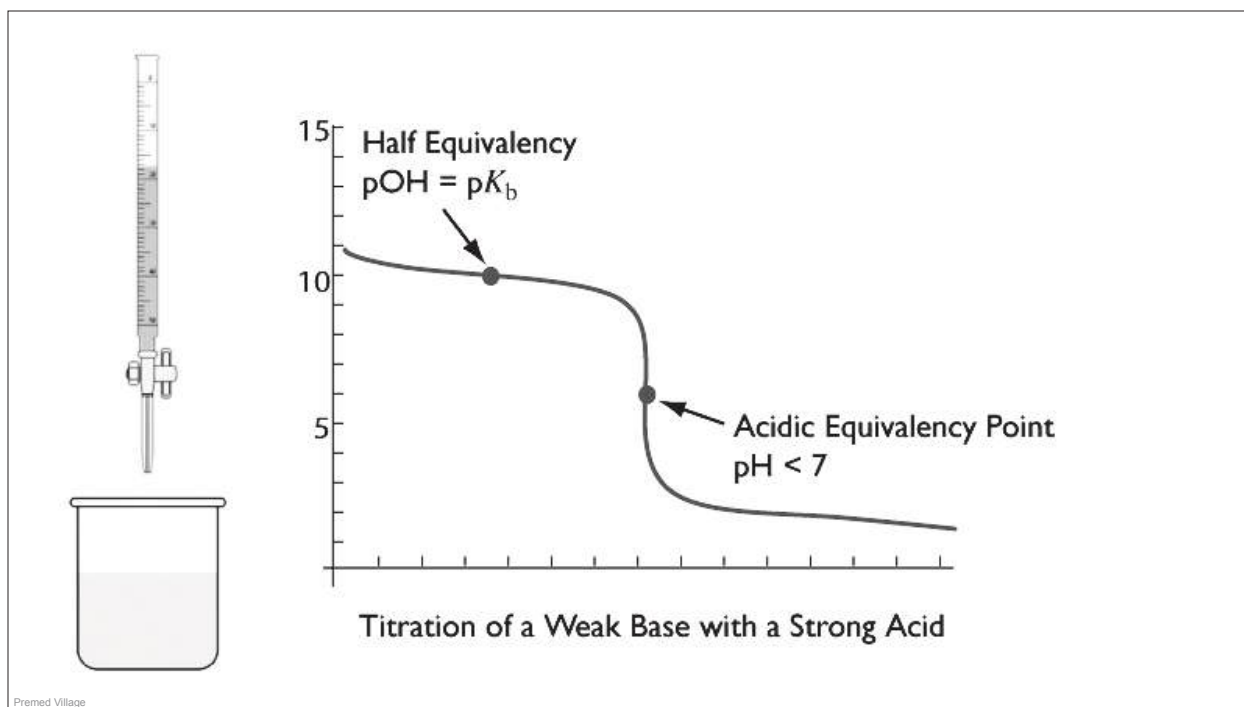


$$N_a V_a = N_b V_b$$

100 ml of HCl solution was completely neutralized by 25ml of 0.2N NaOH solution. What was the normality of the HCL solution?

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Maintenance of acid-base balance in physiology

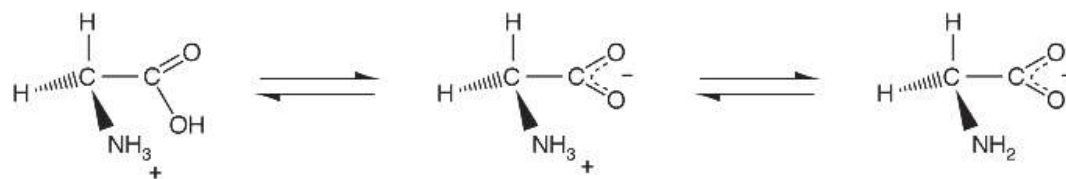
- Exhalation of CO_2
- Excretion of $H_2PO_4^-$ and NH_4^+ by the kidneys
- $NaHCO_3$ buffer system
- Secondary buffer systems including phosphates and proteins

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Which results from combining a concentrated solution of HCl with concentrated K_2CO_3 ?

- A.** formation of a colored complex
- B.** precipitation
- C.** liberation of gas
- D.** a solution of weak base

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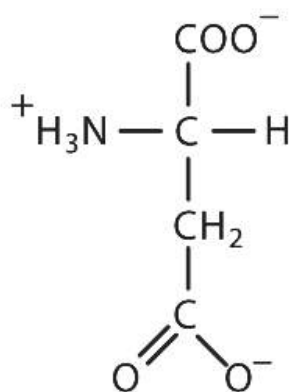
$$K_1 = \frac{[\text{H}^+][\text{HGly}]}{[\text{H}_2\text{Gly}^+]}$$

$$\text{p}K_1 = 2.4$$

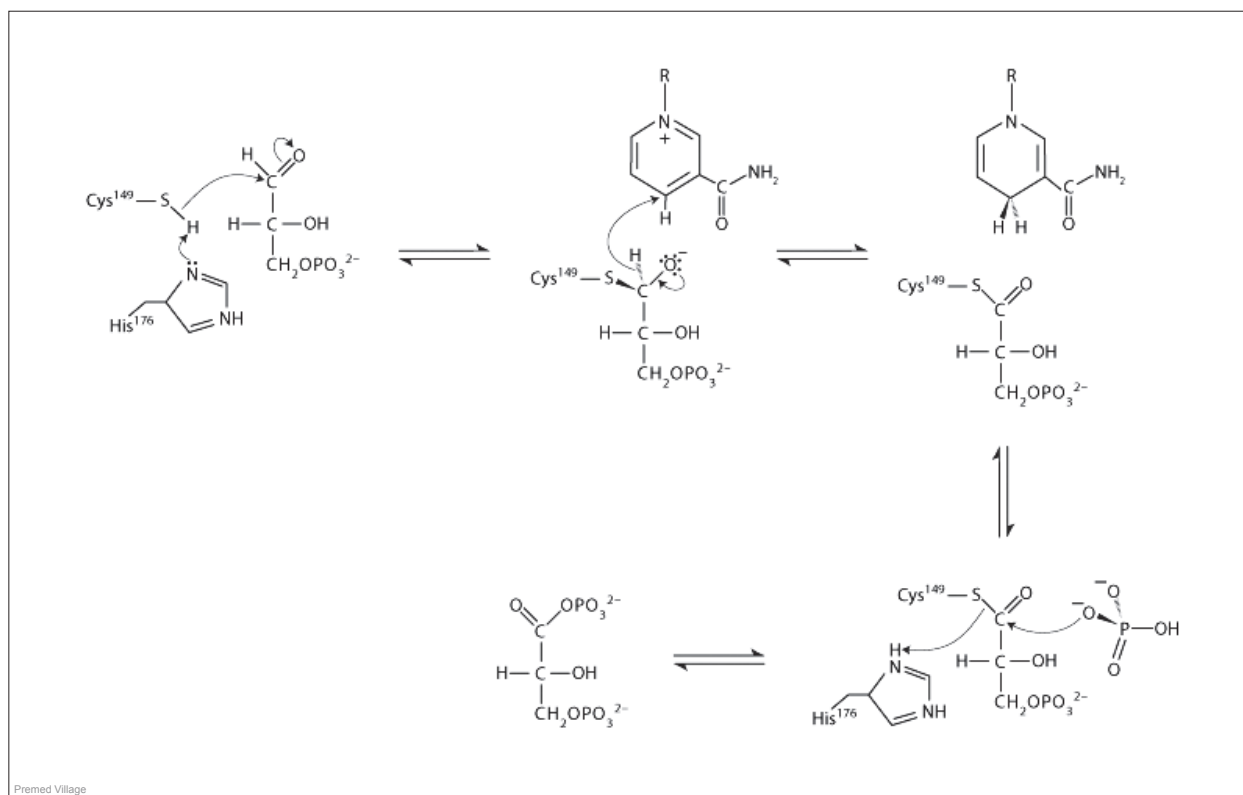
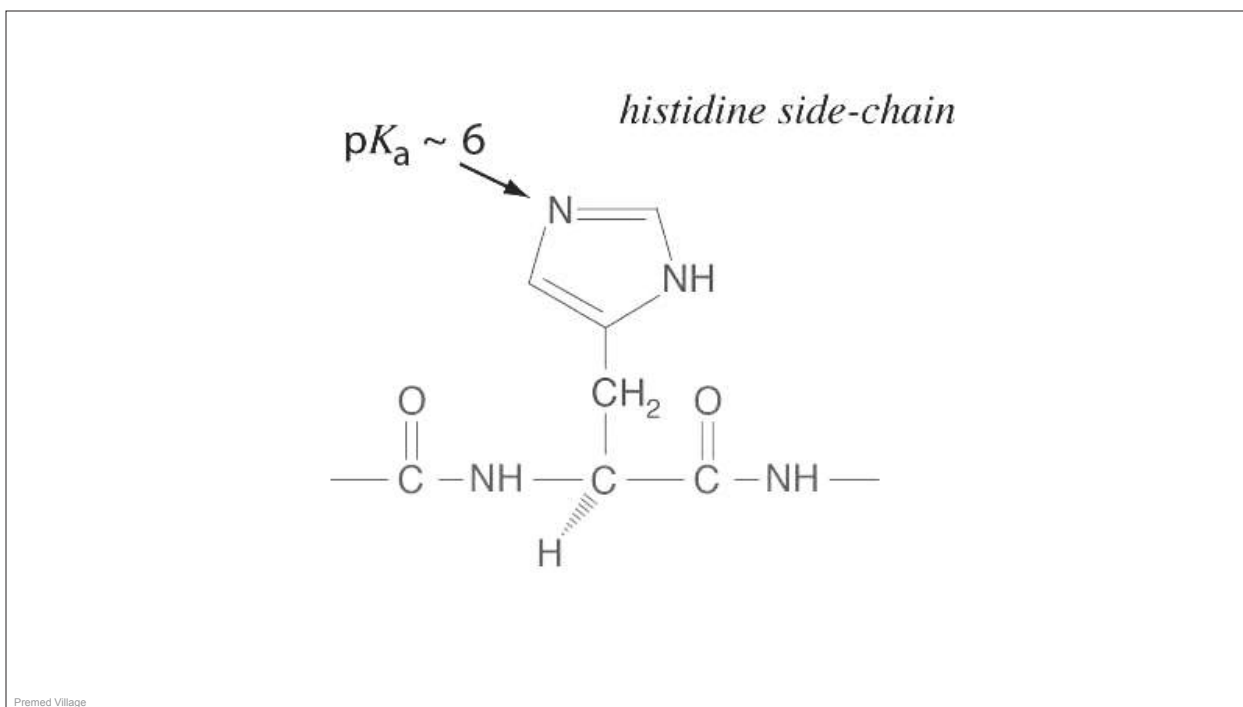
$$K_2 = \frac{[\text{H}^+][\text{Gly}^-]}{[\text{HGly}]}$$

$$\text{p}K_2 = 9.8$$

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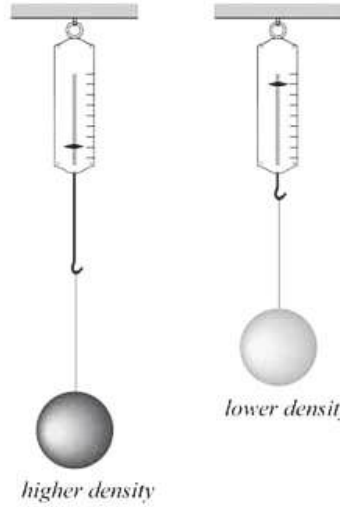


Density

$$\rho = \frac{m}{V}$$

ρ = density
 m = mass
 V = volume

Density is the mass per unit volume.

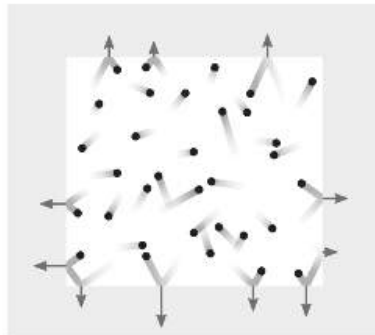


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Pressure

$$P = \frac{F}{A}$$

P = pressure
 F = force
 A = area



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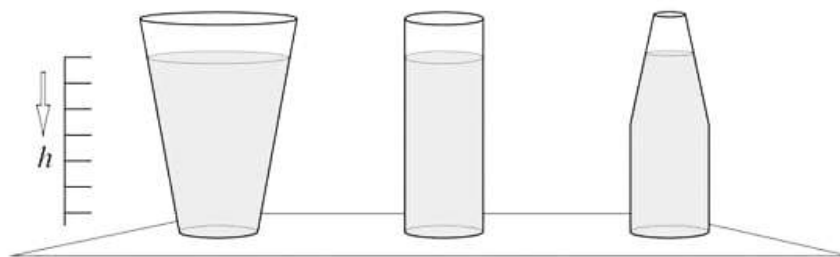
$$1 \text{ Pa} = \frac{1 \text{ N}}{\text{m}^2}$$

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Pressure Increases with Depth

$$P = P_a + \rho gh$$

P = pressure
 P_a = atmospheric pressure
 ρ = density
 g = acceleration due to gravity (10m/s^2)
 h = depth



Pressure is independent of the shape and size of the container.

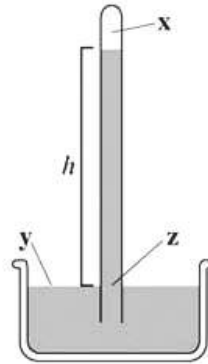
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What is the net force acting on the circular, level bottom of an open-topped water tower having a base 20 m in diameter containing water to a depth of 10 m?

- A. $3.1 \times 10^7 \text{ N}$
- B. $1.0 \times 10^5 \text{ N}$
- C. $6.2 \times 10^7 \text{ N}$
- D. $1.2 \times 10^8 \text{ N}$

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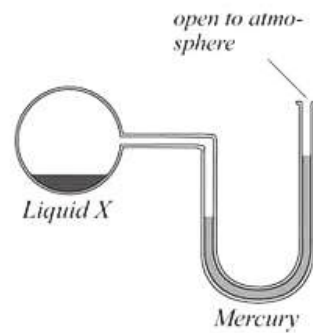
With the common mercury barometer pictured at right, the atmospheric pressure is equal to the product of ρgh (ρ is the density of mercury). Which of the following is not always true with regard to this device when it is accurately measuring atmospheric pressure?



- a. P_x is very nearly a vacuum
- b. $P_y = P_z$
- c. $P_y = P_{\text{atm}}$
- d. $P_y = 760 \text{ torr}$

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After adding a 50 ml sample of *Liquid X* to the vacuum bulb at right, it was observed to boil within the bulb. After a time, the system reached the state shown at right, the boiling having ceased. Assume that the vapor pressure of mercury at this temperature is nearly zero (pressure of the gaseous phase above its liquid phase) what can we conclude from the experiment?



- a. The density of *Liquid X* is greater than the density of mercury.
- b. *Liquid X* possesses implausible properties.
- c. The vapor pressure of *Liquid X* at room temperature is higher than atmospheric pressure.
- d. The bouyancy of *Liquid X* is greater than the bouyancy of mercury.

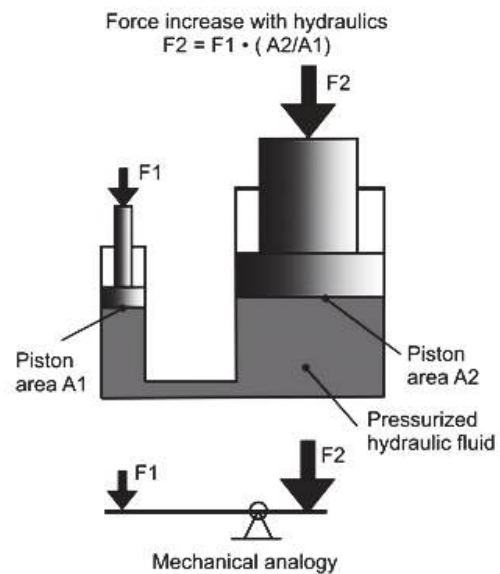
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Pascal's Law

$$\frac{F_a}{A_a} = \frac{F_b}{A_b}$$

F = force
A = area

Pascal's Law states that an increase in the pressure on one of the surfaces enclosing a fluid will be transmitted as an undiminished increase in pressure to all parts of the fluid. This means for our hydraulic press at right that one hundred newtons exerting over one square meter, can hold up four hundred newtons over four square meters.

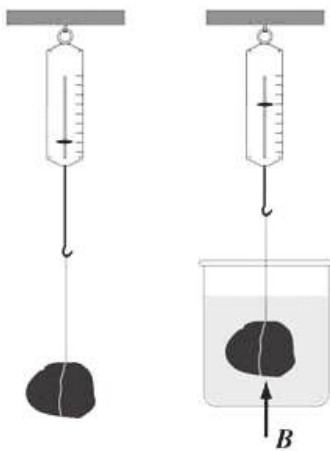


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The Heimlich maneuver—Any pressure applied in the airway against the closed thoracic cavity sealed accidentally by the food particle is transmitted equally to the trachea as to the rest of the lung. If the constricting pressure (applied by the person performing the maneuver) generated in the thorax during the maneuver is large enough, the particle lodged in the trachea is pushed out relieving the choking. This is very similar to pushing out tooth paste by squeezing the tube.

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Archimedes' Principle



$$B = W_{\text{fluid displaced}}$$

B = Buoyant Force

$W_{\text{fluid displaced}}$ = weight of fluid displaced

The buoyant force acting on a submerged mass

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A bar of lead has the dimensions $2 \times 3 \times 5 \text{ cm}^3$ and mass 330 gm. What is the specific gravity of lead?

- A. 1
- B. 10
- C. 11
- D. cannot be determined from given information

If the bar of lead were submerged in water, what would be the apparent loss of weight on the bar?

- A. 300 N
- B. 1 N
- C. 0.3 N
- D. 1/11 N

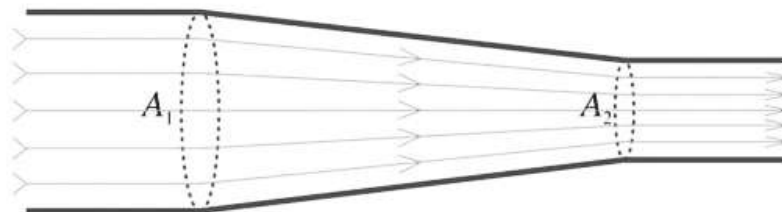
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Continuity of Volume Flux

$$A_1 v_1 = A_2 v_2 = \text{constant}$$

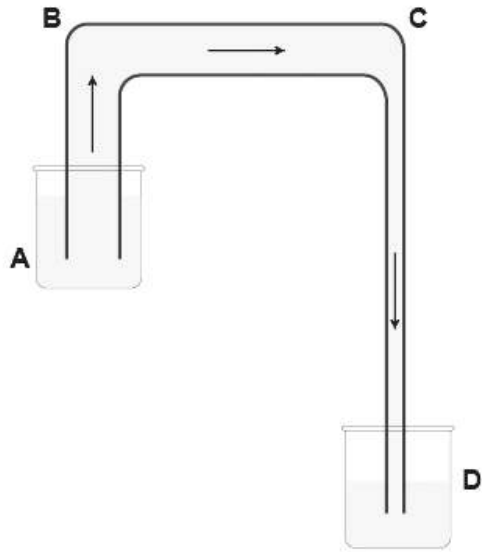
A = vessel cross-sectional area

v = flow speed



In the flow of an ideal fluid, the rate at which fluid volume moves through the vessel (volume flux) is the same everywhere along the pipe. Where vessel diameter is narrowest, the flow speed is greatest.

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The diameter of tube segment AB is 3 cm. The diameter of tube segment CD is 1 cm. When the flow speed through AB is 2 cm/s, what will the flow speed be through CD?

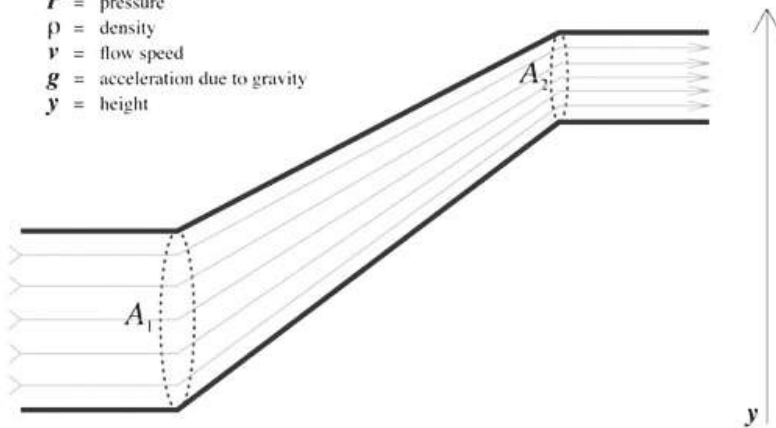
- A. 6 cm/s
- B. 18 cm/s
- C. 9 cm/s
- D. 15 cm/s

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Bernoulli's Equation

$$P + \frac{1}{2}\rho v^2 + \rho gy = \text{constant}$$

- P = pressure
- ρ = density
- v = flow speed
- g = acceleration due to gravity
- y = height



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An aneurysm is caused by the weakening of the arterial wall where a bulge occurs and the cross-section of a vessel increases considerably. At the cross-section of an aneurysm

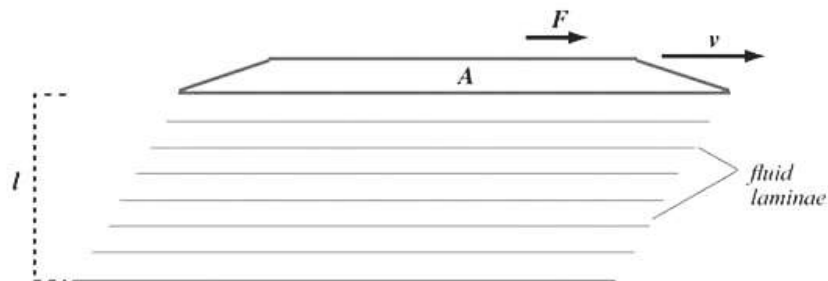
- A. flow velocity will be reduced and the pressure will be reduced
- B. flow velocity will be reduced and the pressure will increase
- C. flow velocity will increase and the pressure will be reduced
- D. flow velocity will increase and the pressure will increase

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Viscosity

η = viscosity
 F = shearing force
 A = sheared area
 v = sliding speed
 l = fluid thickness

$$\eta = \frac{F/A}{v/l}$$



The figure above shows laminae, or layers of liquid, between two surfaces. The more viscous the fluid, the larger the shearing force required for the top surface to slide past the bottom surface at a given speed. Viscosity reflects friction between the laminae, or fluid layers.

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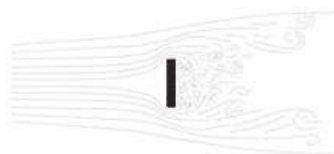
The Causes of Turbulent Flow

$$RN = \frac{\rho v d}{\eta}$$

- RN = Reynolds number
- ρ = fluid density
- v = flow speed
- d = geometrical property of the flow
(diameter of obstruction, pipe width)
- η = viscosity



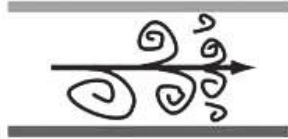
laminar (streamline) flow
(low Reynolds number)



turbulent flow
(high Reynolds number)

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Most blood flow is remarkably free of turbulence, although, under both normal or abnormal conditions, turbulence may occur in certain areas of the circulatory system. Which of the following would be most likely to directly contribute to turbulence?



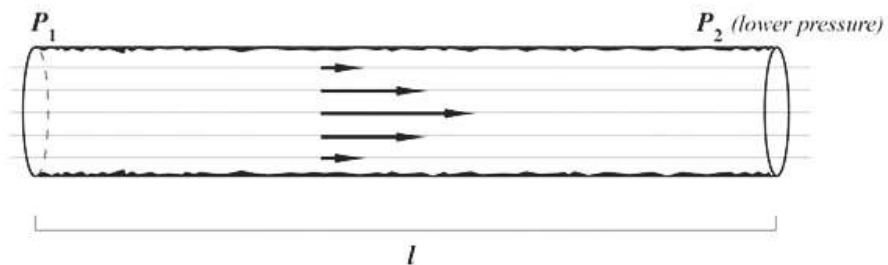
- decreased cardiac output
- increased blood viscosity
- localized narrowing of an arterial vessel
- decrease in blood density

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Poiseuille's Law

$$Q = \frac{\Delta P \pi r^4}{8 \eta l}$$

- Q = volume flux
 ΔP = change in pressure
 r = pipe or vessel radius
 η = viscosity
 l = pipe or vessel length



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With the plunger exerting the same negative pressure, the total time required to draw 10ml of blood through a syringe with a needle having half the length and half the diameter would be

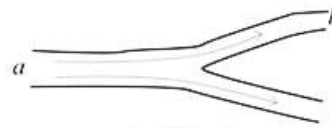
- A. 1/2 as long
- B. the same
- C. 8 times longer
- D. 32 times longer

A large artery branches into two smaller arteries, each with 50% of the radius of the larger. Since all blood flowing into the junction enters the smaller arteries, the volume flux within the larger must be twice the volume flux through either of the smaller. Thus, from Poiseuille's Law:

$$\frac{\Delta P_a r_a^4}{l_a} = \frac{2\Delta P_b r_b^4}{l_b}$$

Which follows from this relationship?

- Pressure drop per unit length is much greater in a small artery than in the large.
- Pressure drop per unit length is double in the large artery vs. the small.
- Total flow speed in the small arteries equals total flow speed in the large.
- Pressure drop per unit length is double in the small artery vs. the large.



$$Q = \frac{\Delta P \pi r^4}{8 \eta l}$$

Poiseuille's Law

Q = volume flux
 ΔP = change in pressure
 r = vessel radius
 η = viscosity
 l = vessel length

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The answer is (a)

Because of the extreme effect of the decreasing radius on viscous dissipation as described by Poiseuille's Law, decreasing the radius causes a very large increase in the pressure drop per unit length.

In our example, if we substitute $(0.5)r_a$ for r_b :

$$\frac{\Delta P_a r_a^4}{l_a} = \frac{2\Delta P_b r_b^4}{l_b}$$

$$\frac{\Delta P_a r_a^4}{l_a} = \frac{2\Delta P_b (0.5 r_a)^4}{l_b}$$

$$\frac{\Delta P_a}{l_a} = \frac{1}{8} \frac{\Delta P_b}{l_b}$$

A MAJOR CONSEQUENCE OF POISEUILLE'S LAW IS THAT IN THE CARDIOVASCULAR SYSTEM, THE NARROW VESSELS ARE MUCH SHORTER. IF NOT, THERE WOULDN'T BE PRESSURE REMAINING AFTER BLOOD FLOWS THROUGH THE CAPILLARIES FOR IT TO RETURN TO THE HEART.



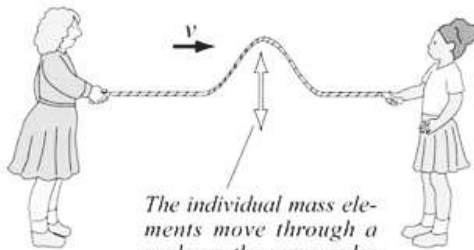
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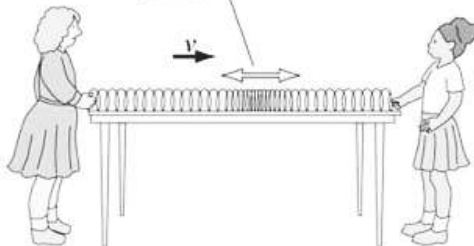
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Transverse and Longitudinal Waves



A transverse pulse. If the displacements associated with wave disturbances move in a direction perpendicular to wave motion, the wave is transverse.

The individual mass elements move through a cycle as the wave pulse passes.



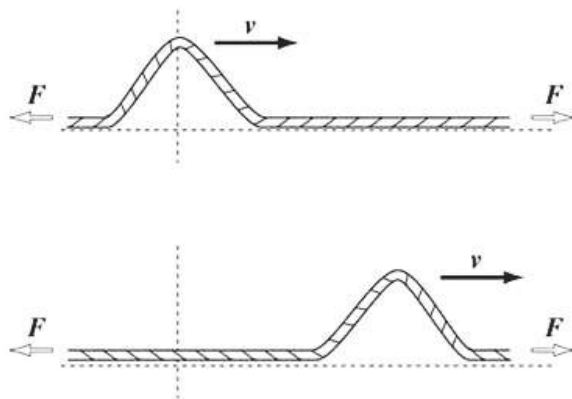
A longitudinal pulse. If the displacements associated with wave disturbances move in a direction parallel to wave velocity, the wave is longitudinal.

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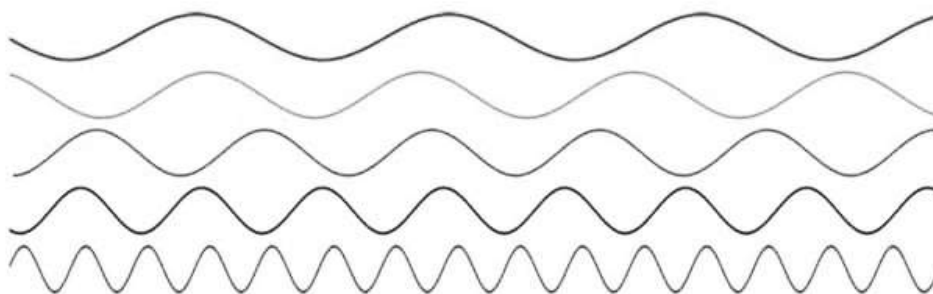
Speed of a Wave on a Stretched String

$$v = \sqrt{\frac{F}{\mu}}$$

v = wave speed
 F = tension
 μ = mass per unit length

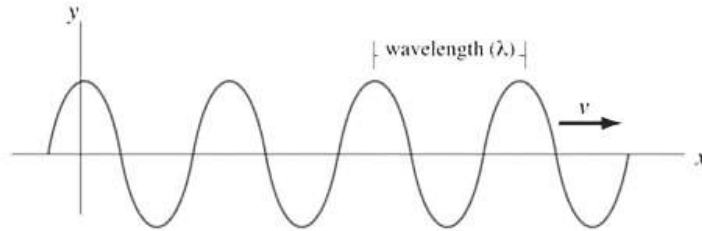


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The wavelength of a harmonic wave divided by its speed of propagation is equal to:



- a. the frequency
- b. the angular frequency
- c. the wave number
- d. the period

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A tuning fork produces an E note (frequency = 660 Hz). The wavelength is 0.5 m. At what speed do sound waves move through the air of this room?



- a. 132 m/s
- b. 165 m/s
- c. 330 m/s
- d. 1320 m/s

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An FM radio station broadcasts at 100MHz on the dial. What is the wavelength of its signal?

- a. 1.0×10^{-8} m
- b. 0.33 m
- c. 3 m
- d. 100 m

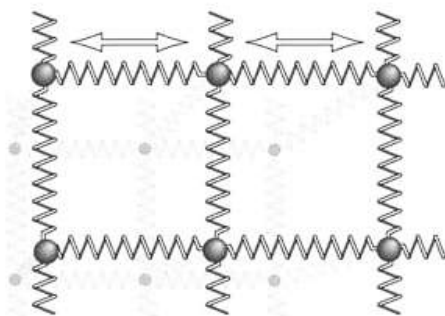


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Sound Waves

$$v = \sqrt{\frac{B}{\rho}}$$

v = speed of sound
 B = bulk modulus
 ρ = density

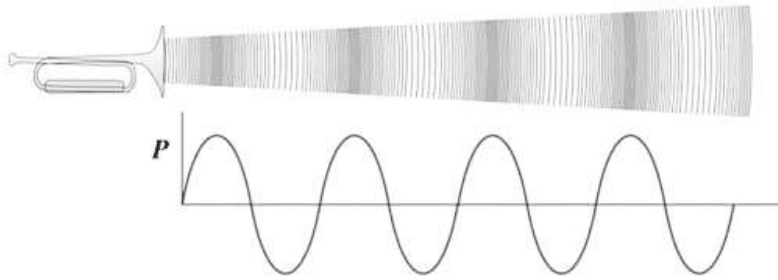


Sound wave propagation occurs by means of the elasticity of the medium. Imagine a three dimensional matrix in which mass elements are connected by springs. Increasing the strength of the springs (bulk modulus) would increase the speed of waves through the medium. Increasing the mass of the elements (density) would slow the waves down.

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Which of the following is a true statement concerning sound waves?

- a. Sound waves can pass through a vacuum.
- b. The speed of sound does not depend on the medium of propagation.
- c. Sound waves are longitudinal waves.
- d. Sound waves cannot be reflected.



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Loudness



$$\beta = 10 \log \left(\frac{I}{I_0} \right)$$

β = loudness in decibels

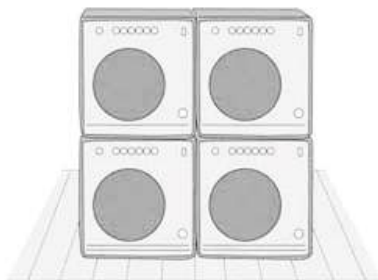
I = intensity

$I_0 = 10^{-12} \text{ W/m}^2$

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After judging a value of 120 dB a few meters in front of the stage to be insufficiently loud enough, a rock-and-roll band doubled the number of amplifiers in its stack. What was the loudness after the addition of the new amplifiers?

- a. 123 dB
- b. 130 dB
- c. 144 dB
- d. 240 dB

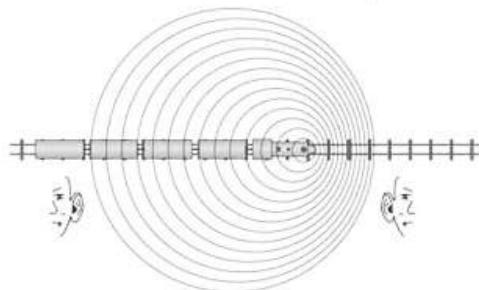


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Doppler Effect

$$f' = f \left(\frac{v \pm v_o}{v \mp v_s} \right)$$

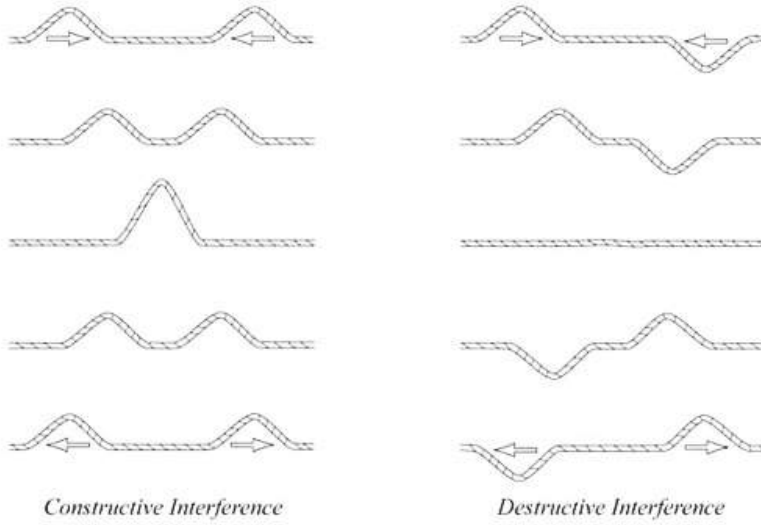
f' = observed frequency
 f = source frequency
 v = wave speed
 v_o = speed of observer
 v_s = speed of source



Because of the Doppler effect, the measured frequency of sound is greater for the observer the train is approaching than for the observer the train is leaving.

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Constructive and Destructive Interference



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Standing Waves on a Stretched String

$$\lambda_n = 2L, L, \frac{2L}{3}, \dots, \frac{2L}{n}$$

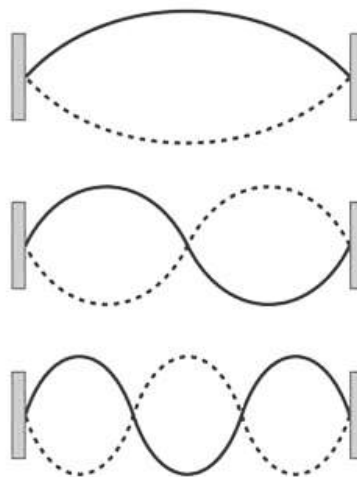
The wavelengths of the normal modes correspond to the possible waves with nodes at the fixed ends.

$$f = \frac{v}{\lambda_n} = \frac{n}{2L}v$$

It's a simple matter to move from wavelengths to frequency if you know the wave speed (deriving from the tension, F , and the mass per unit length, μ , of the string):

$$v = \sqrt{\frac{F}{\mu}}$$

- λ_n = wavelengths of normal modes
- L = length of string
- n = 1, 2, 3, ...
- f = frequencies of normal modes
- v = wave speed



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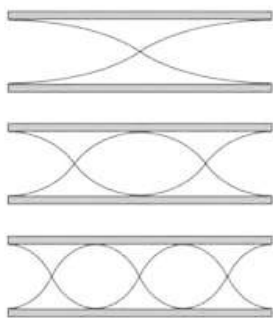
Standing Waves in Air Columns

Pipe Open at Both Ends

$$\lambda_n = 2L, L, \frac{2L}{3}, \dots, \frac{2L}{n}$$

$$f = \frac{v}{\lambda_n} = \frac{n}{2L}v$$

($n = 1, 2, 3, \dots$)



λ_n = wavelengths
of normal
modes

L = length of
pipe

f = frequencies
of normal
modes

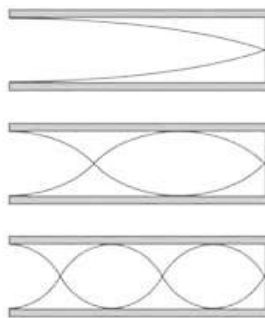
v = wave speed

Pipe Closed at One End

$$\lambda_n = 4L, \frac{4L}{3}, \frac{4L}{5}, \dots, \frac{4L}{n}$$

$$f = \frac{v}{\lambda_n} = \frac{n}{4L}v$$

($n = 1, 3, 5, \dots$)



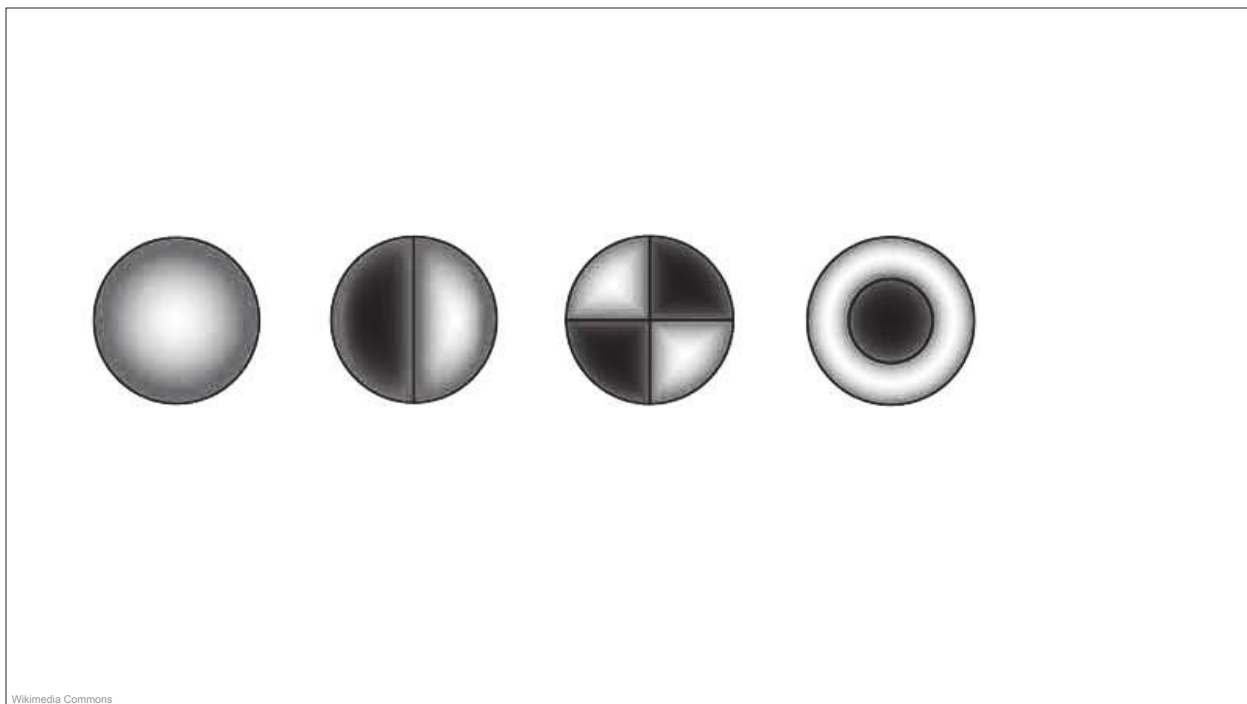
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A flute is an example of a musical instrument that functions as a pipe closed at one end. What is the lowest musical note produced by a 0.75m long flute (the speed of sound in this particular air is 330 m/s).

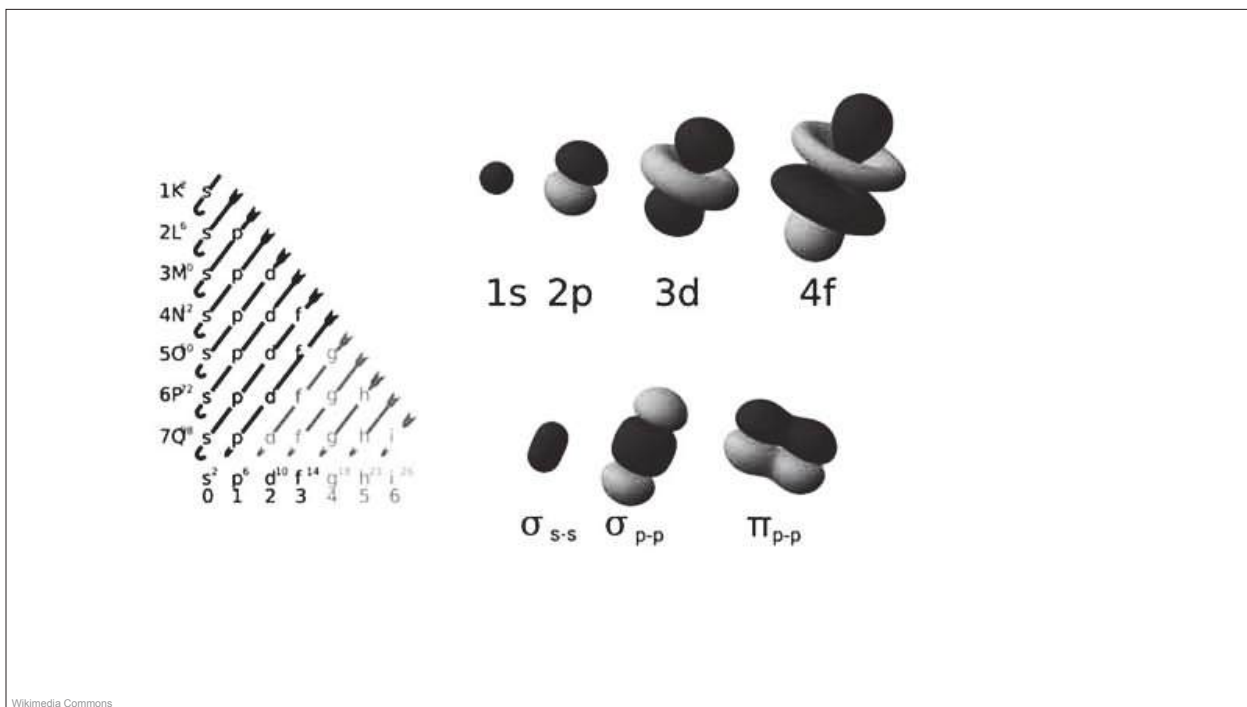
- A (110 Hz)
- B (248 Hz)
- A (220 Hz)
- E (660 Hz)



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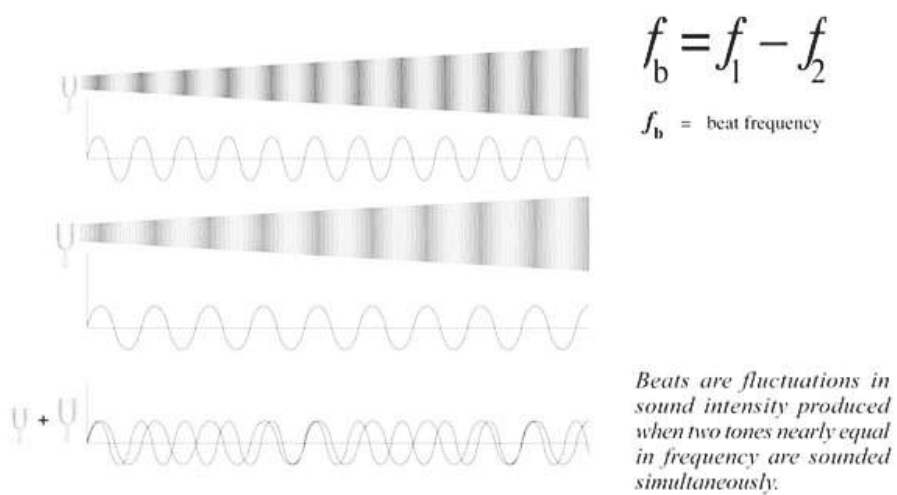


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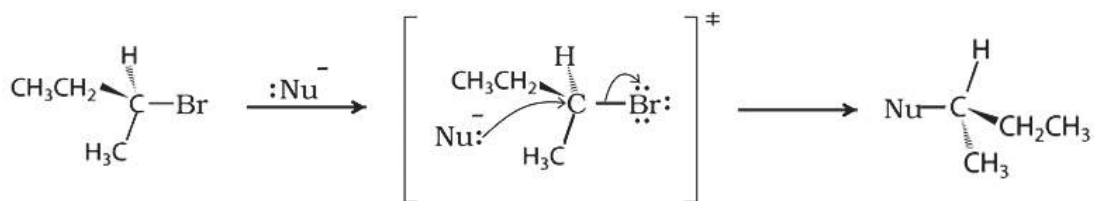
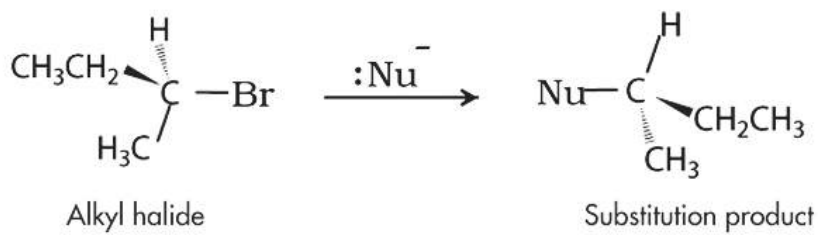
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Beats



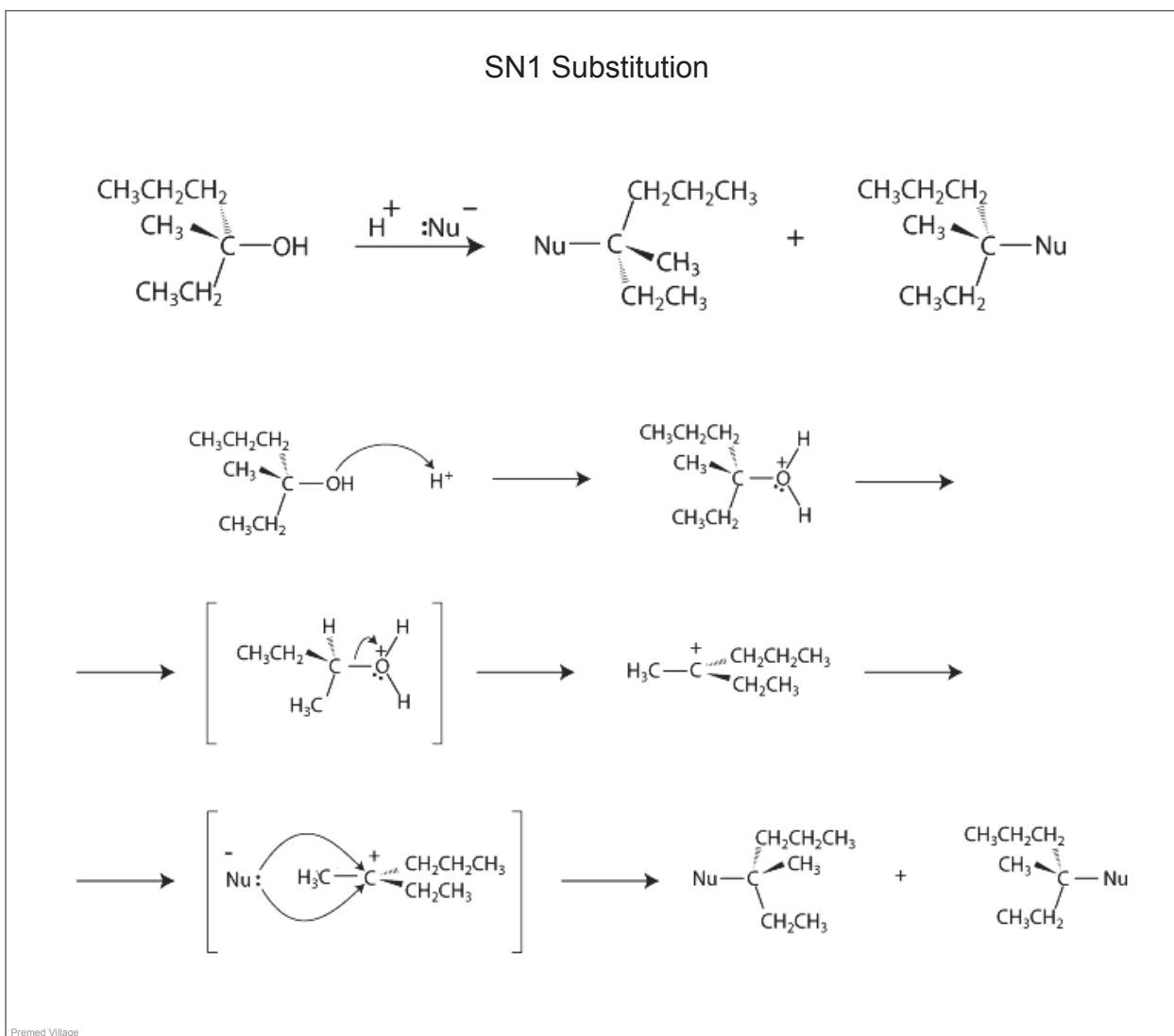
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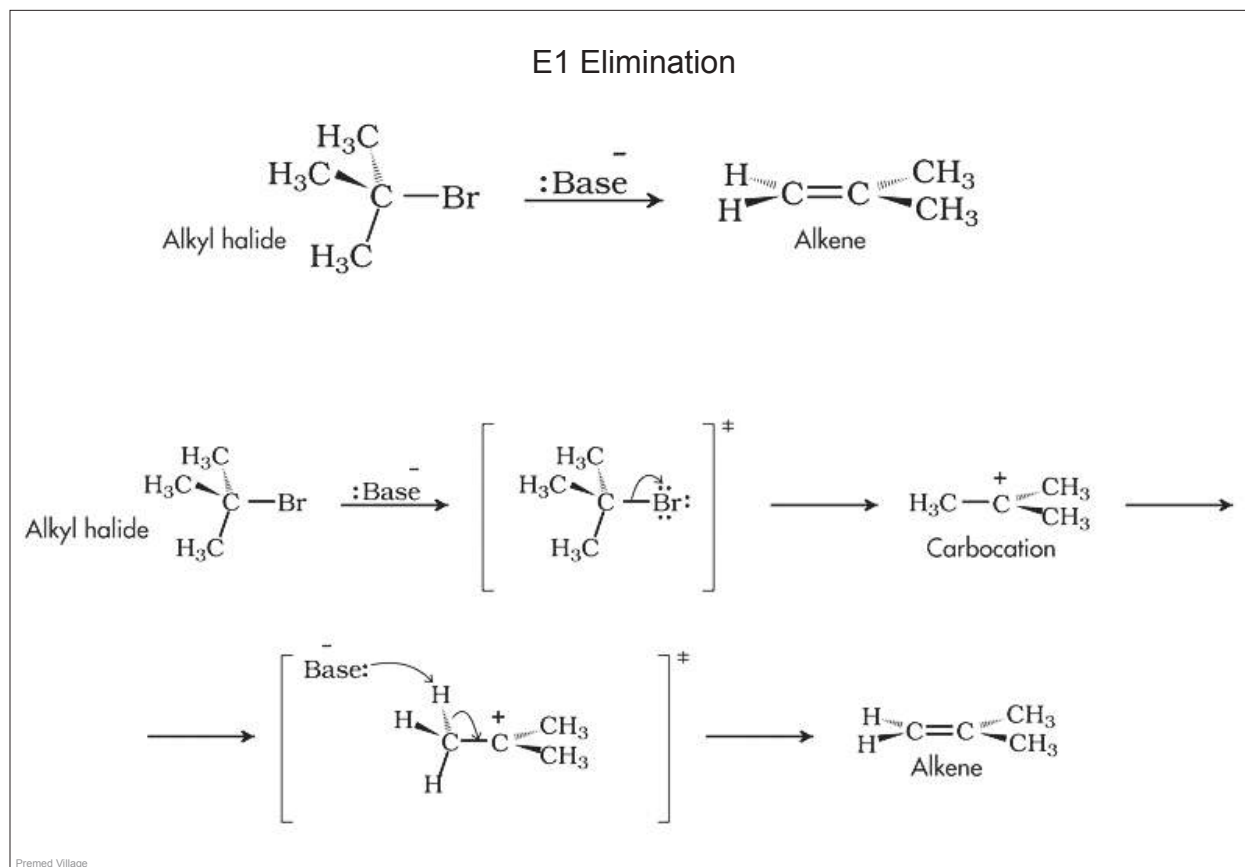
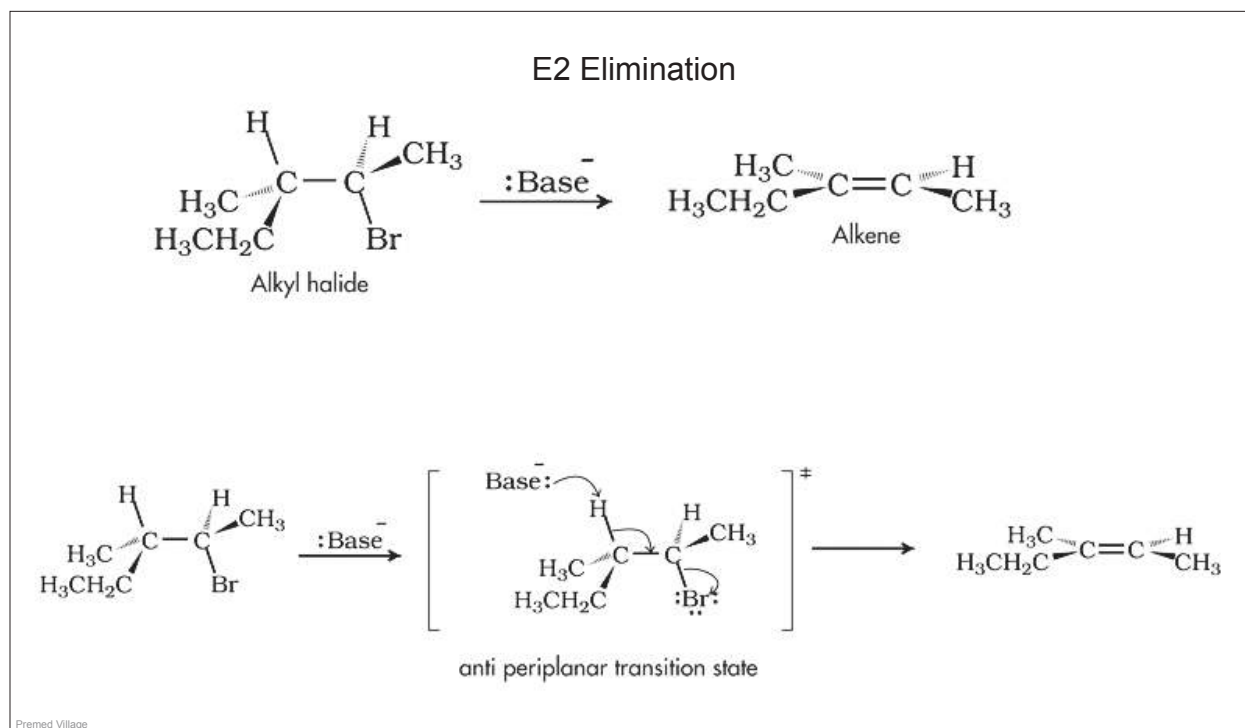
SN2 Substitution



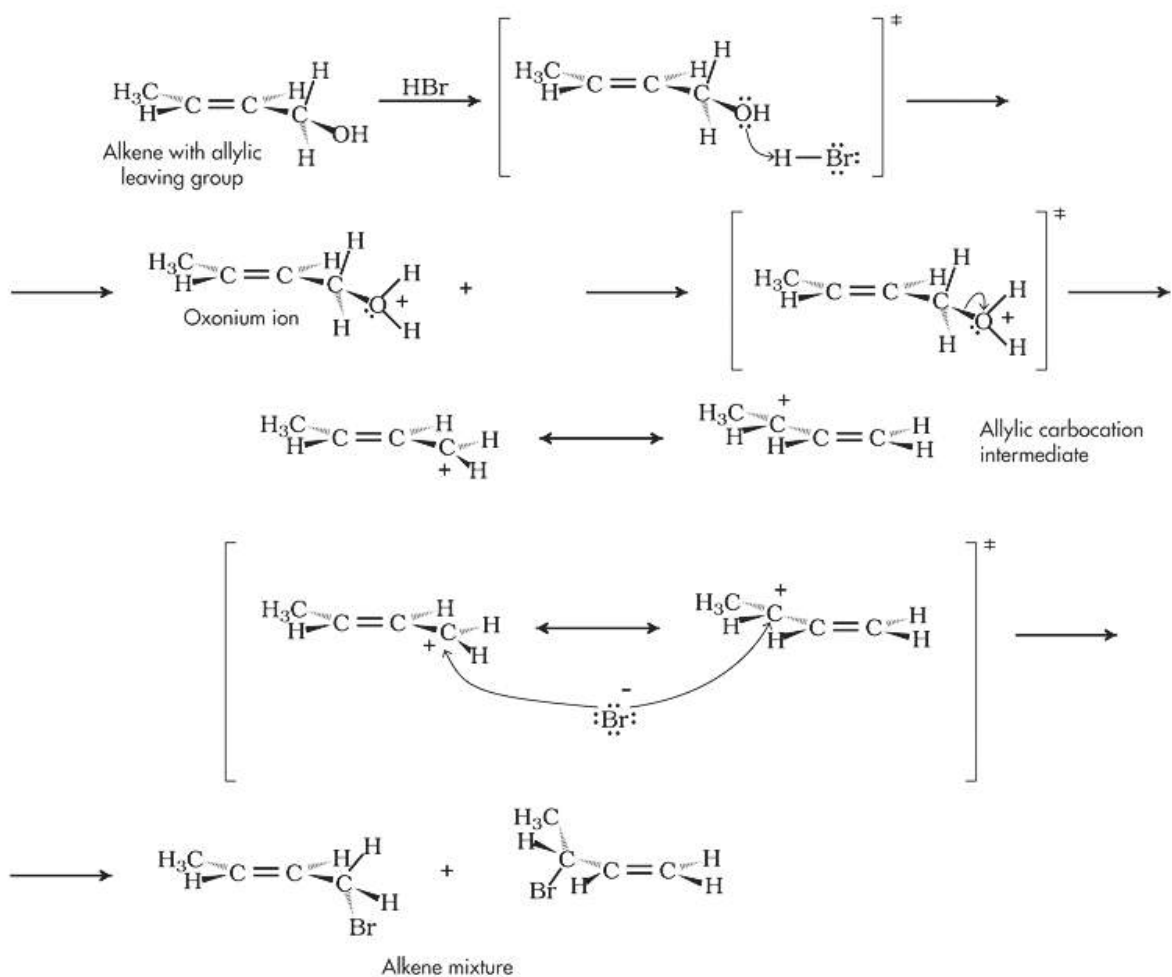
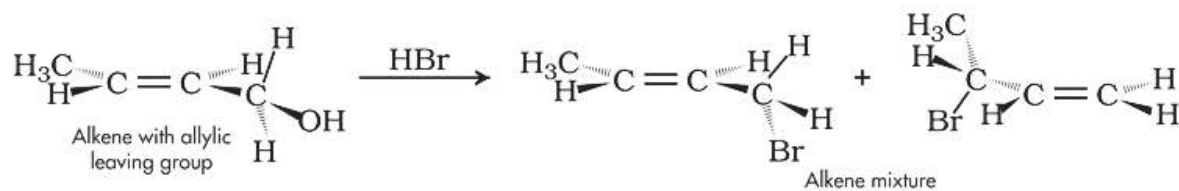
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SN1 Substitution





SN1 Substitution with Hydroxide Leaving as Water at the Allylic Position

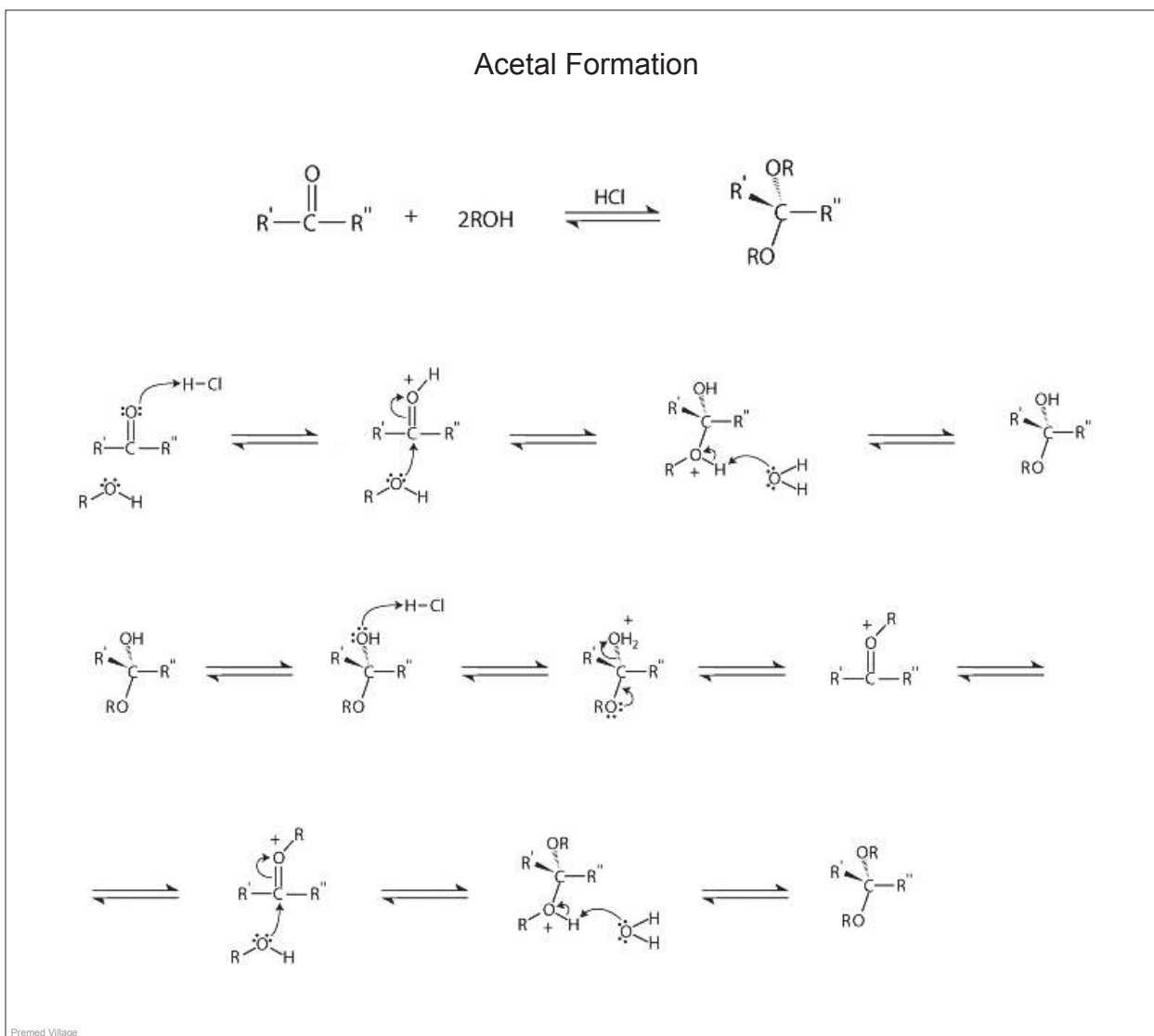


Substitution vs. Elimination

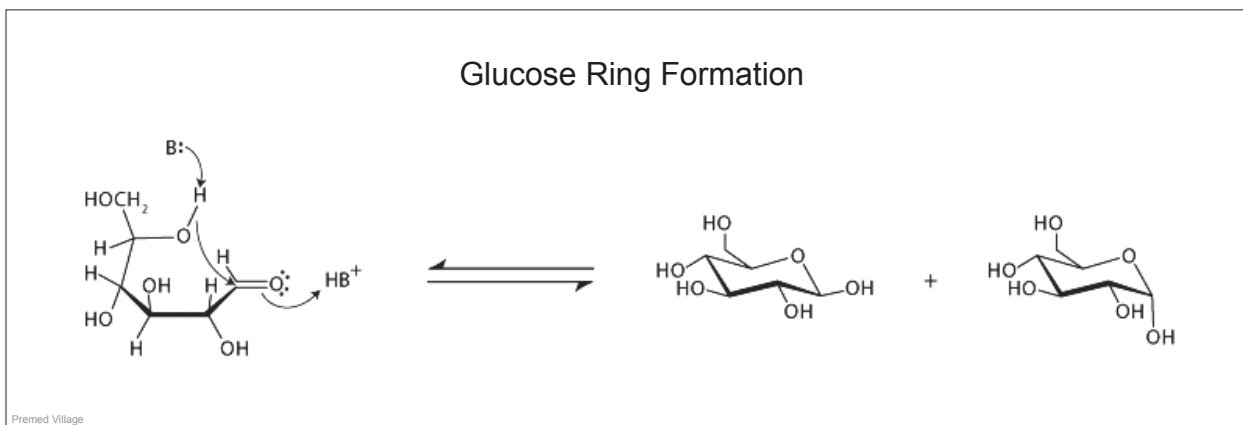
Substrate	If the substrate is a primary alkyl halide, the reaction will almost certainly be SN2. Exceptions: A bulky hindered base like tert-butoxide will tend to react with E2. Watch out for allylic primary alkyl halides. If the substrate is tertiary, the reaction cannot be SN2.
Nucleophile	Charged nucleophiles/bases will favor SN2/E2. Deciding between SN2 & E2, look at the basicity. Strong bases with secondary substrates will favor E2. Weak bases like Cl ⁻ , CN ⁻ favor SN2. Uncharged nucleophiles/bases favor SN1/E1.
Solvent	SN2 substitution is favored by polar, aprotic solvents like DMSO, acetonitrile, diethyl ether etc.
Temperature	If the choice is between E1 and SN1, high temperature favors elimination.

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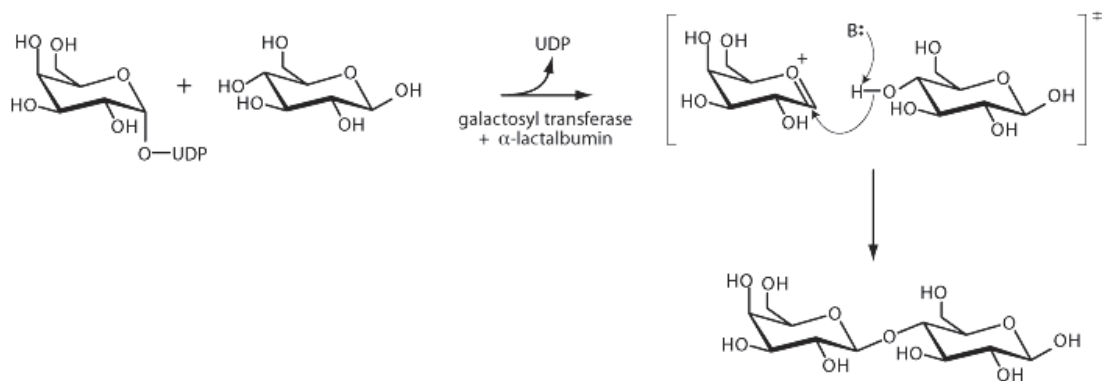
Acetal Formation



Glucose Ring Formation

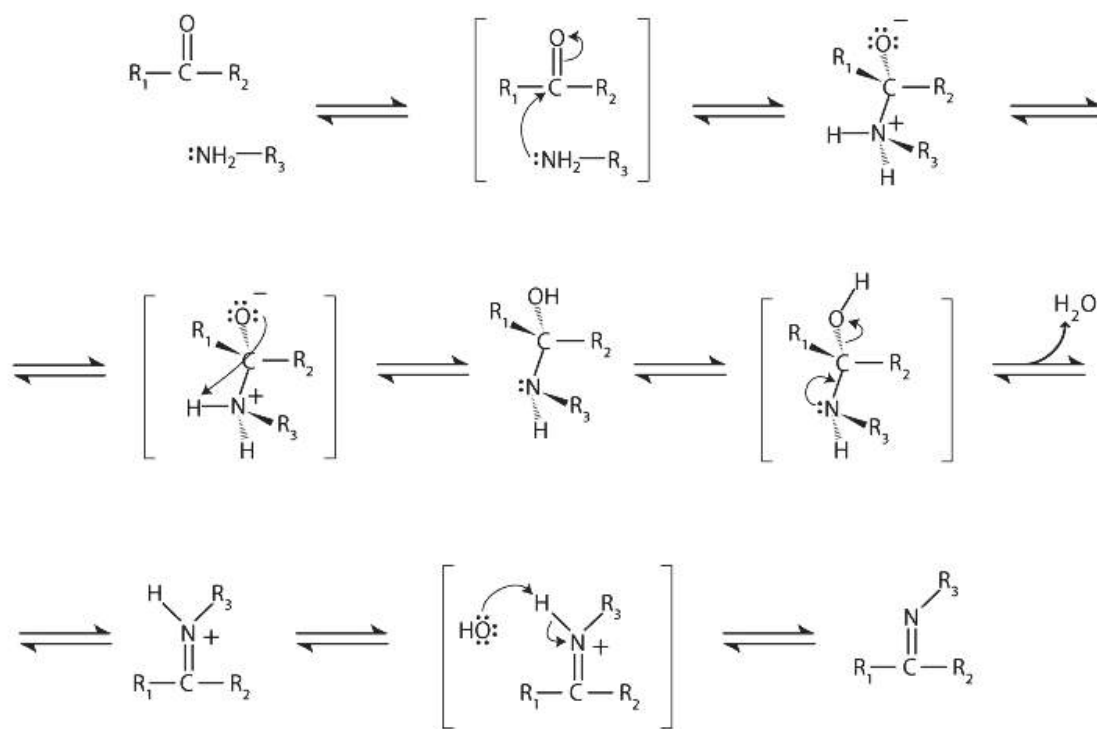
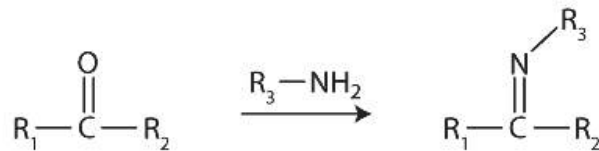


Glycosidic Bond Formation



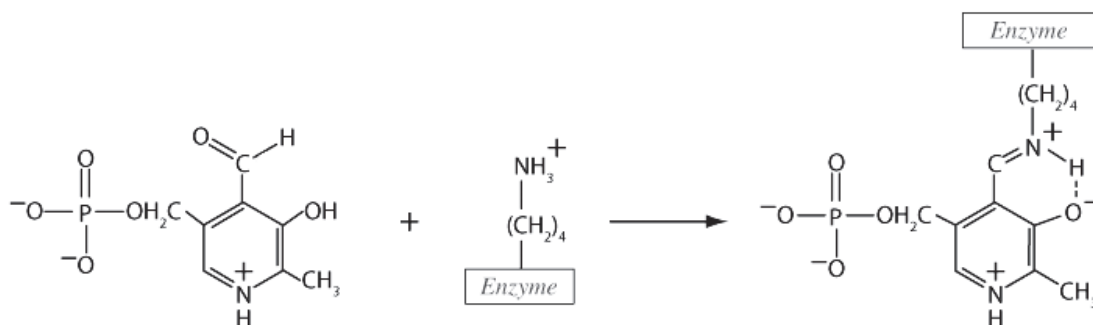
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Imine Formation



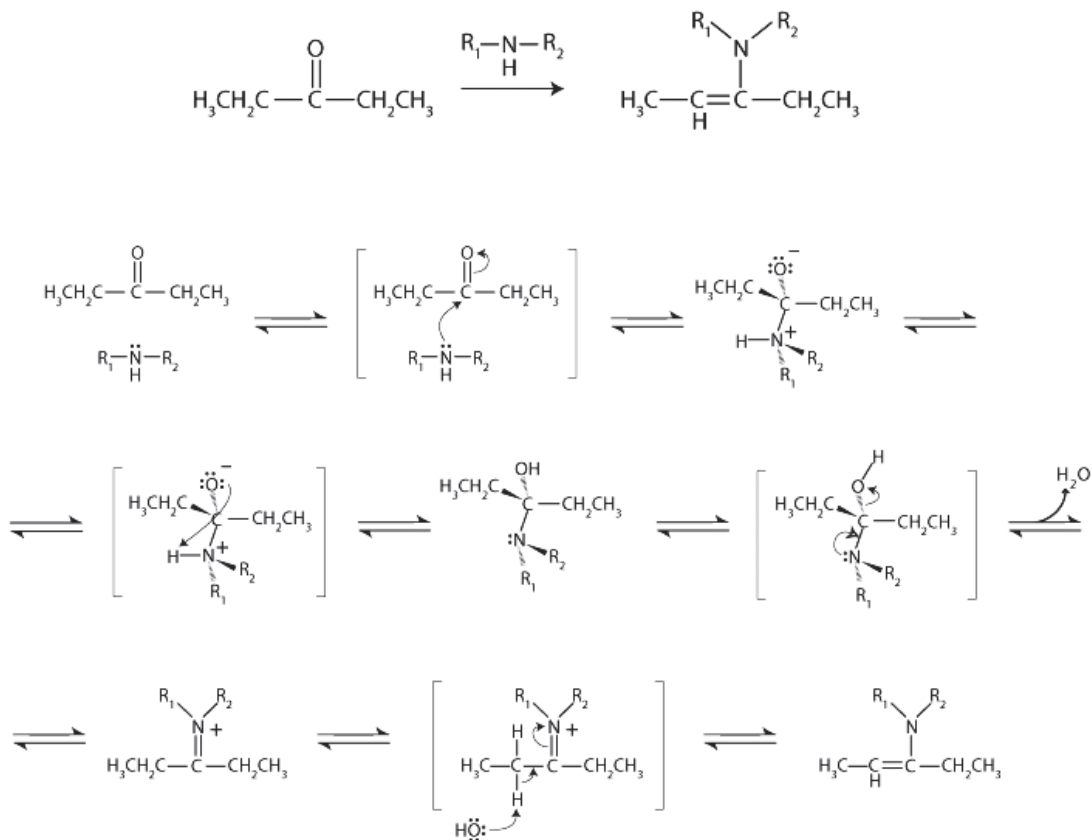
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Formation of Enzyme-PLP Schiff Base



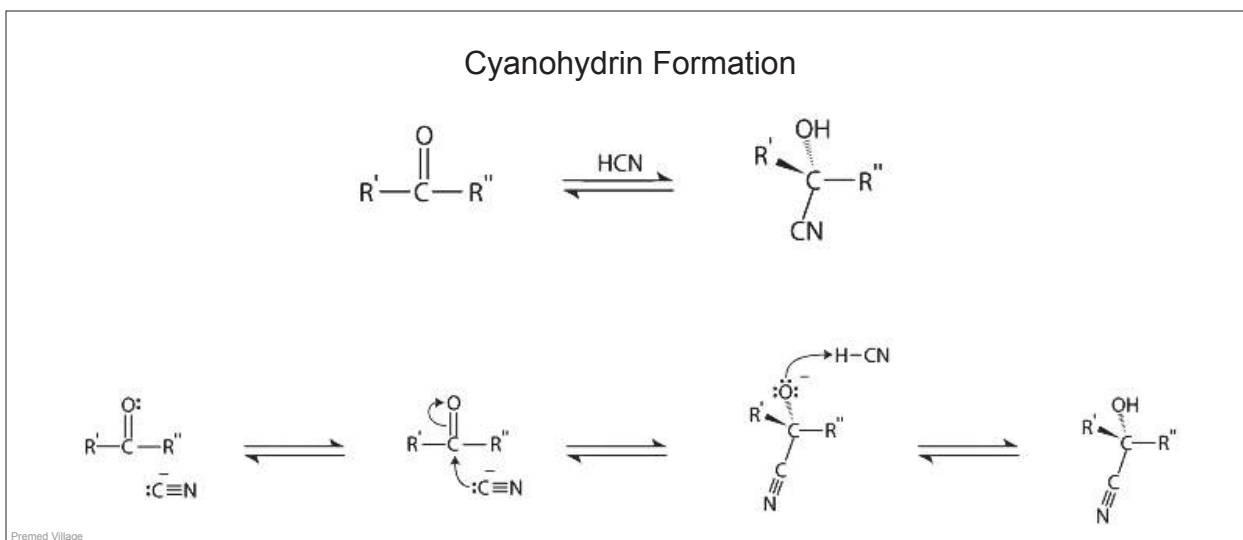
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Enamine Formation

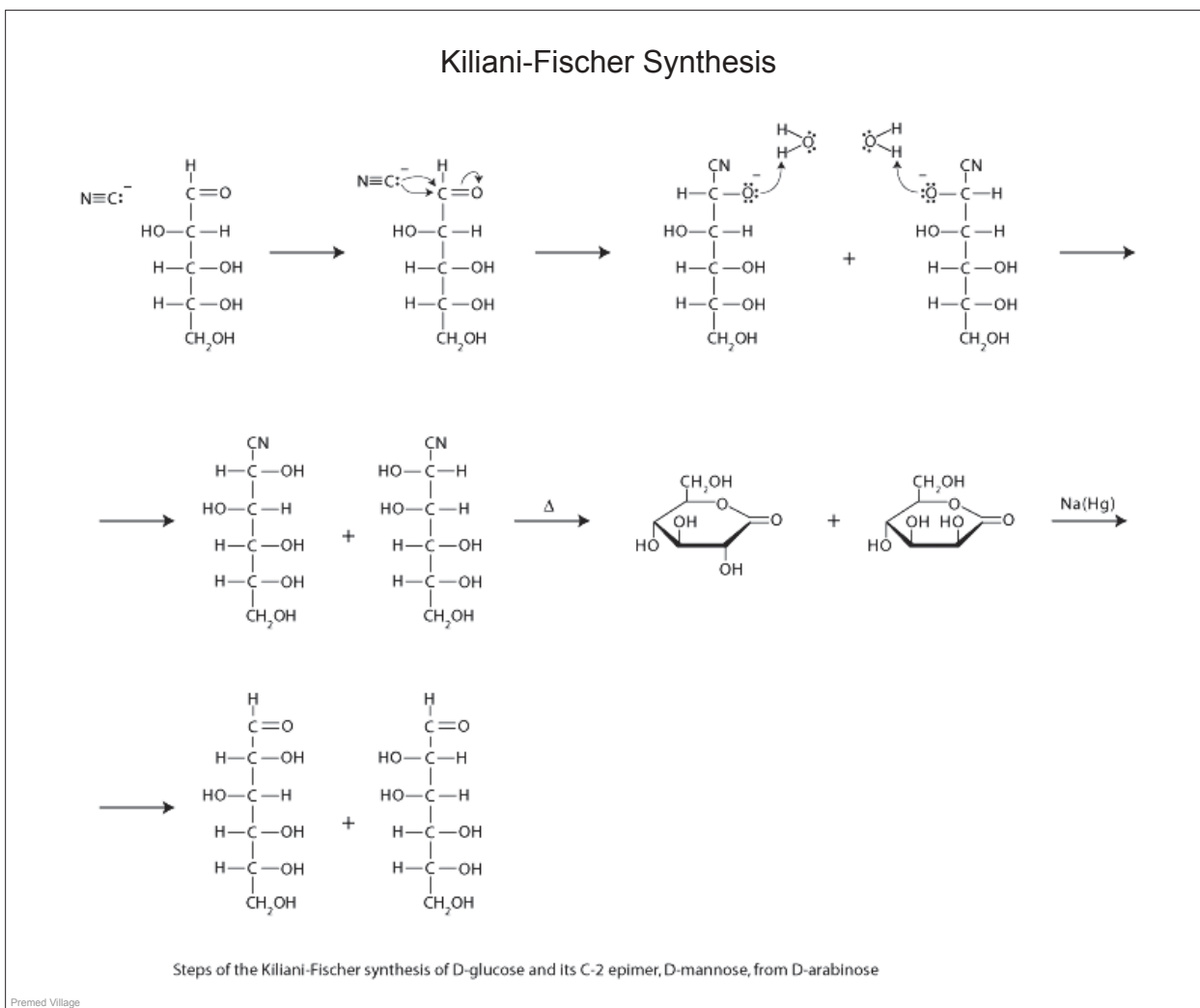


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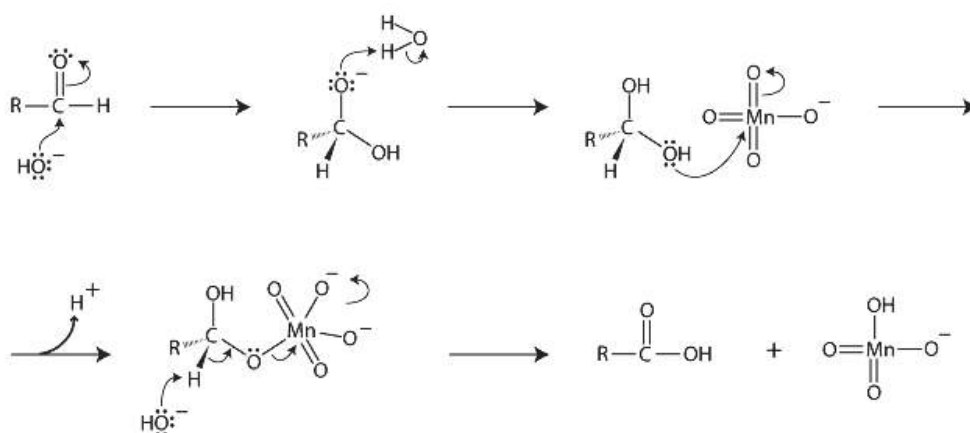
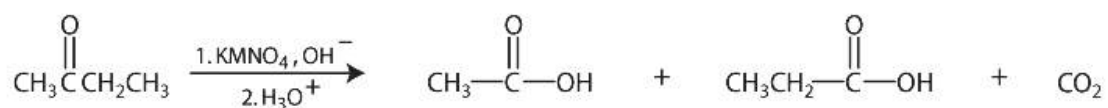
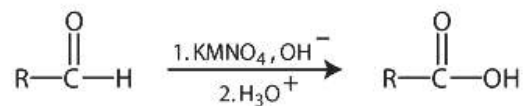
Cyanohydrin Formation



Kiliani-Fischer Synthesis

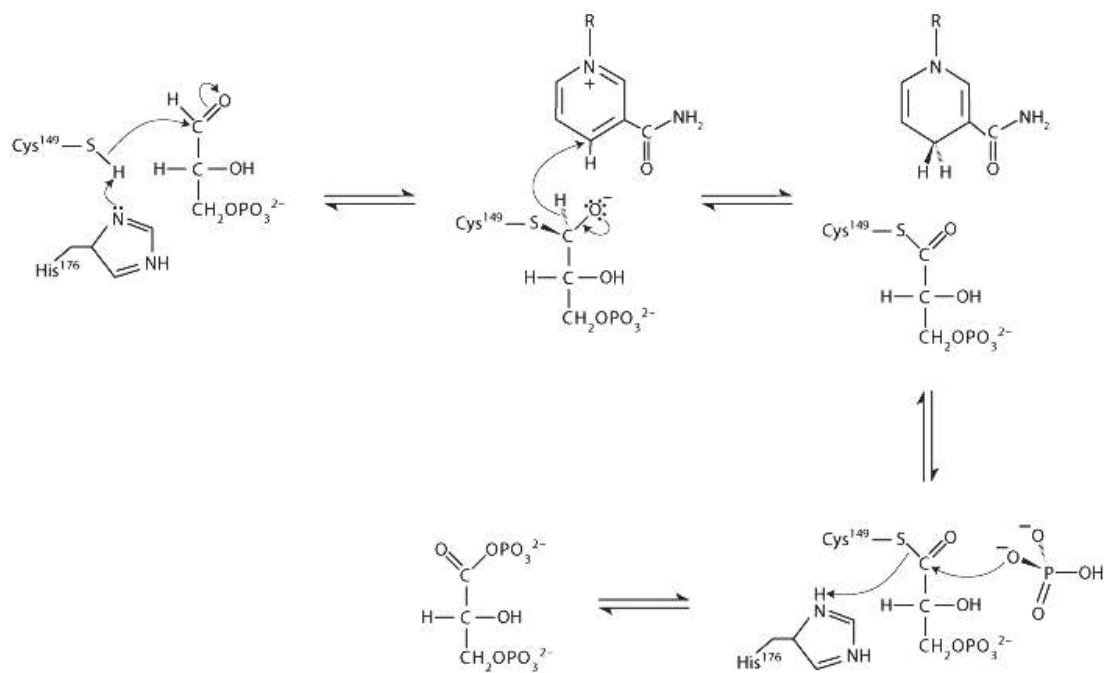


Oxidation of Aldehydes & Ketones



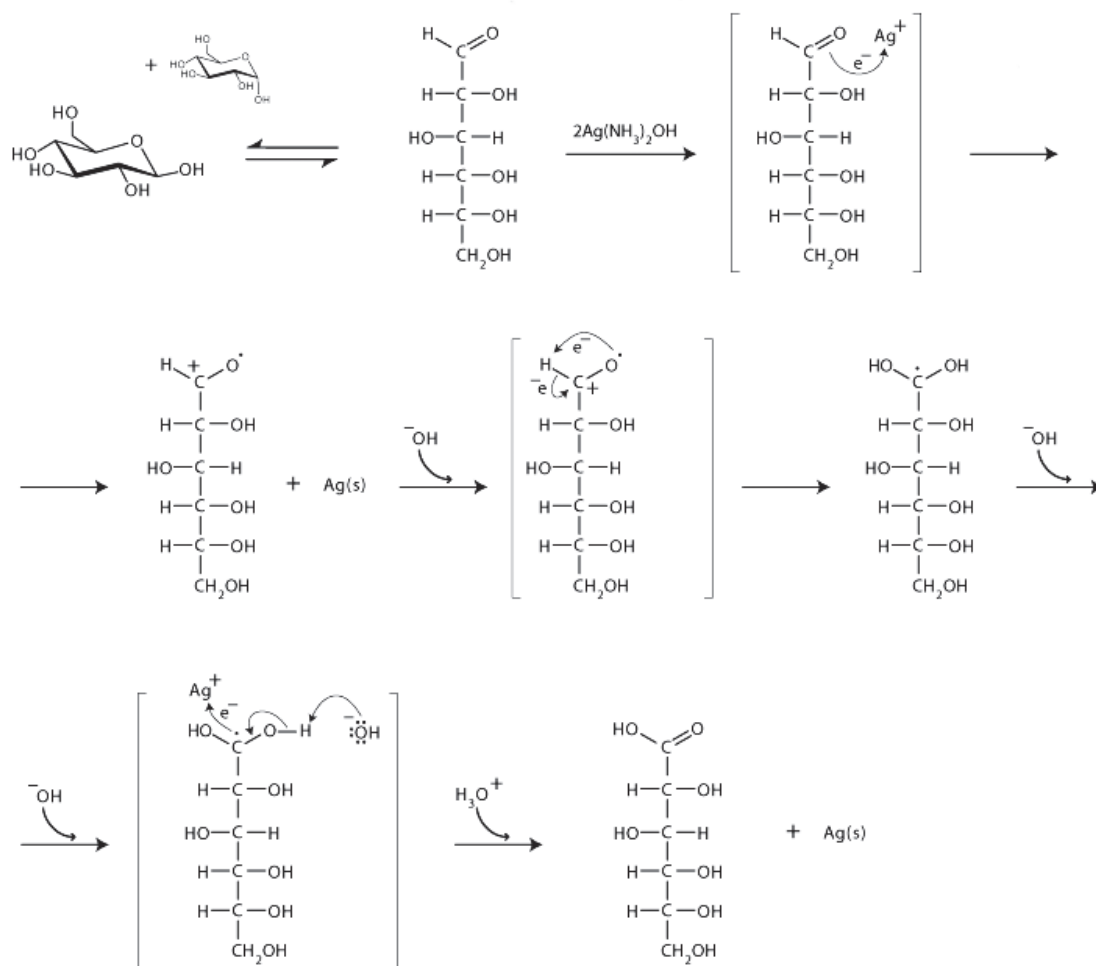
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Glyceraldehyde 3-Phosphate Dehydrogenase

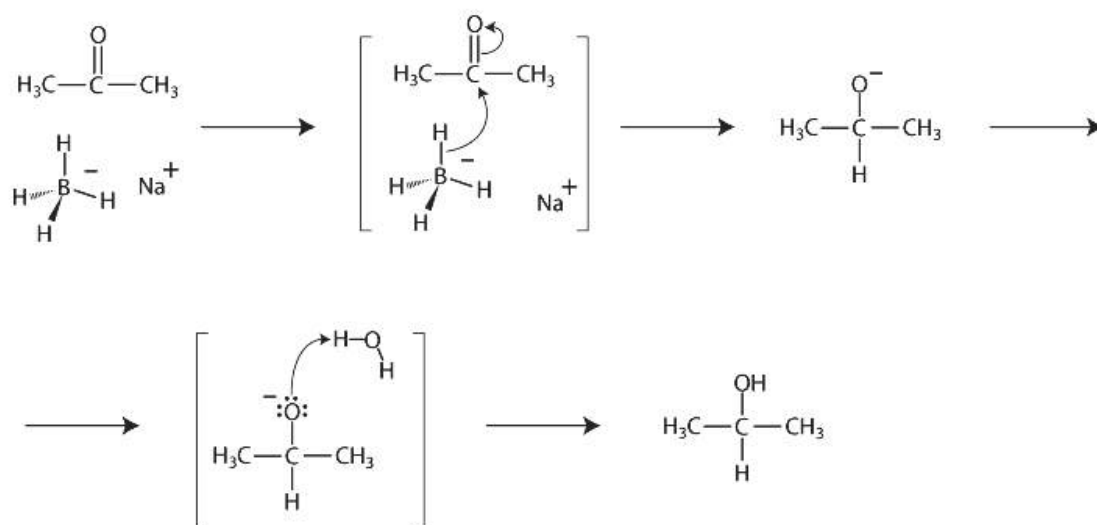
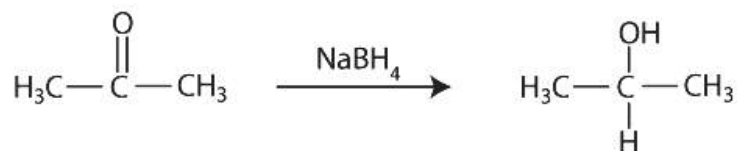


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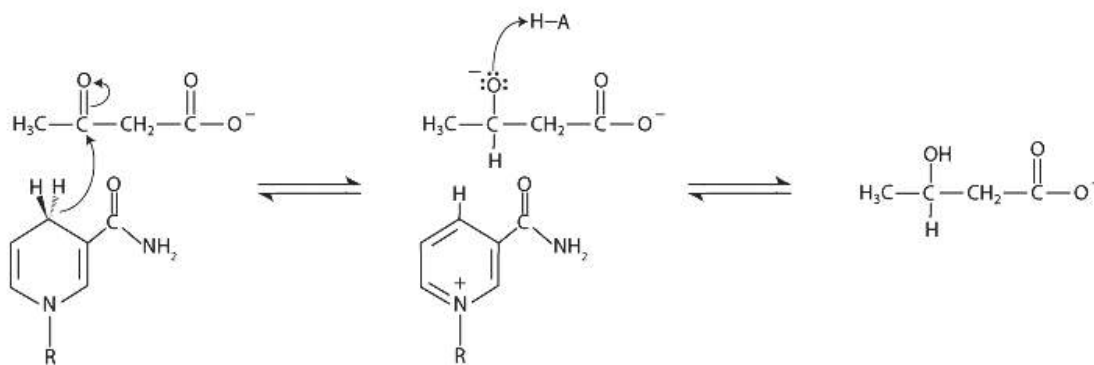
Tollens' Test



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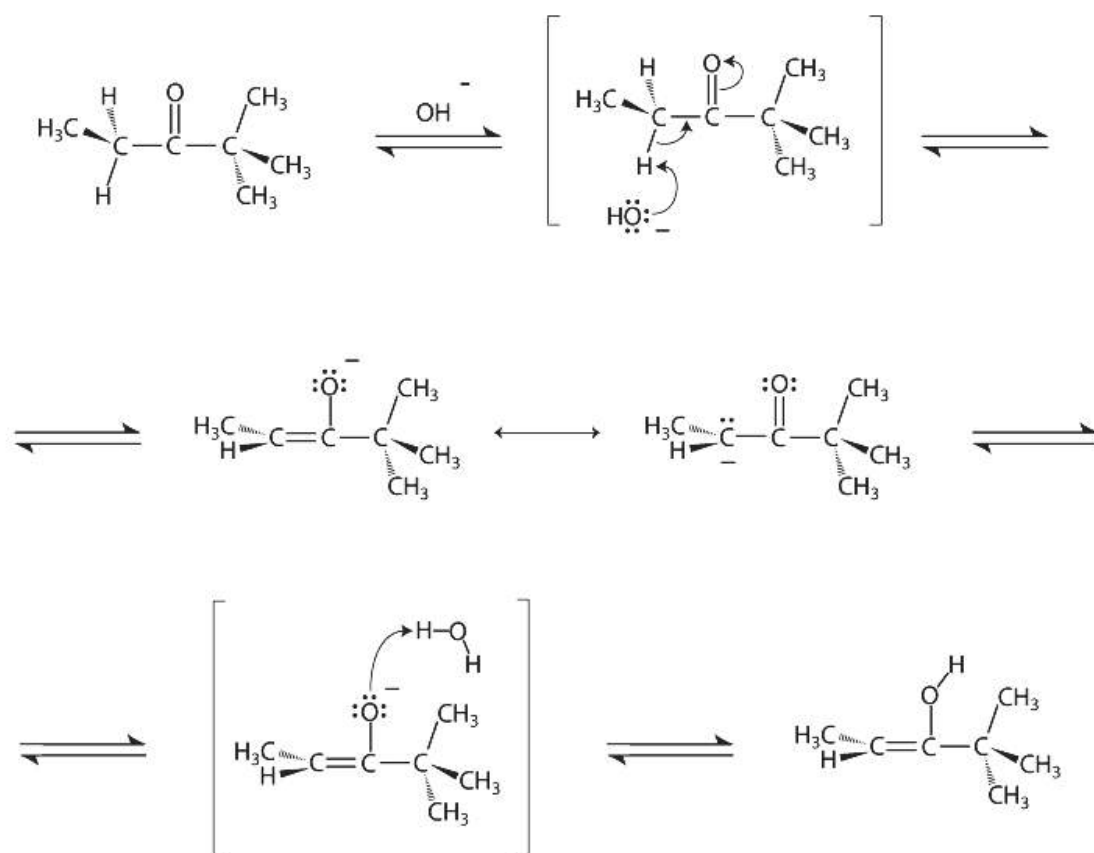
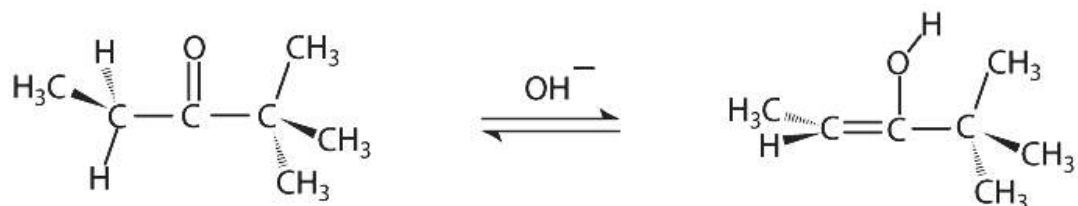
Reduction of Aldehydes and Ketones with NaBH_4 

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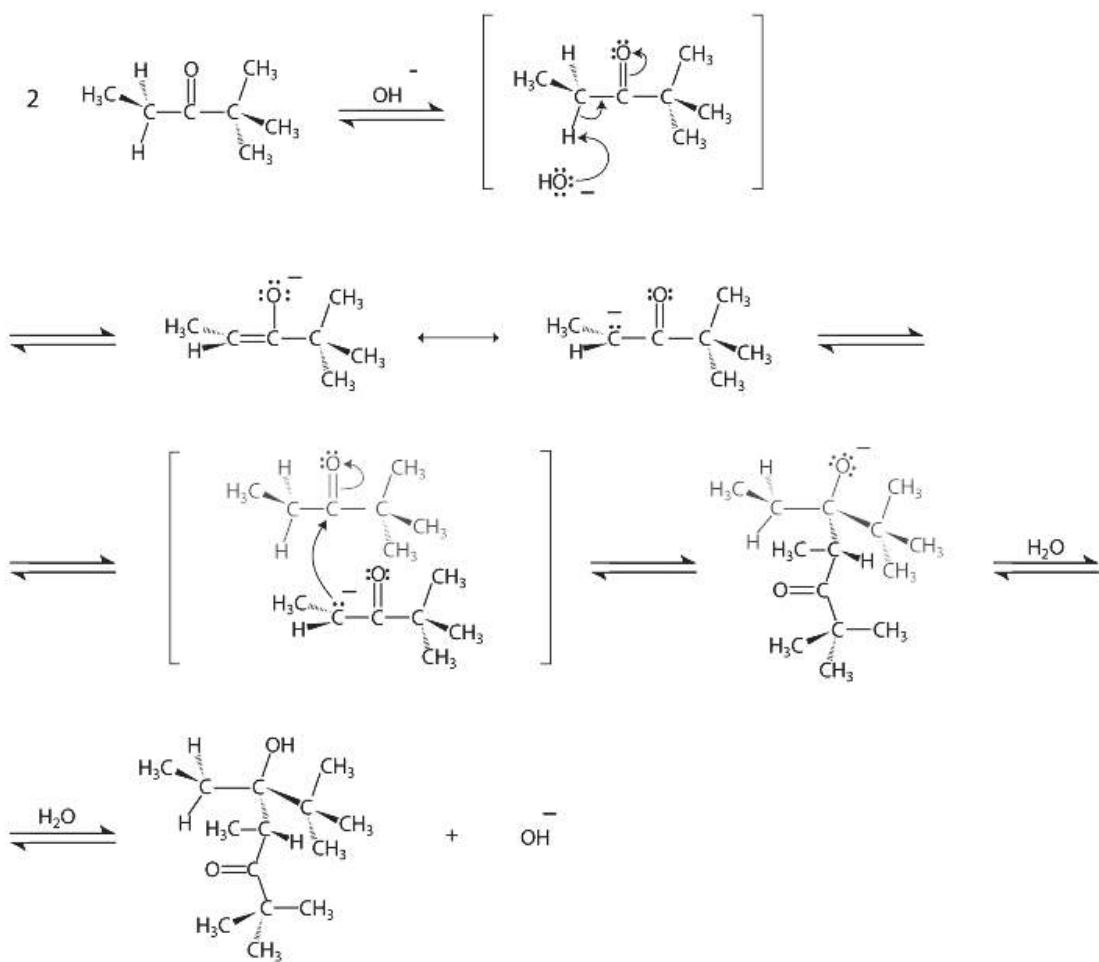
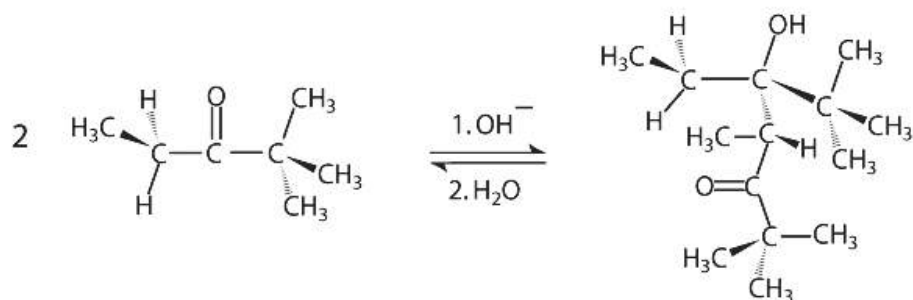
β -Hydroxybutyrate Dehydrogenase

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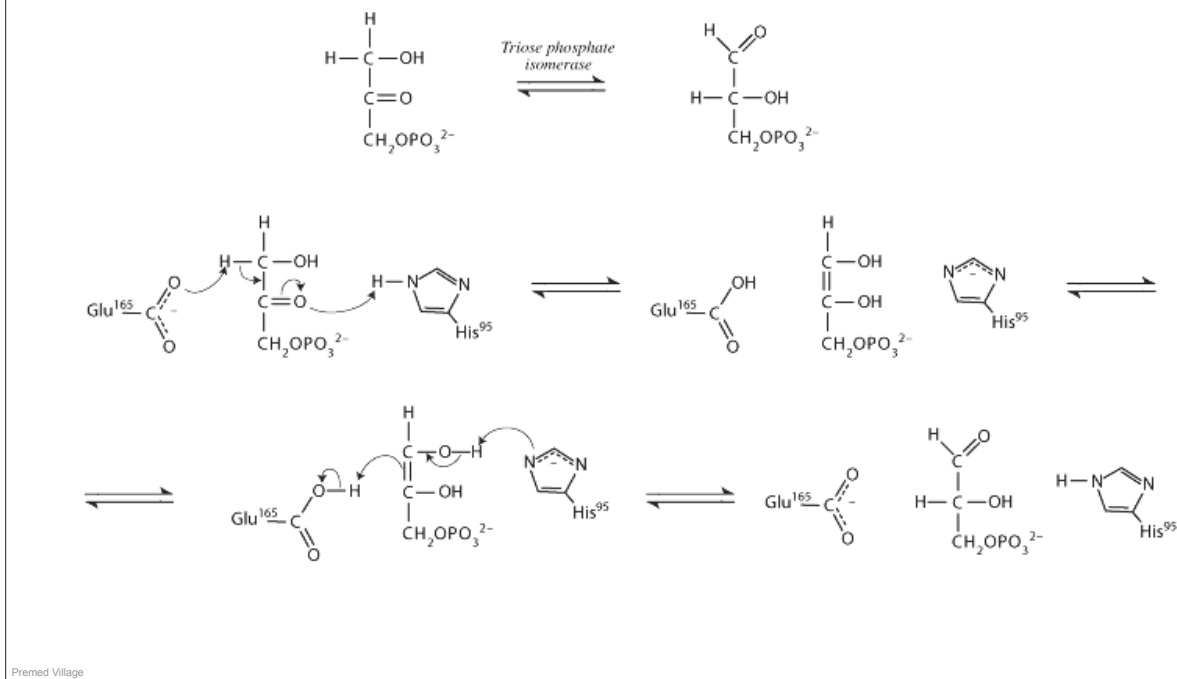
Keto-Enol Tautomerism



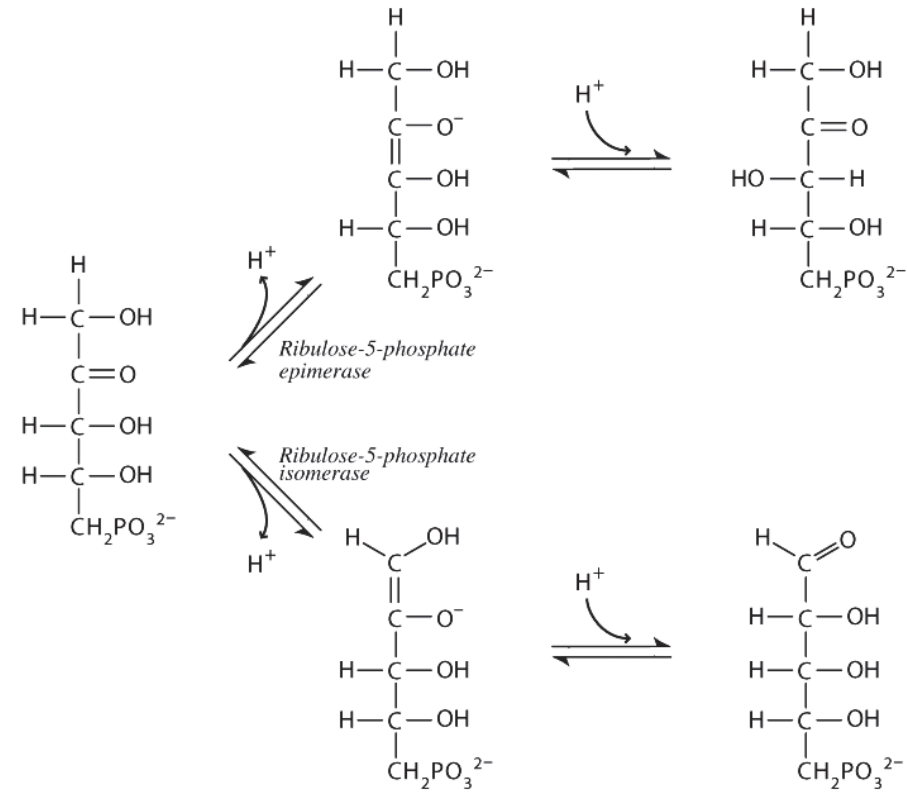
Aldol Addition



Triose Phosphate Isomerase

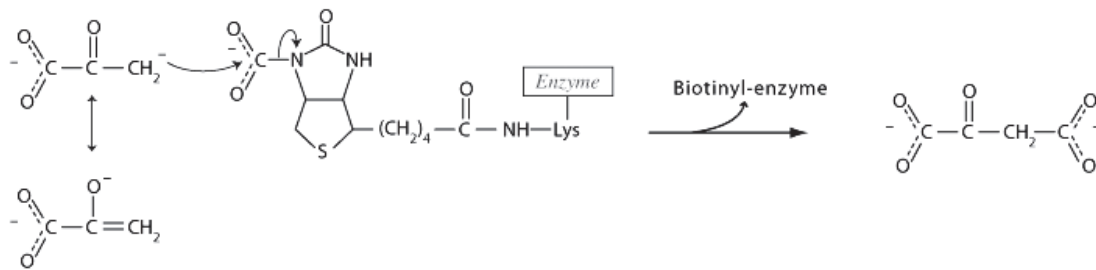


Ribulose-5-phosphate Epimerase and Isomerase



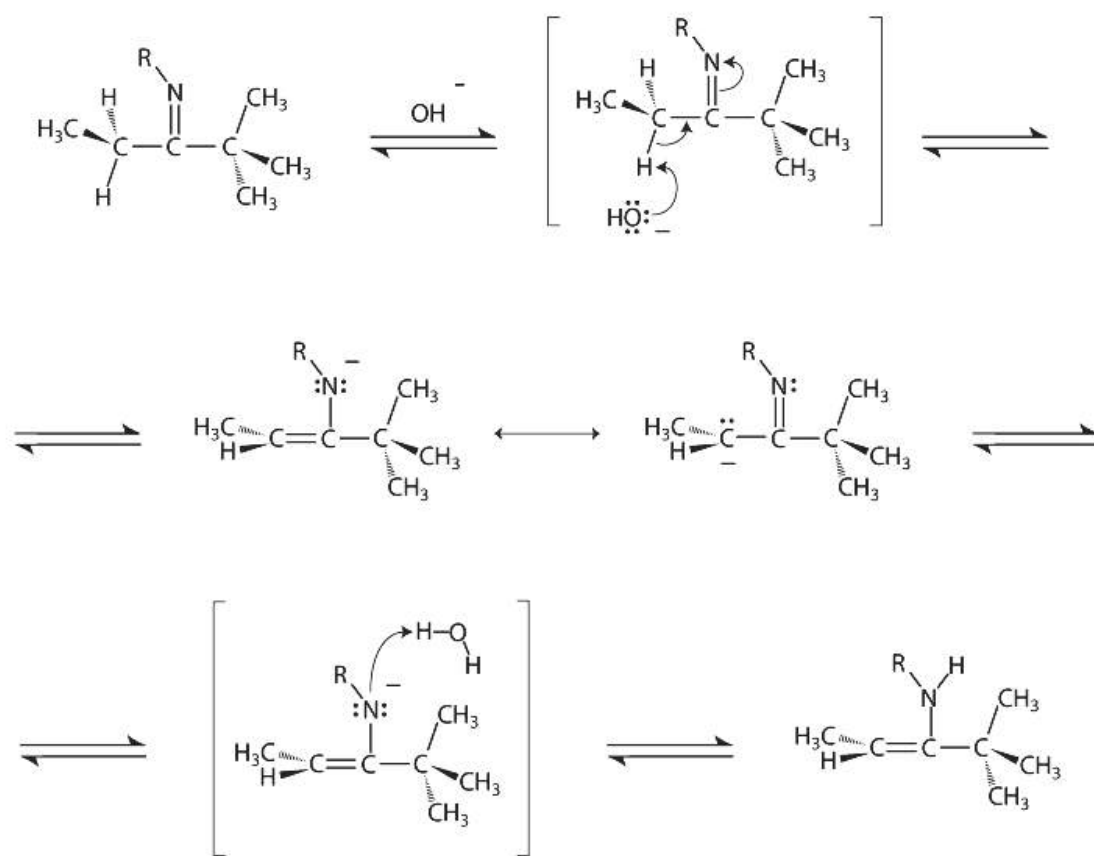
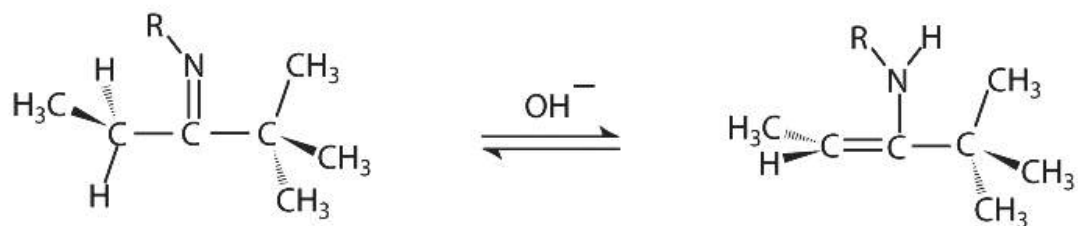
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Pyruvate Carboxylase



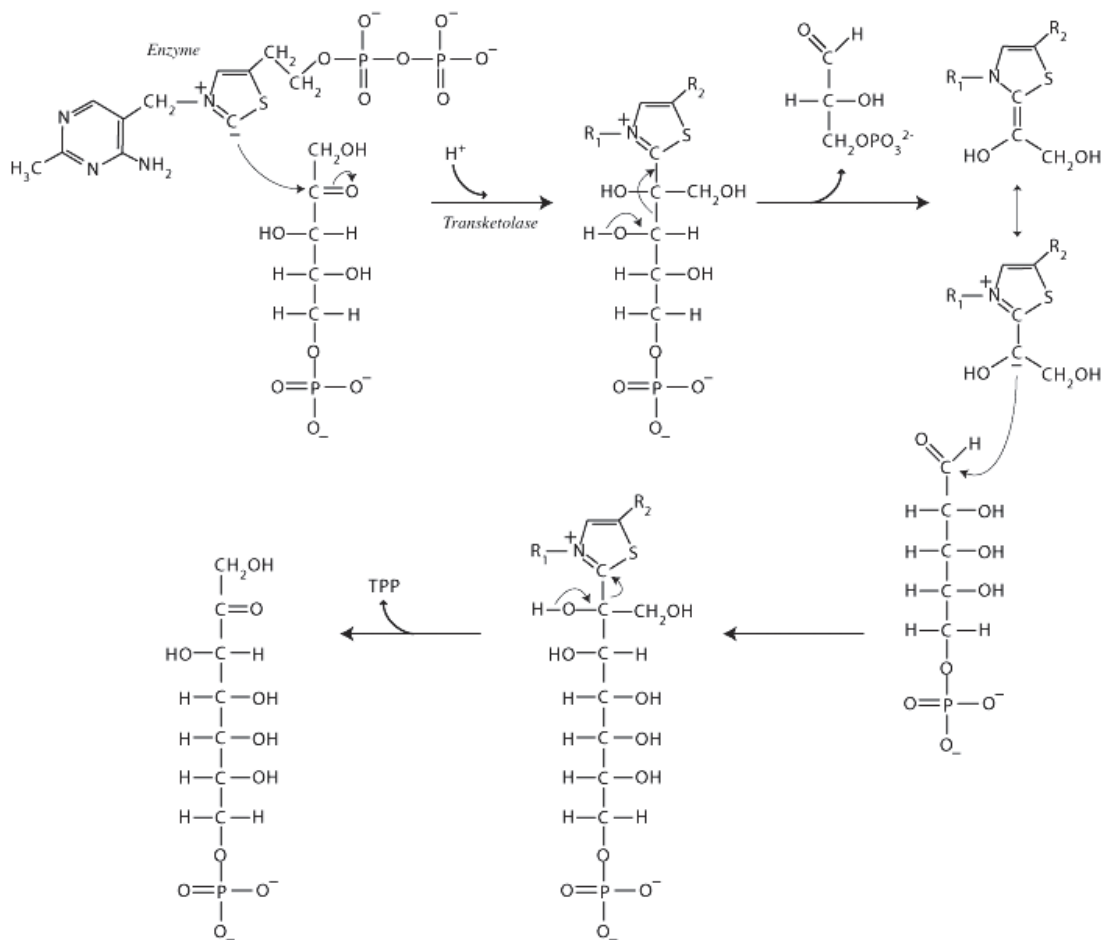
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Imine-Enamine Tautomerism



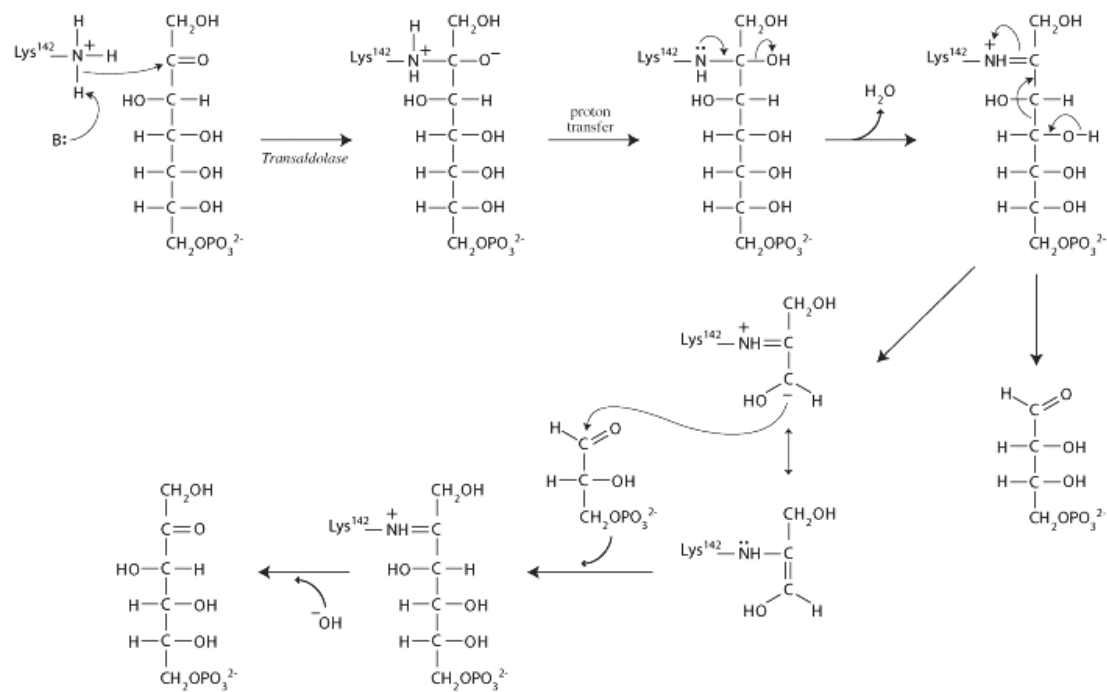
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Transketolase



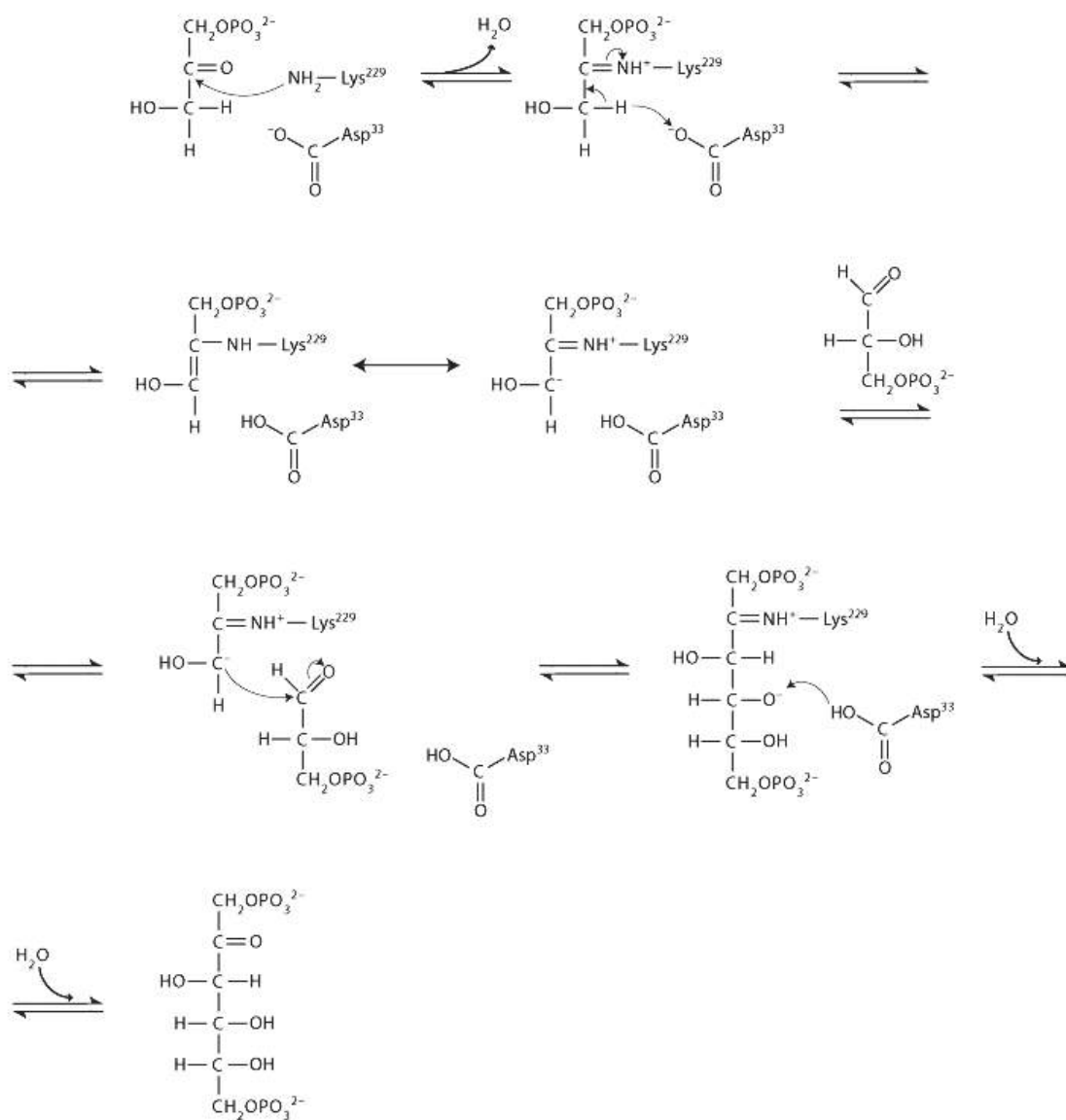
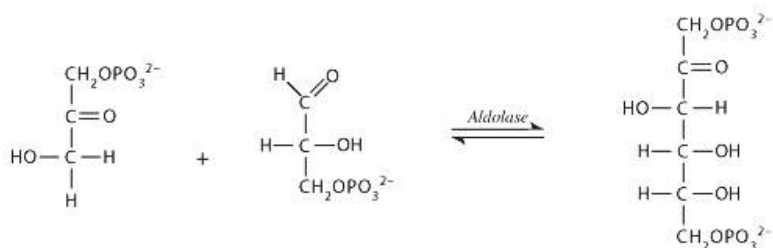
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Transaldolase

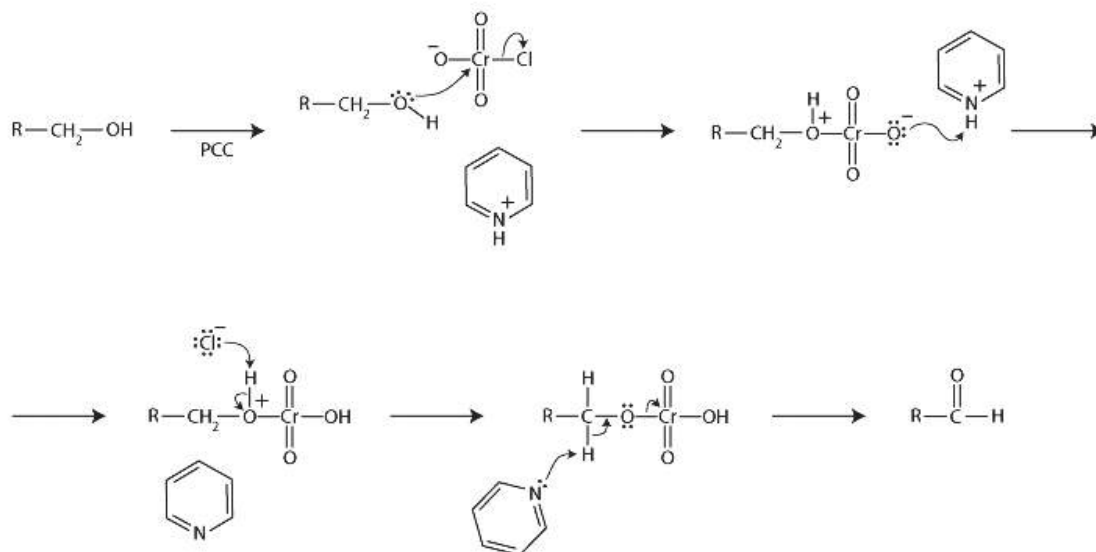
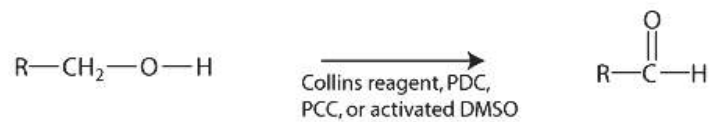
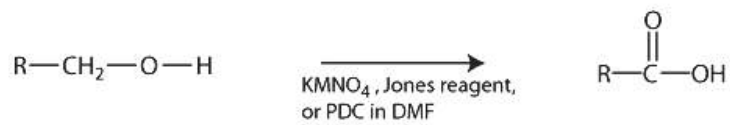


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Aldolase

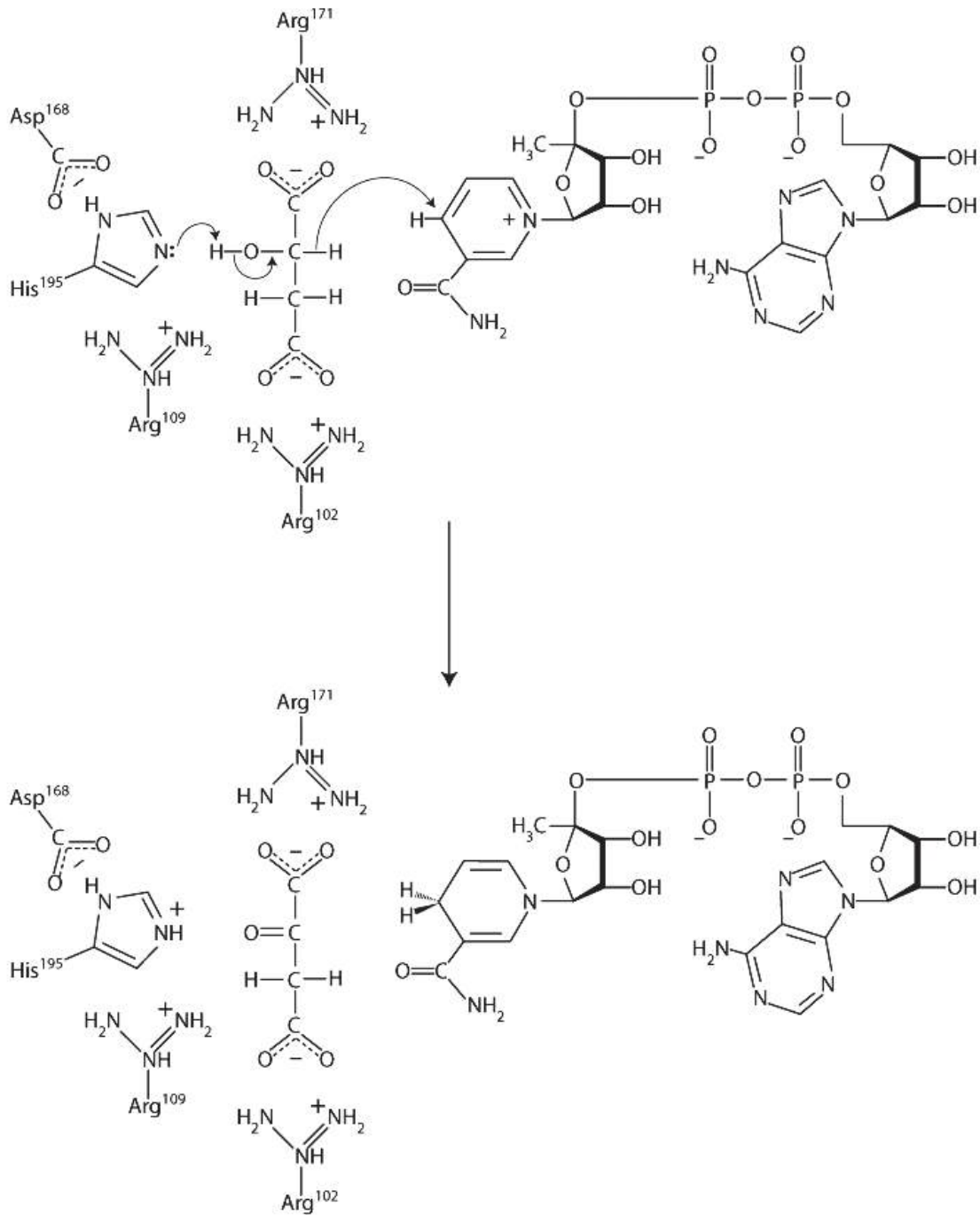


Oxidation of Alcohols

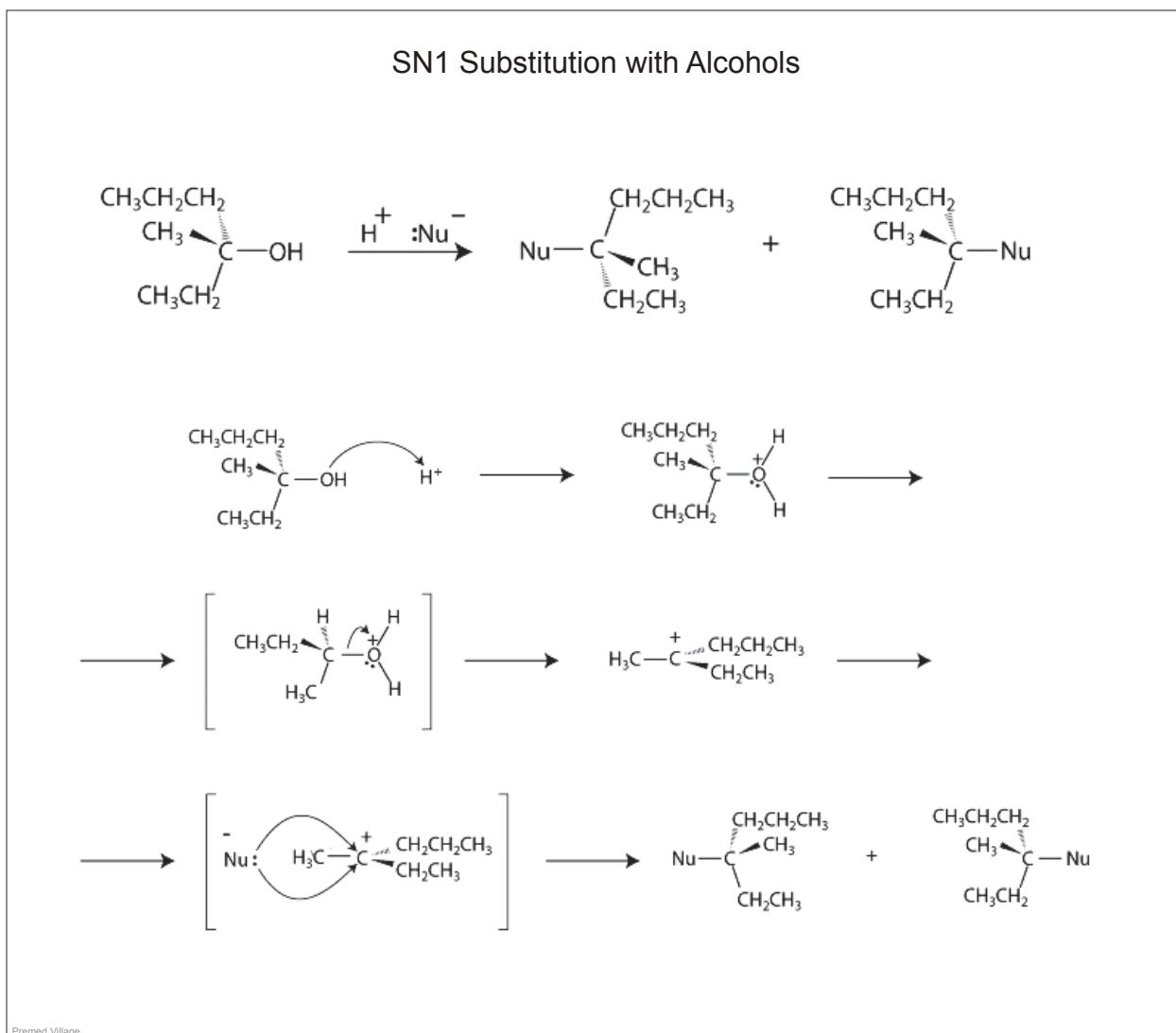


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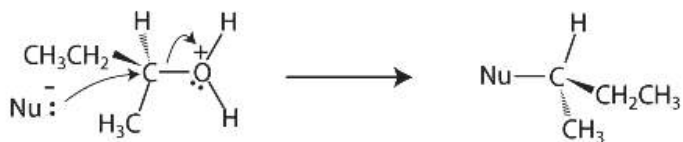
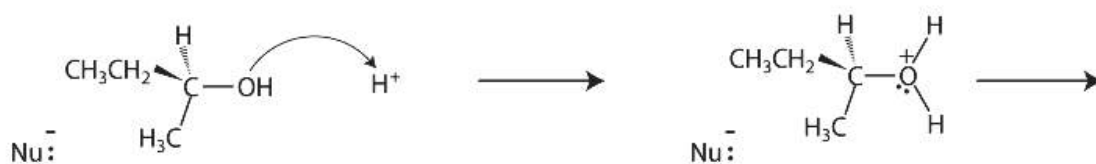
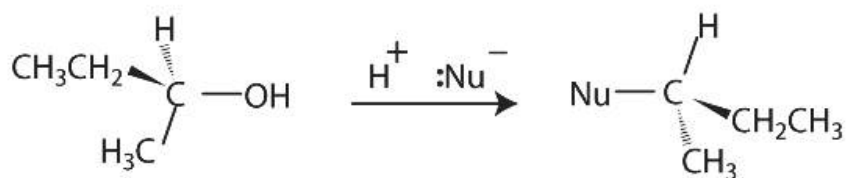
Malate Dehydrogenase



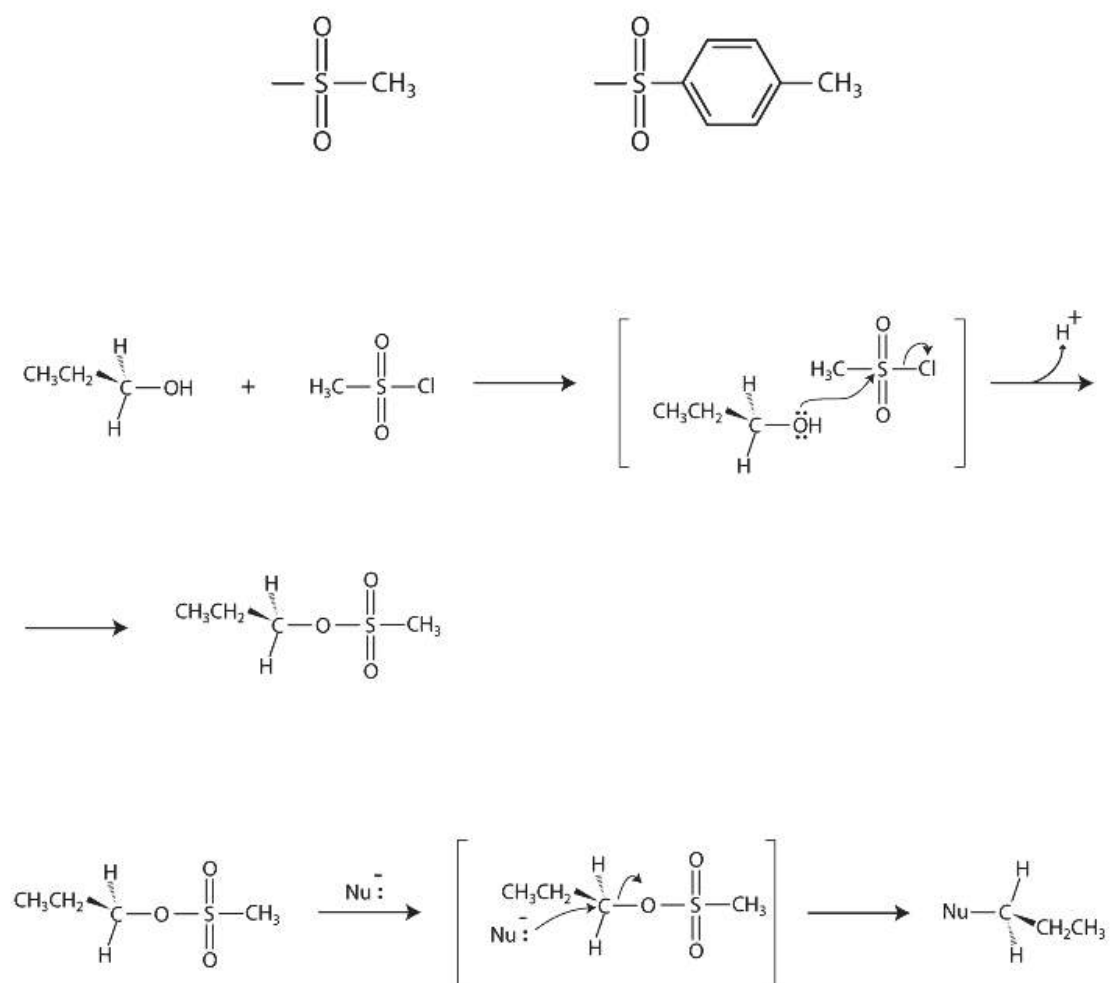
SN1 Substitution with Alcohols



SN2 Substitution with Alcohols

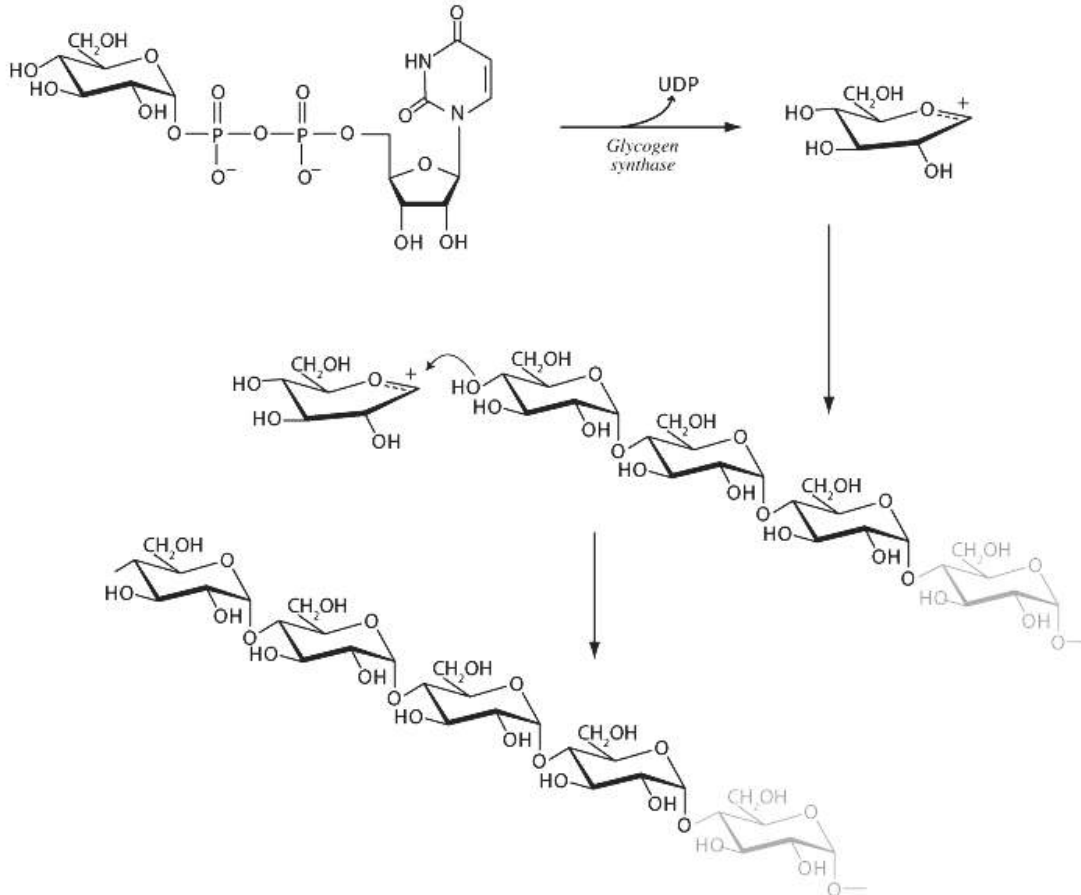


Mesylate and Tosylate Leaving Groups

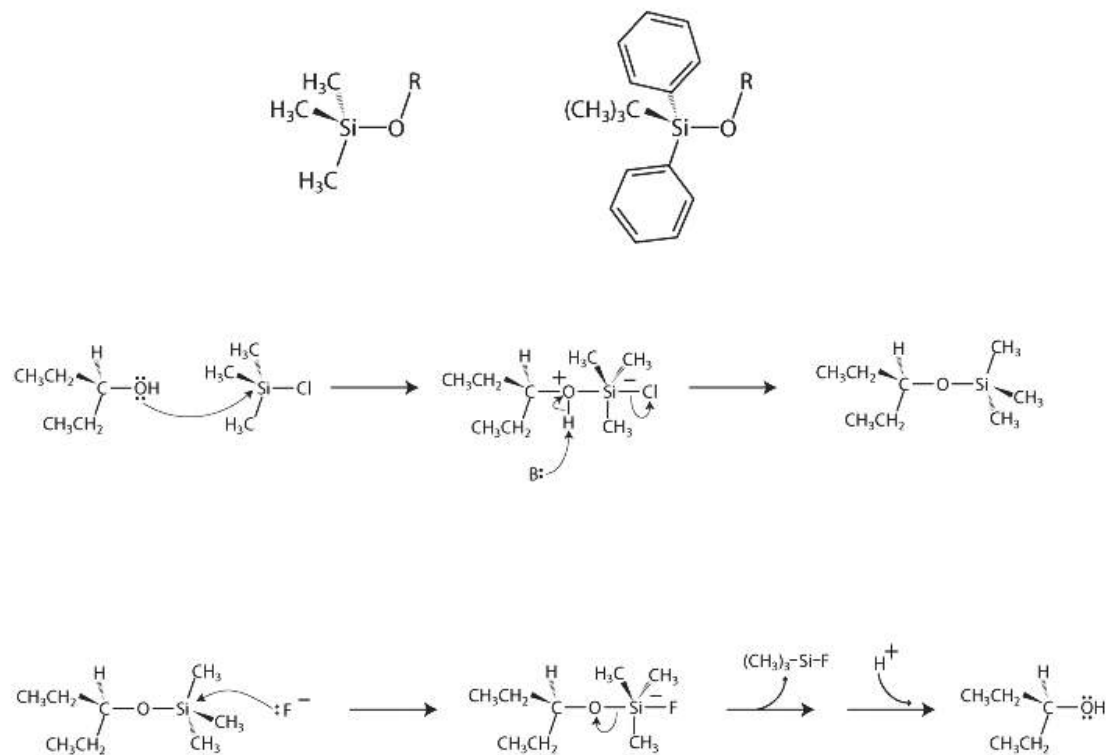


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UDP Leaving Group in Glycogen Synthesis

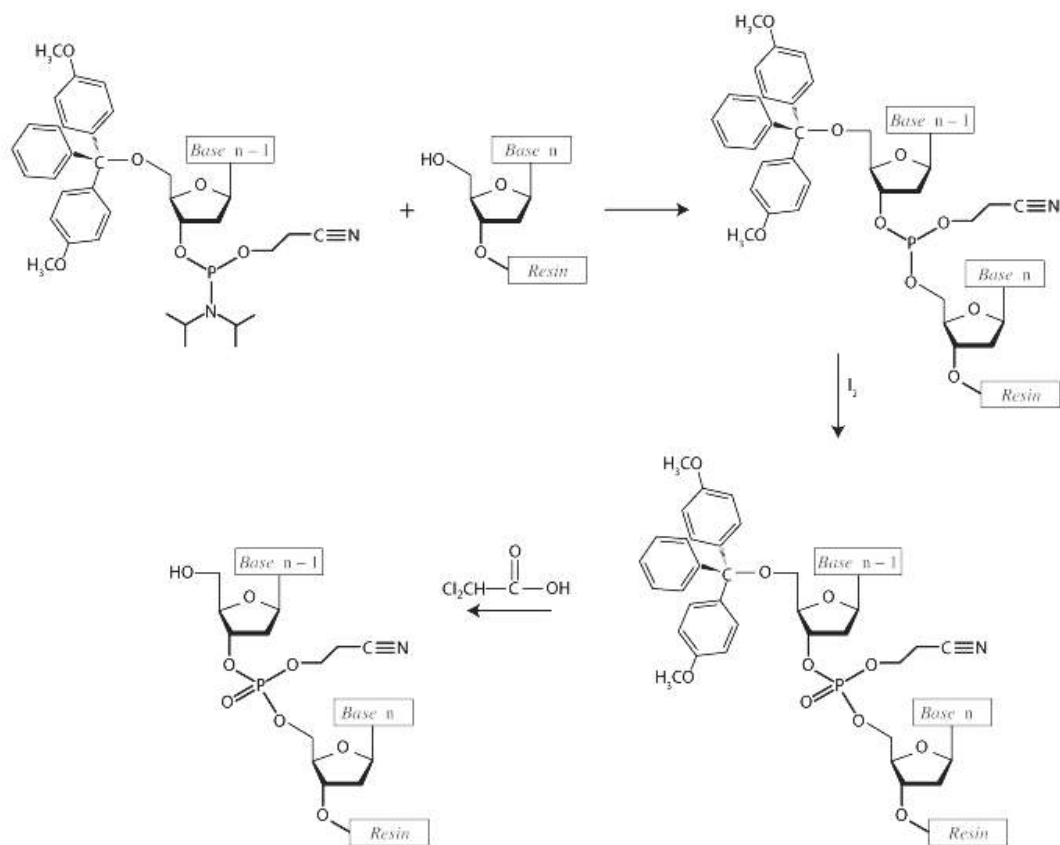


Silyl Protecting Groups



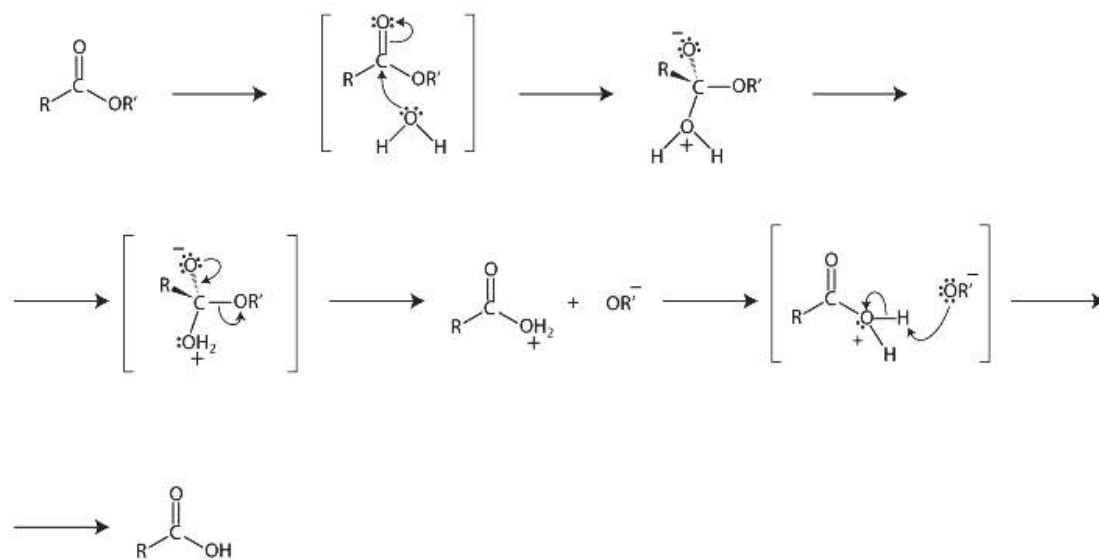
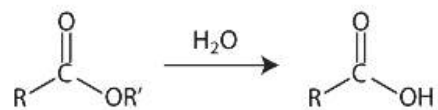
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DMT Protecting Group in Solid Phase DNA Synthesis



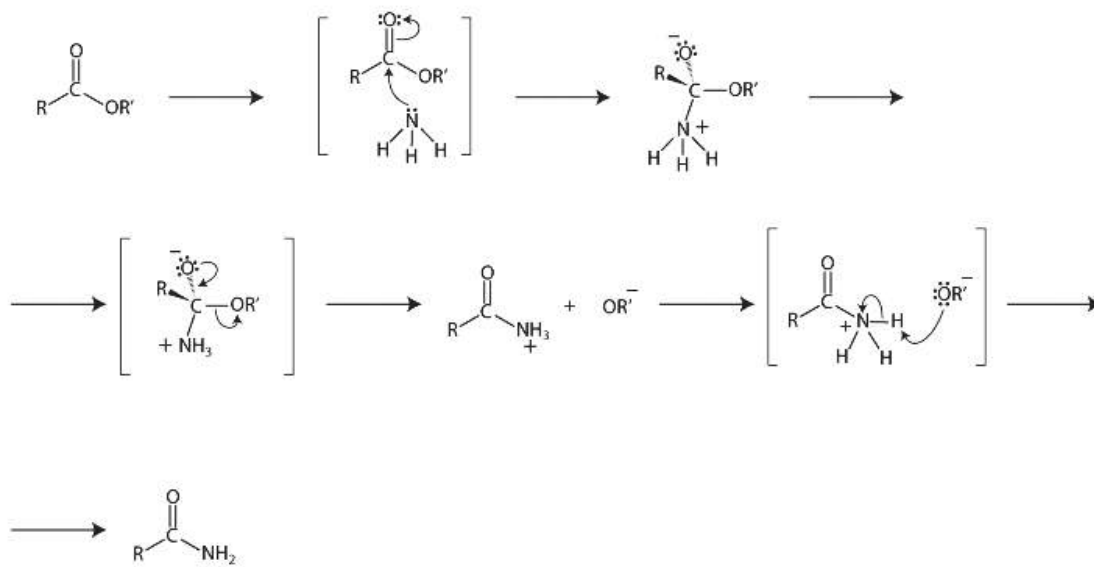
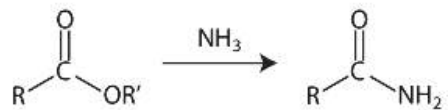
Premed Village

Ester Hydrolysis



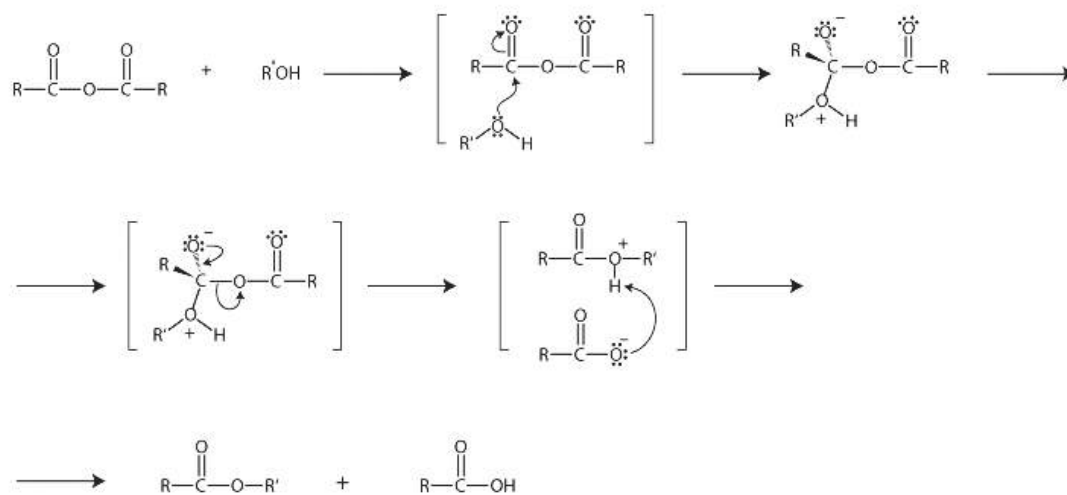
Promed Village

Ester Aminolysis

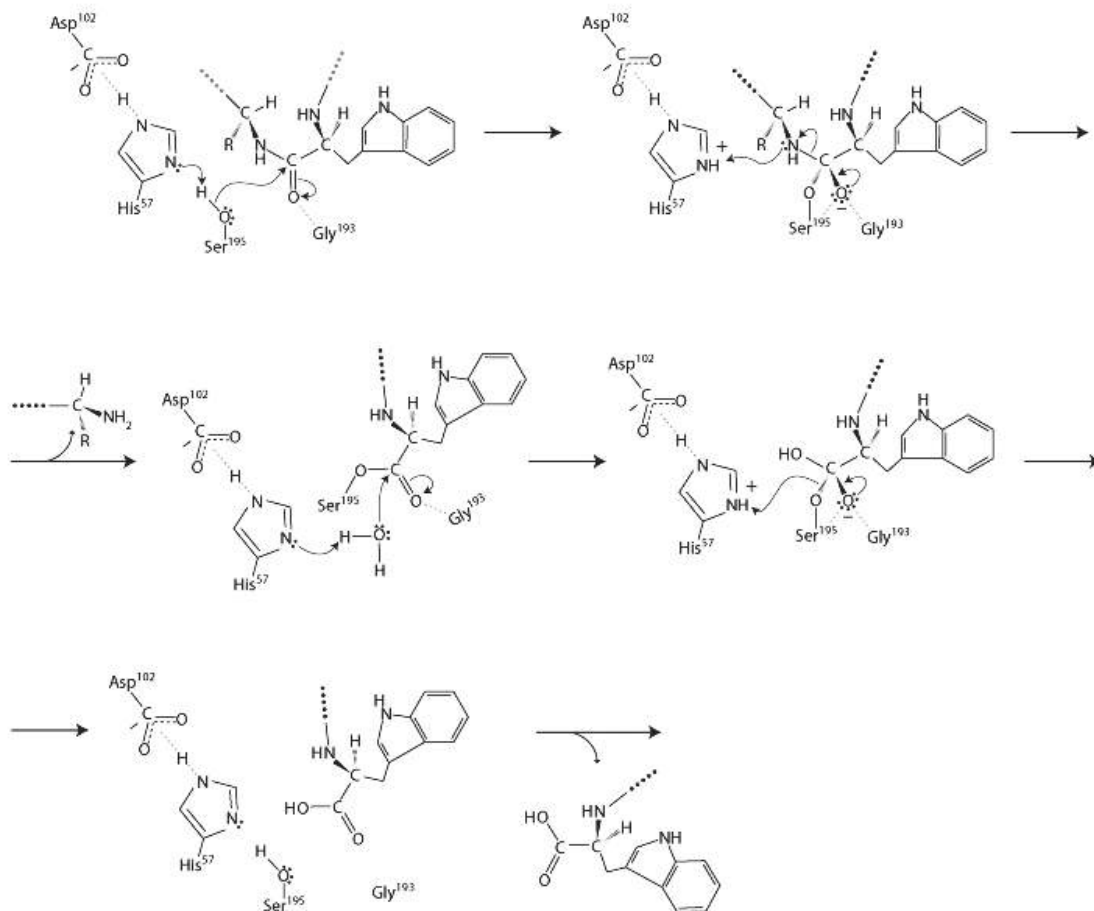


Premed Village

Esterification of an Anhydride

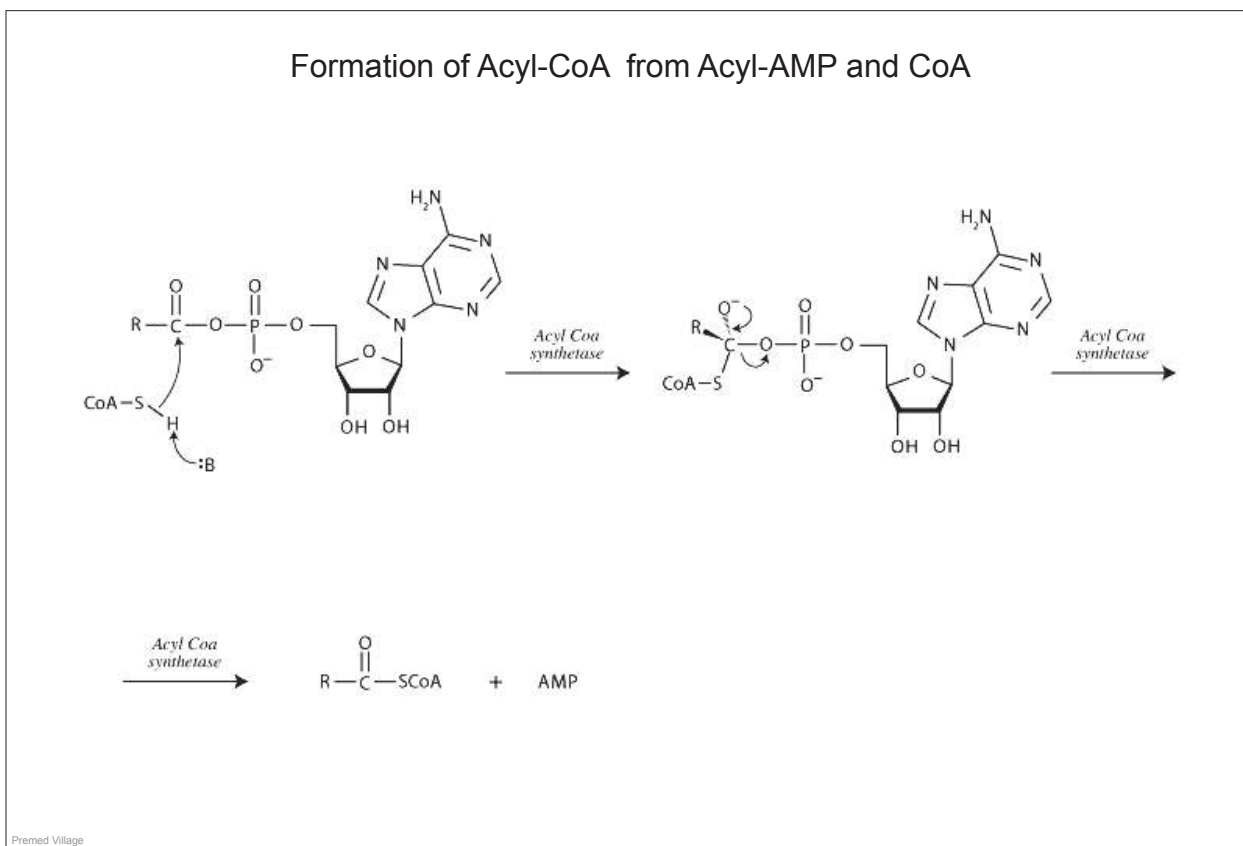


Chymotrypsin



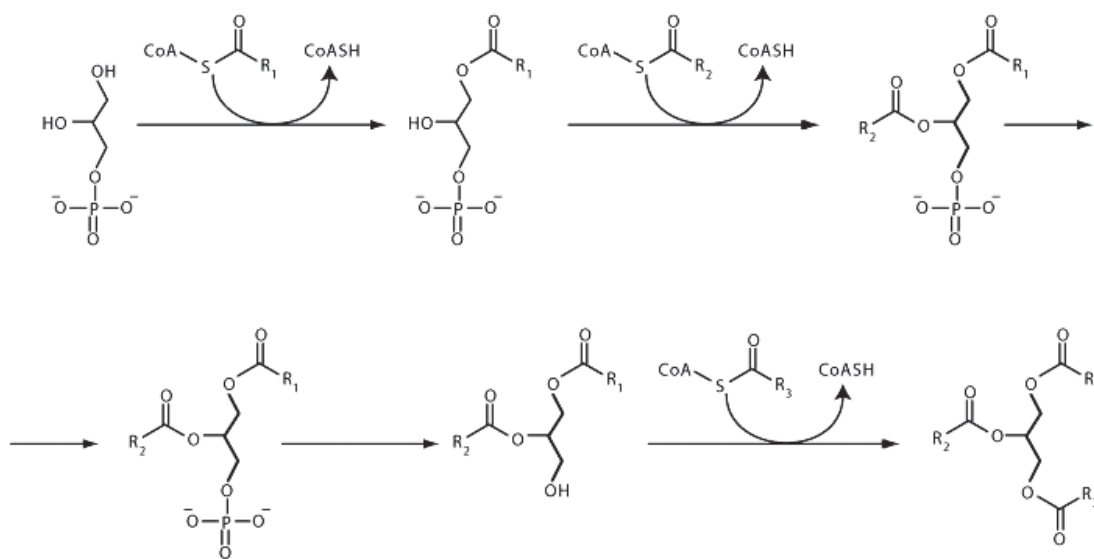
Premed Village

Formation of Acyl-CoA from Acyl-AMP and CoA



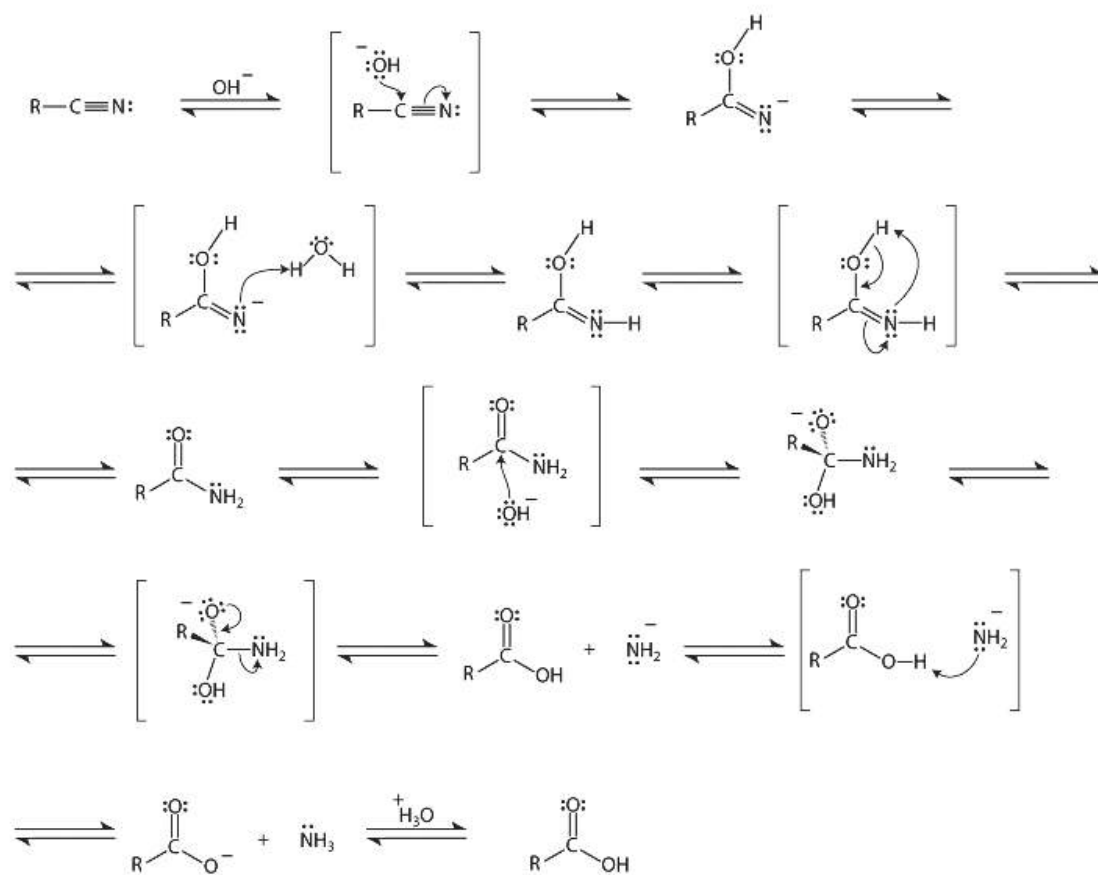
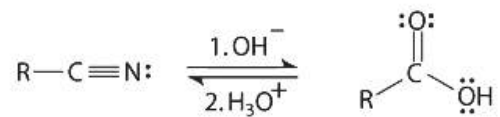
Premed Village

Triglyceride Synthesis

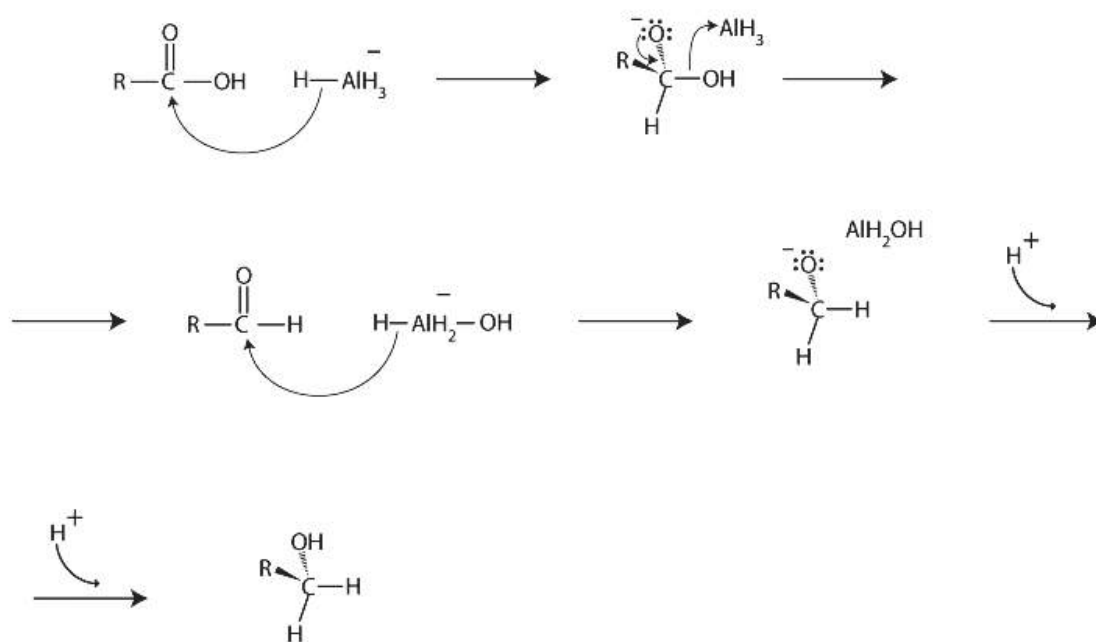
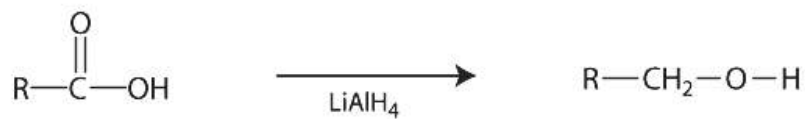


Premed Village

Nitrile Hydrolysis

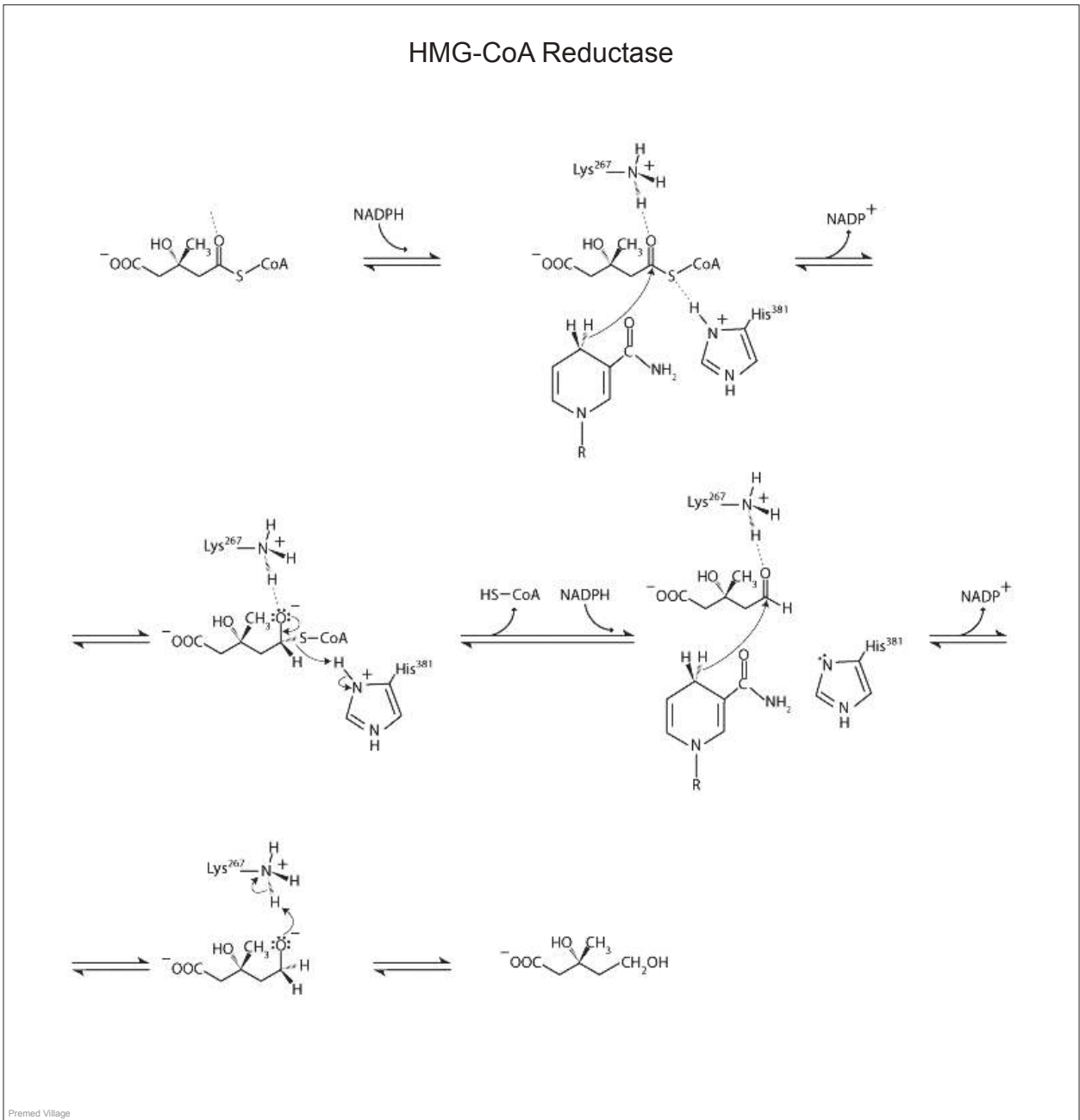


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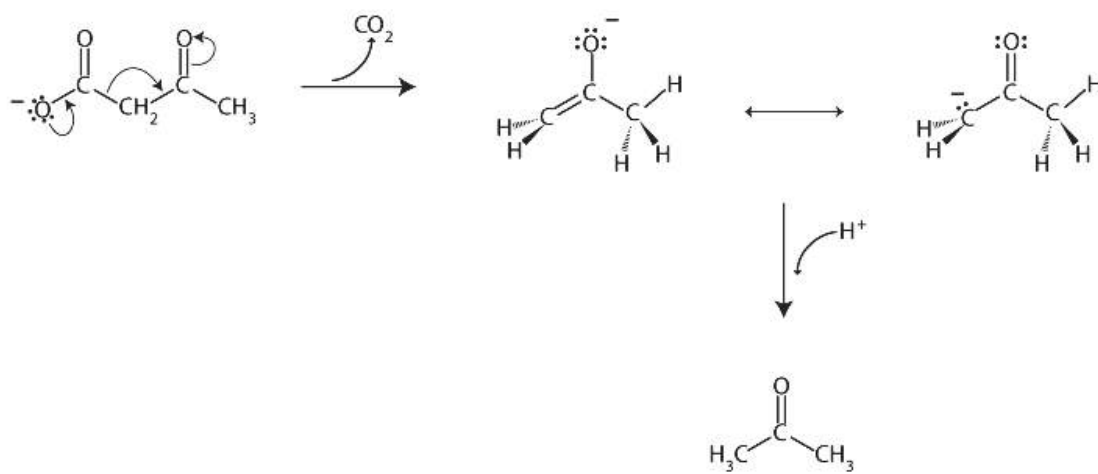
Reduction of Carboxylic Acids with LiAlH_4 

Premed Village

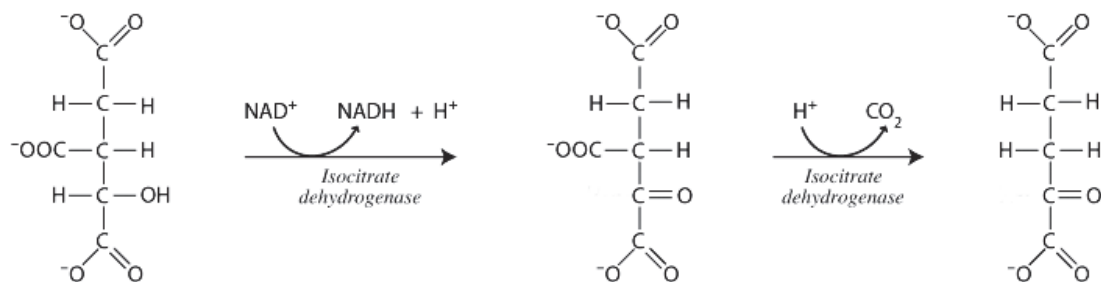
HMG-CoA Reductase



Premed Village

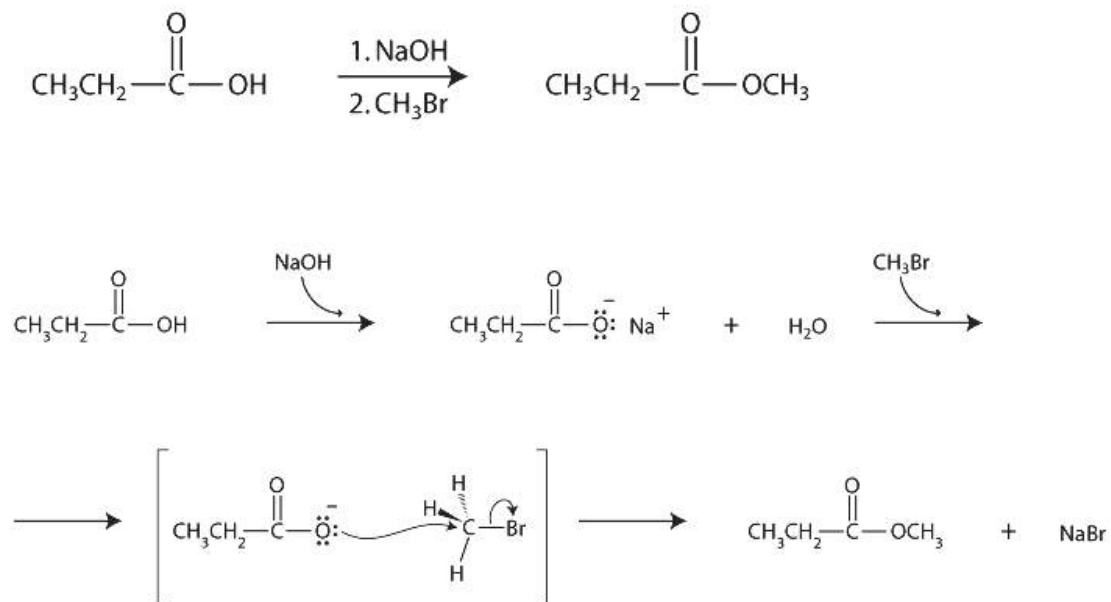
Decarboxylation of β -Keto Acids

Isocitrate Dehydrogenase



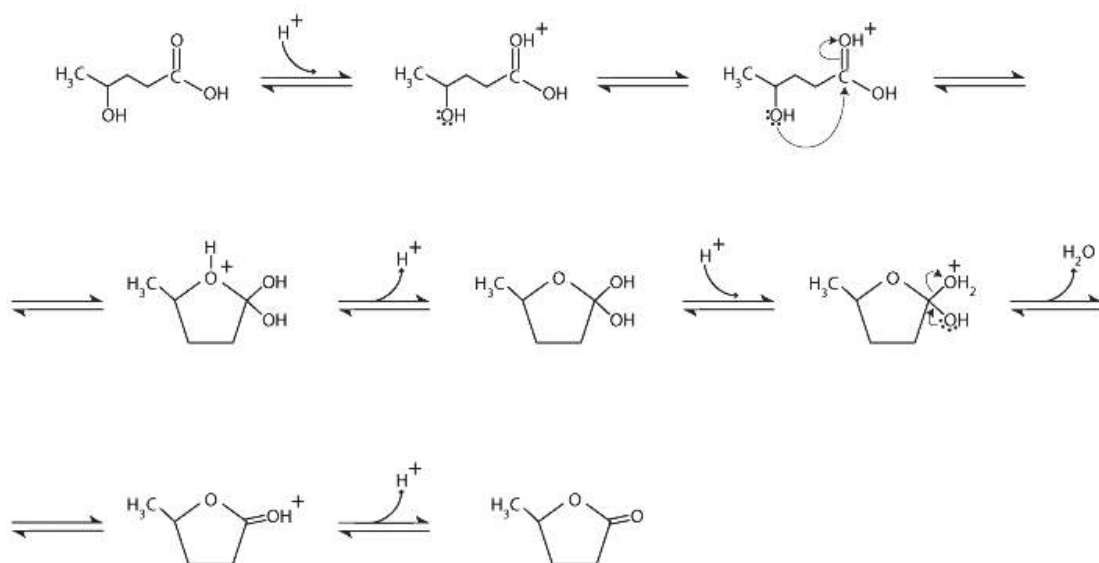
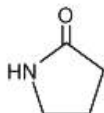
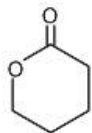
Premed Village

Use of Carboxylate Nucleophile



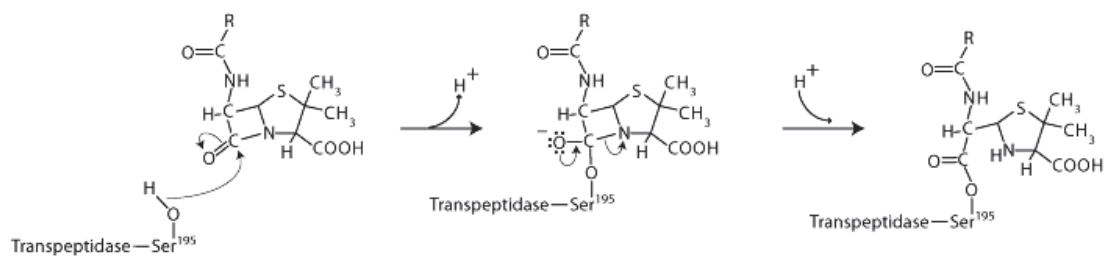
Premed Village

Lactones and Lactams



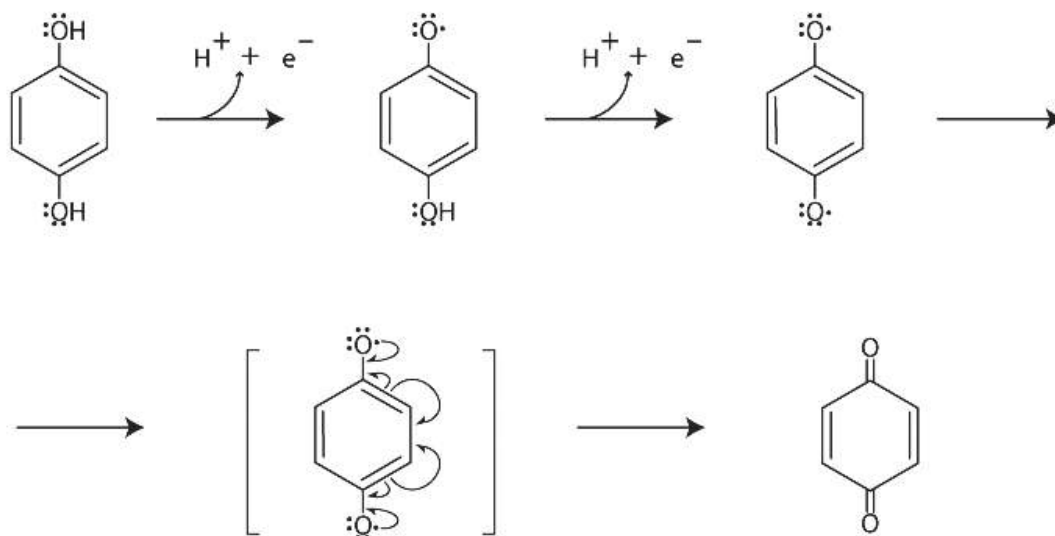
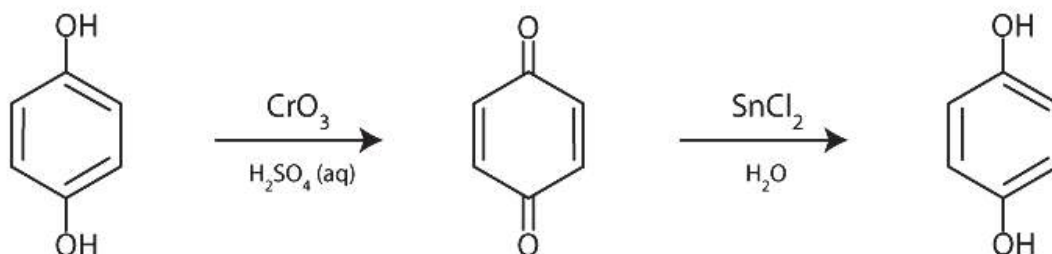
Premed Village

Penicillin

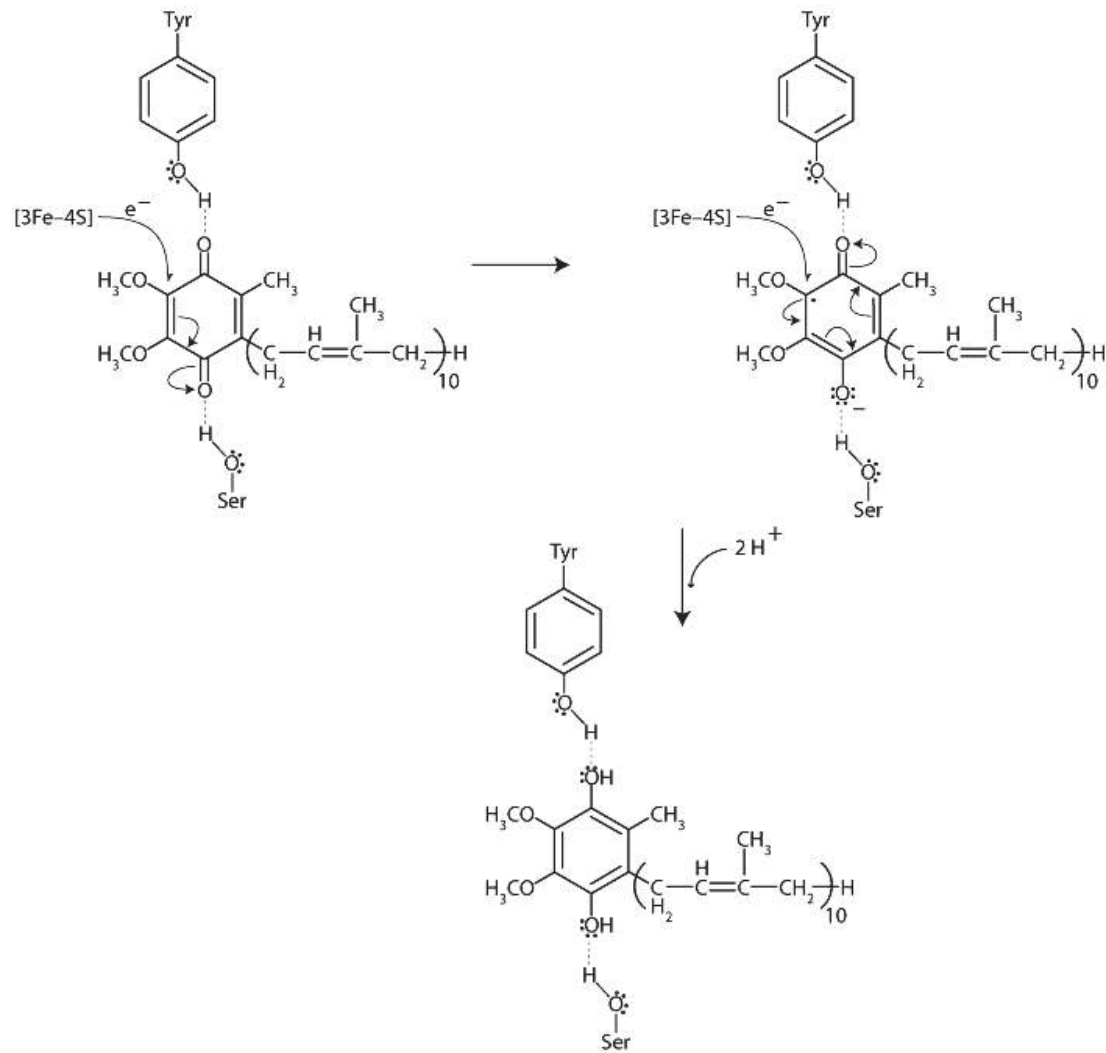


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Dehydroxybenzene and Benzoquinone

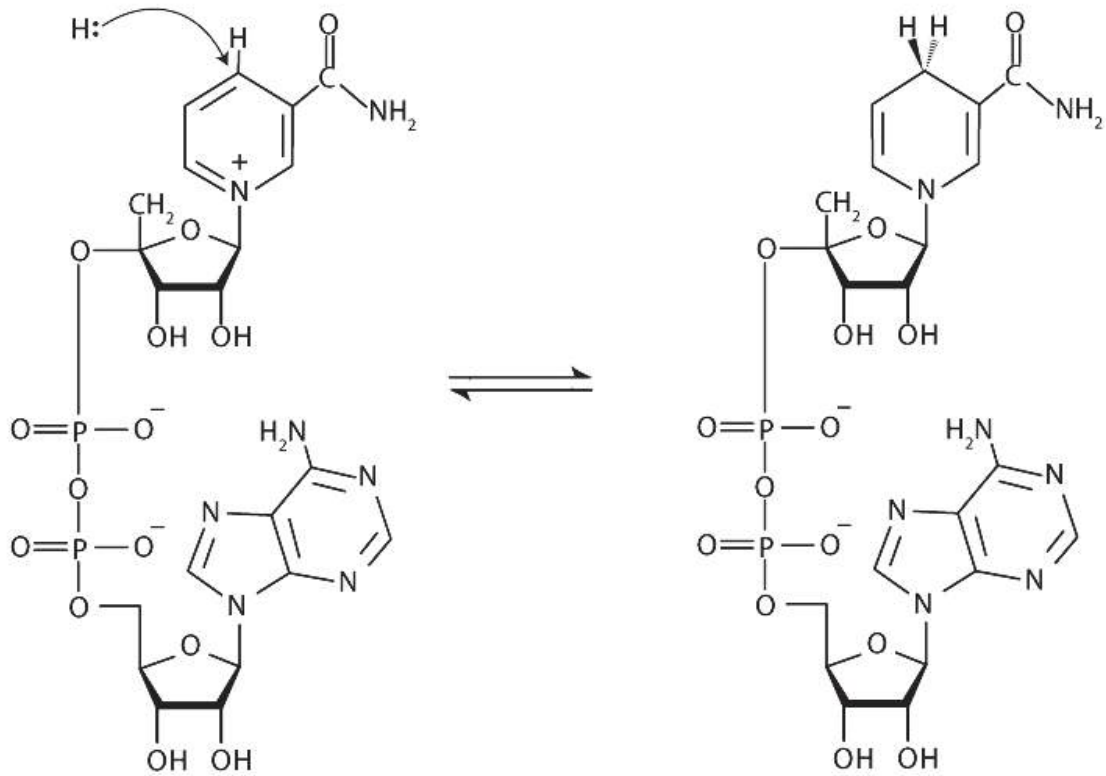


Ubiquinone

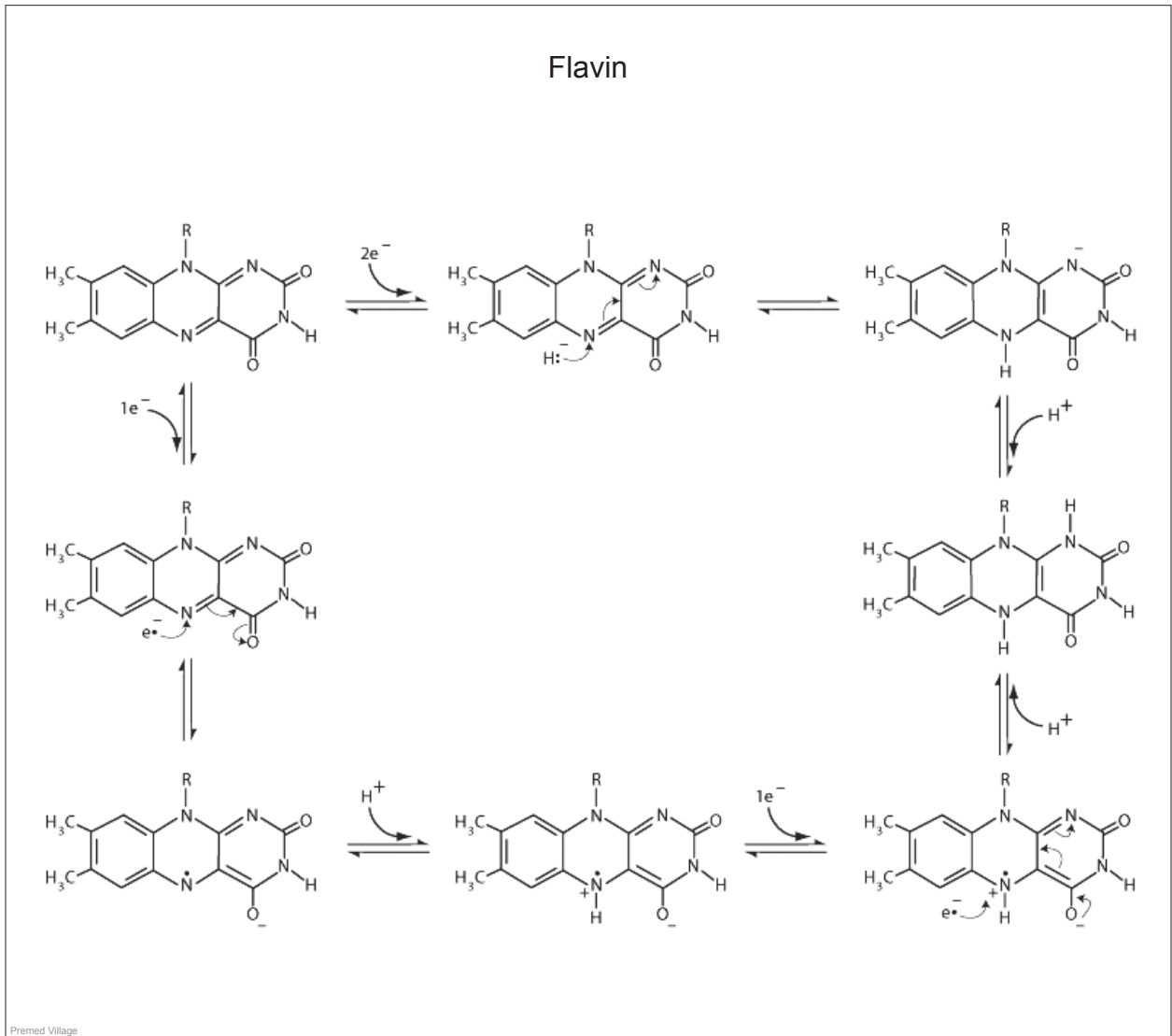


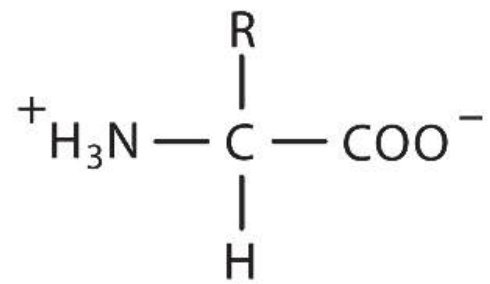
Premed Village

Reduction of NAD⁺

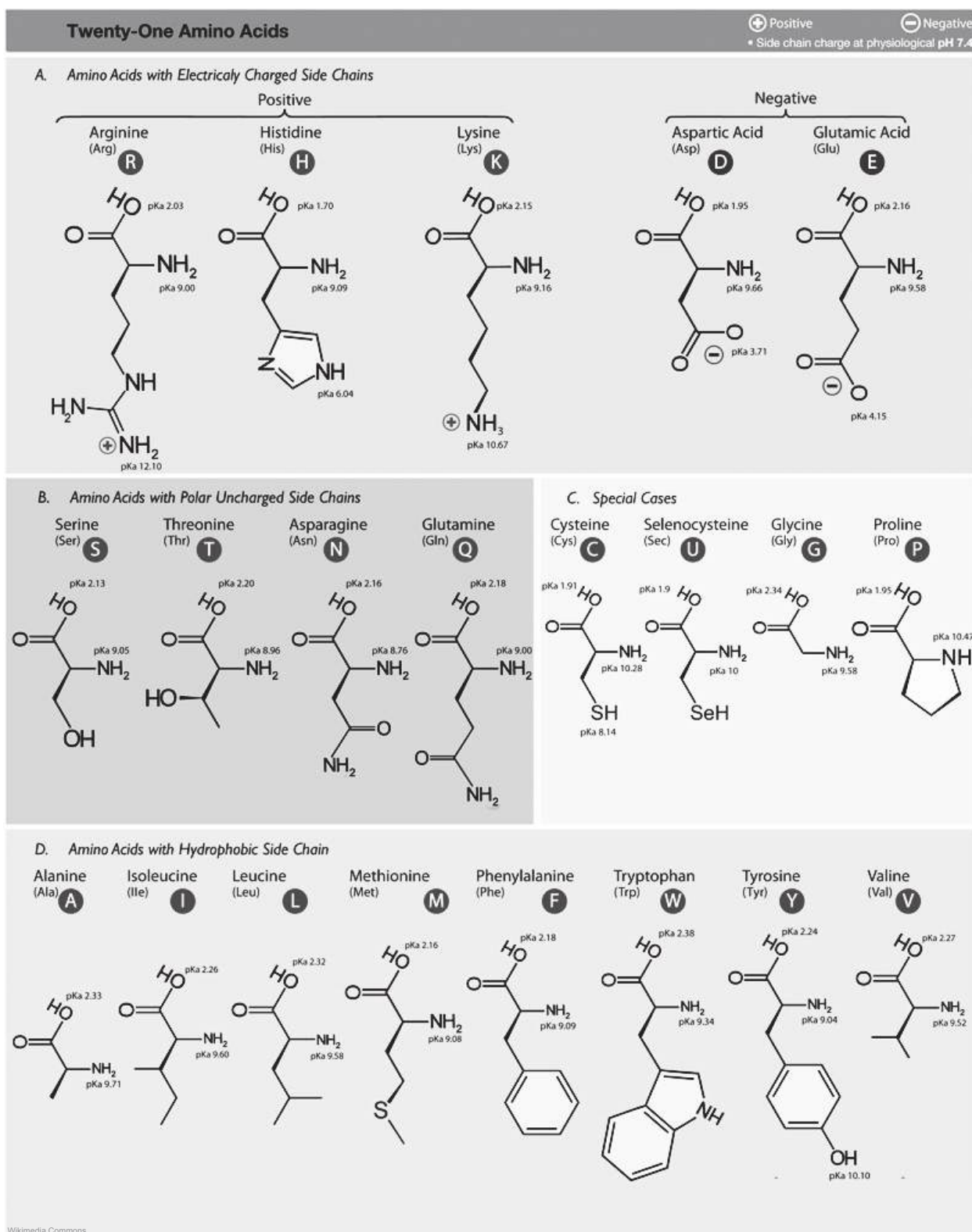


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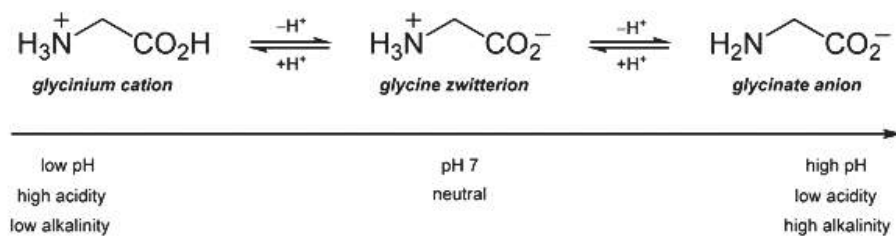




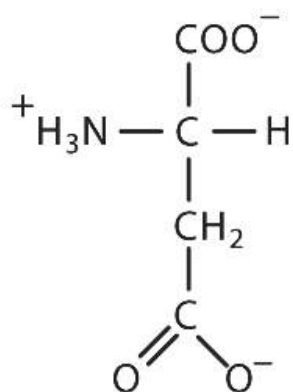
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Amino Acids



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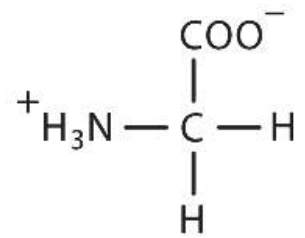
Premed Village

Amino Acid	pKa
Asp (D)	3.9
Glu (E)	4.3
Arg (R)	12.0
Lys (K)	10.5
His (H)	6.08
Cys (C)	8.28 (-SH)
Tyr (Y)	10.1

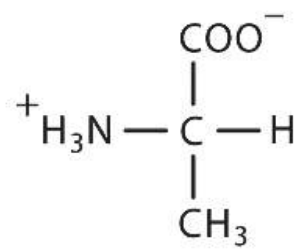
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Kyte and Doolittle (1)	Rose, et al (2)	Wolfenden, et al (3)	Janin (1979) (4)
Ile	Cys	Gly,Leu,Ile	Cys
Val		Val,ala	Ile
	Phe,Ile		Val
Leu	Val	Phe	Leu,Phe
	Leu,Met,Trp	Cys	Met
Phe		Met	Ala,Gly,Trp
Cys			
Met,Ala	His	Thr,Ser	
	Tyr	Trp,Tyr	His,Ser
Gly	Ala		Thr
Thr,Ser	Gly		Pro
Trp,Tyr	Thr		Tyr
Pro		Asp,Lys,Gln	Asn
		Glu,His	Asp
His	Ser	Asp	Gln,Glu
Asn,Gln	Pro,Arg		
Asp,Glu	Asn		
Lys	Gln,Asp,Glu		Arg
Arg	Lys	Arg	Lys

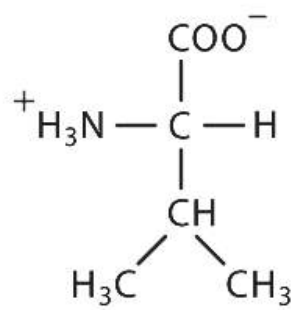
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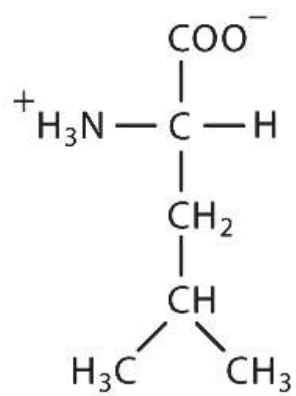
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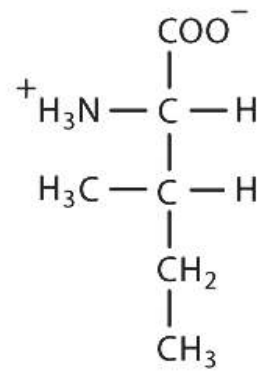


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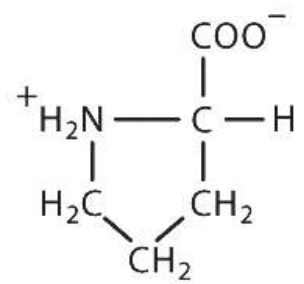


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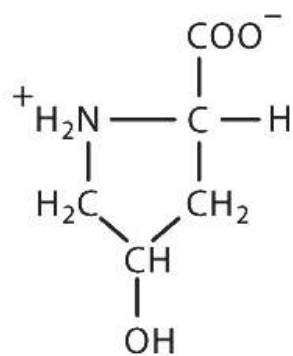
Amino Acids



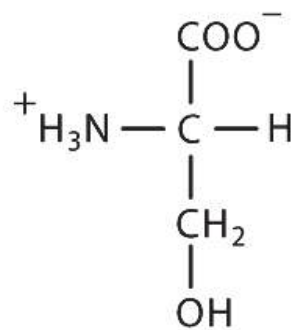
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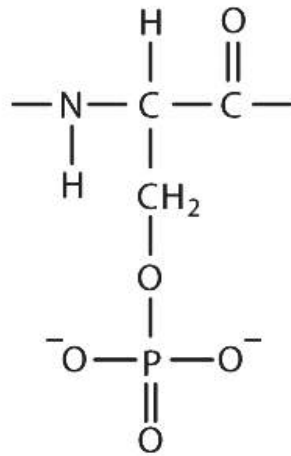
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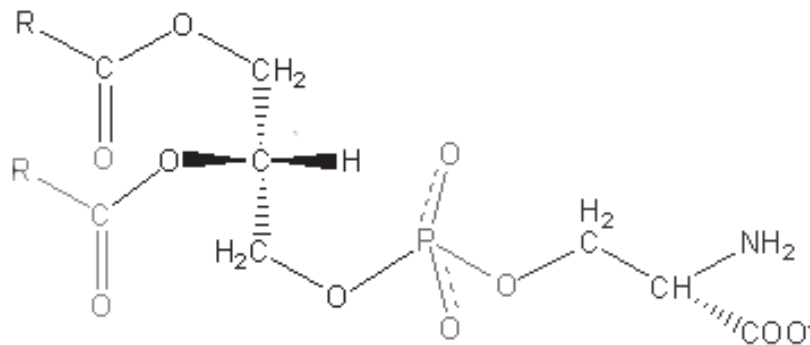
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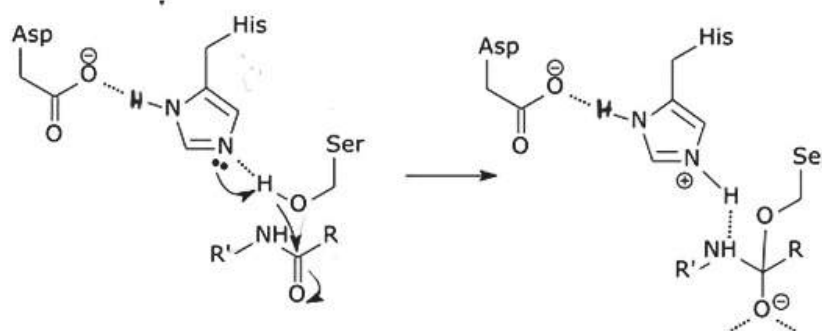
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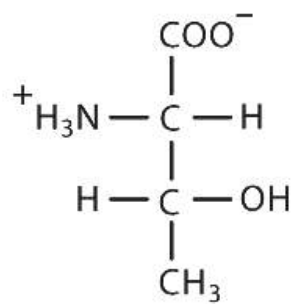
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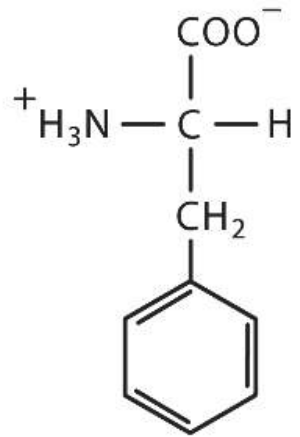
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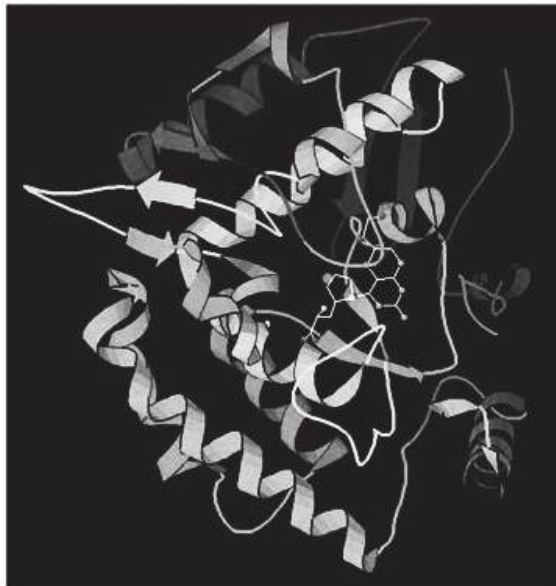
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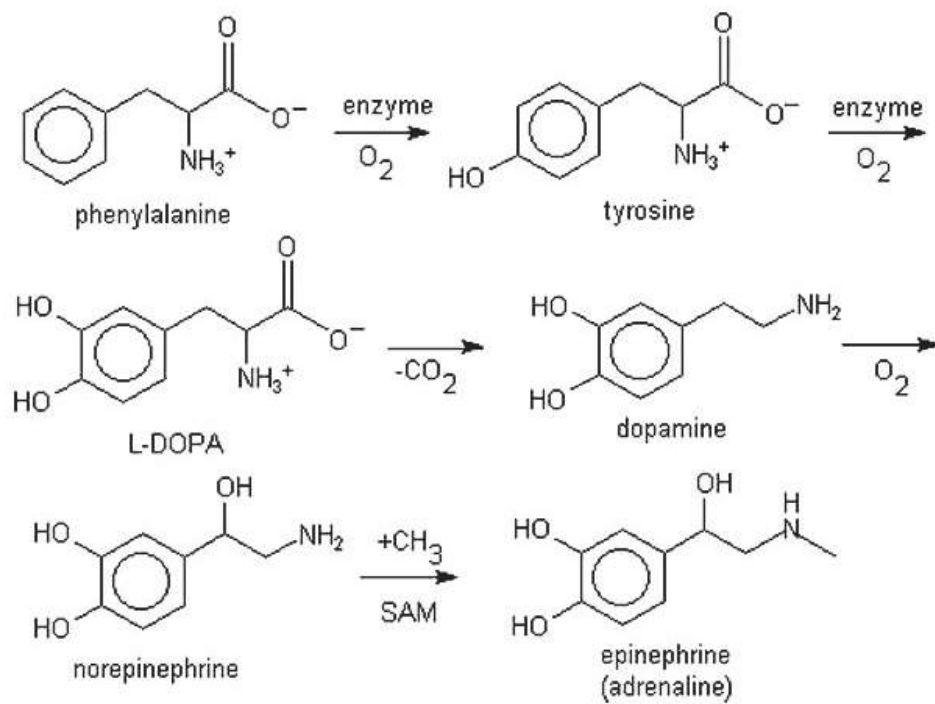
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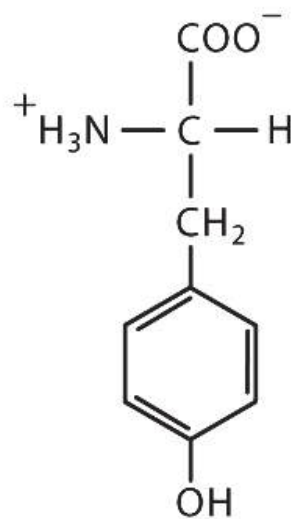
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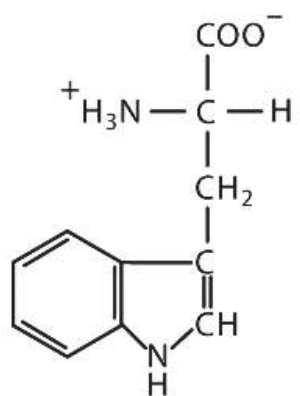
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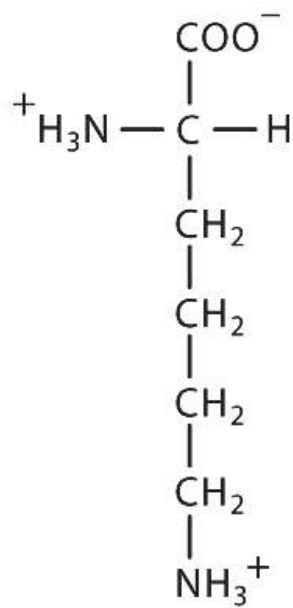
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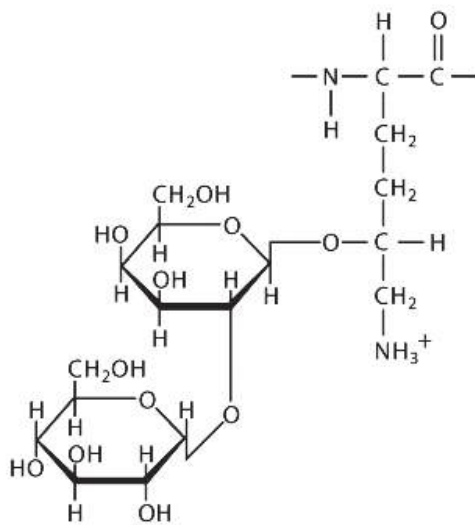
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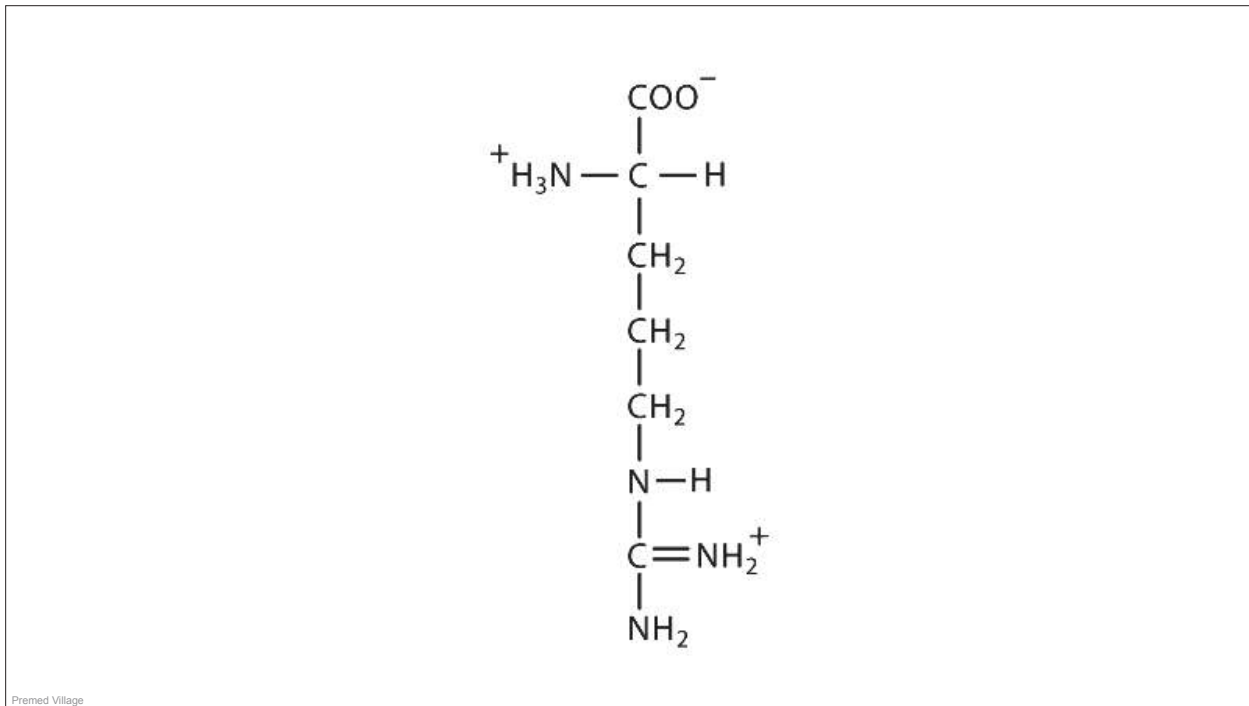
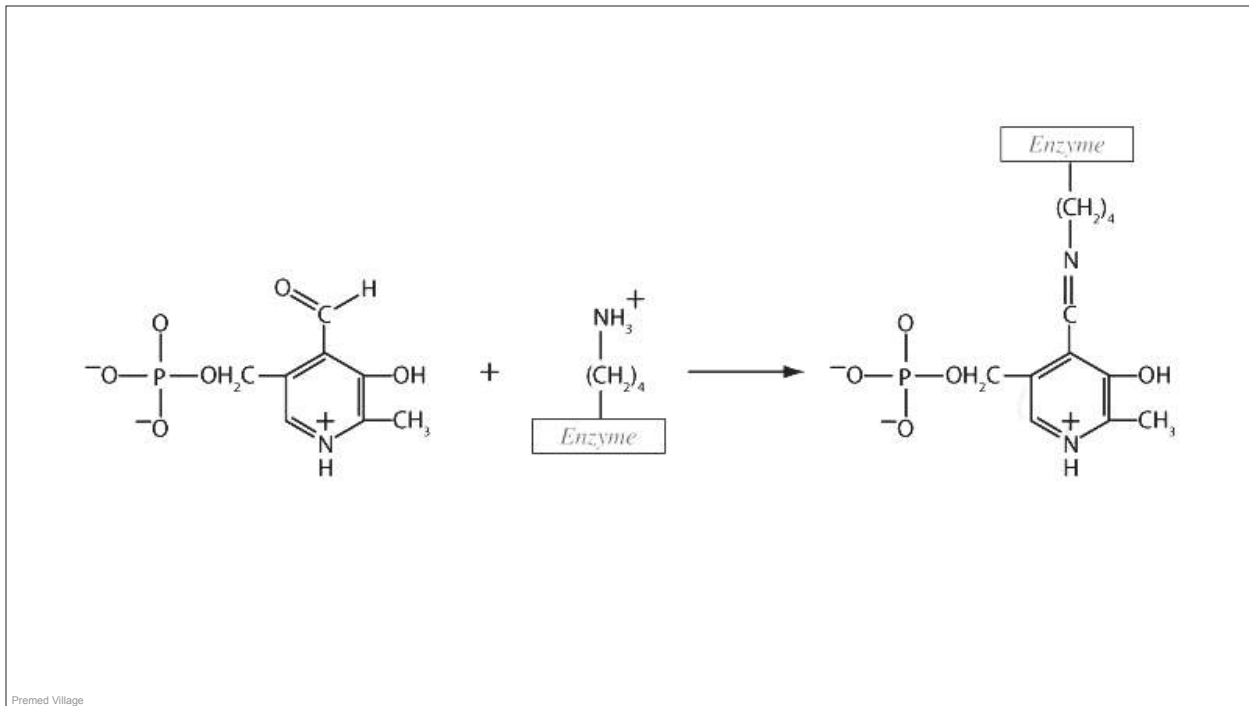


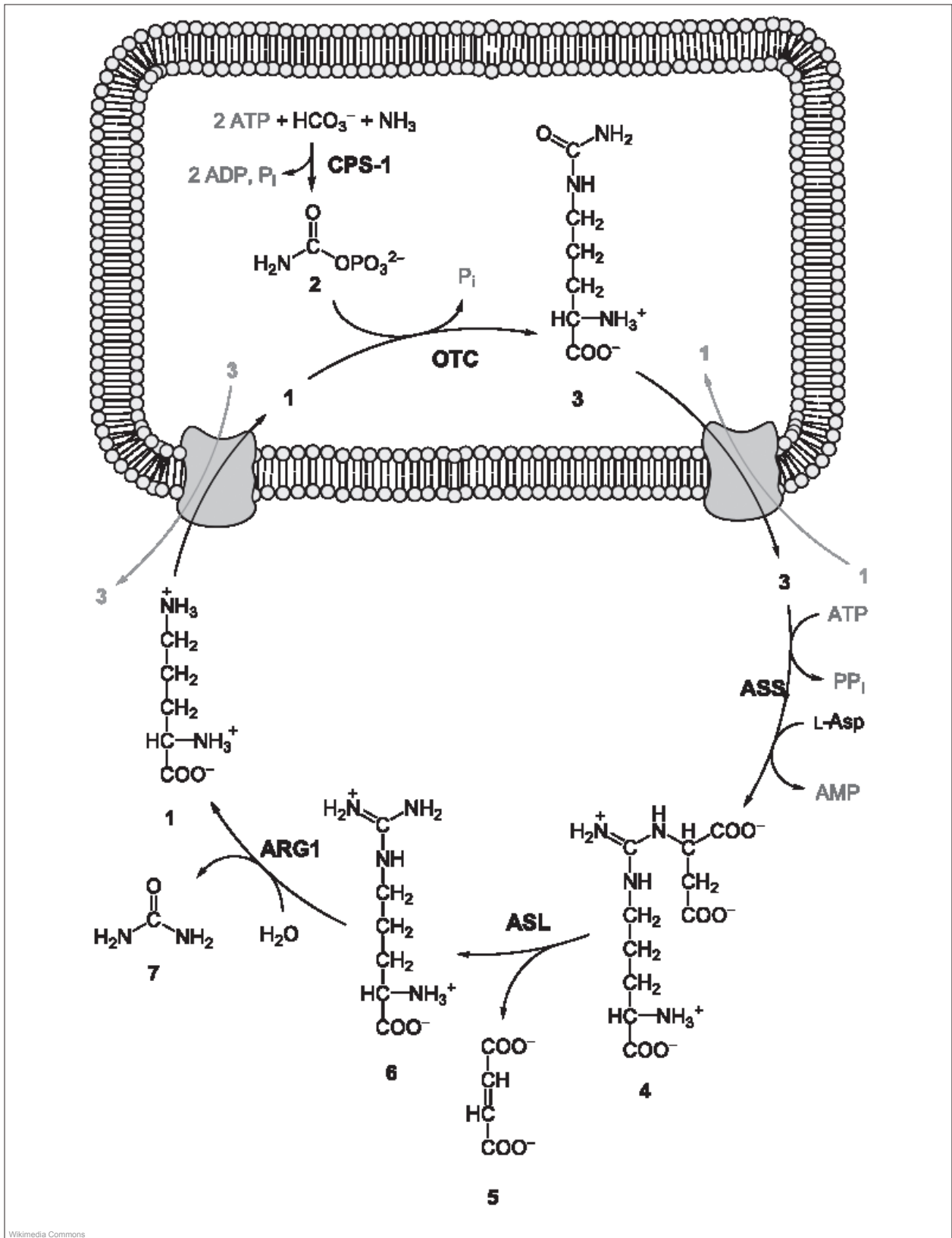
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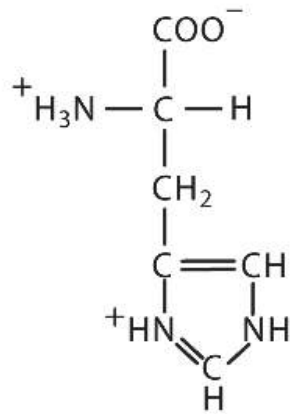


Premed Village

Amino Acids



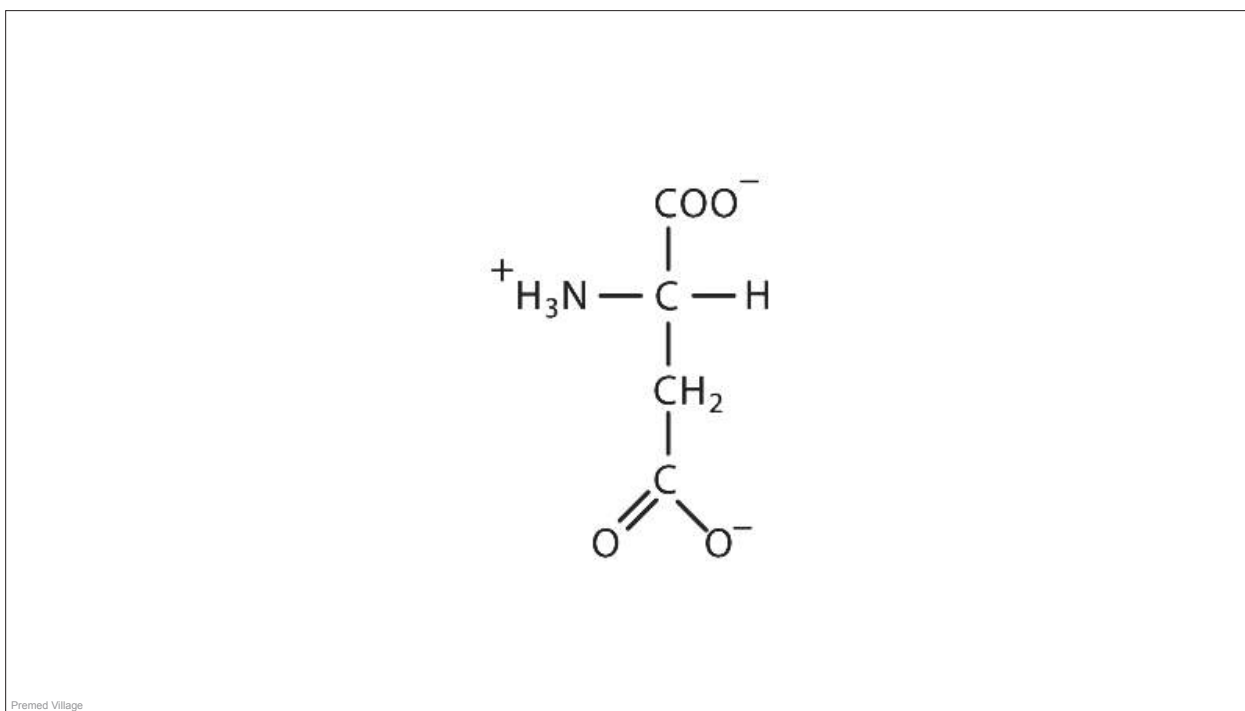
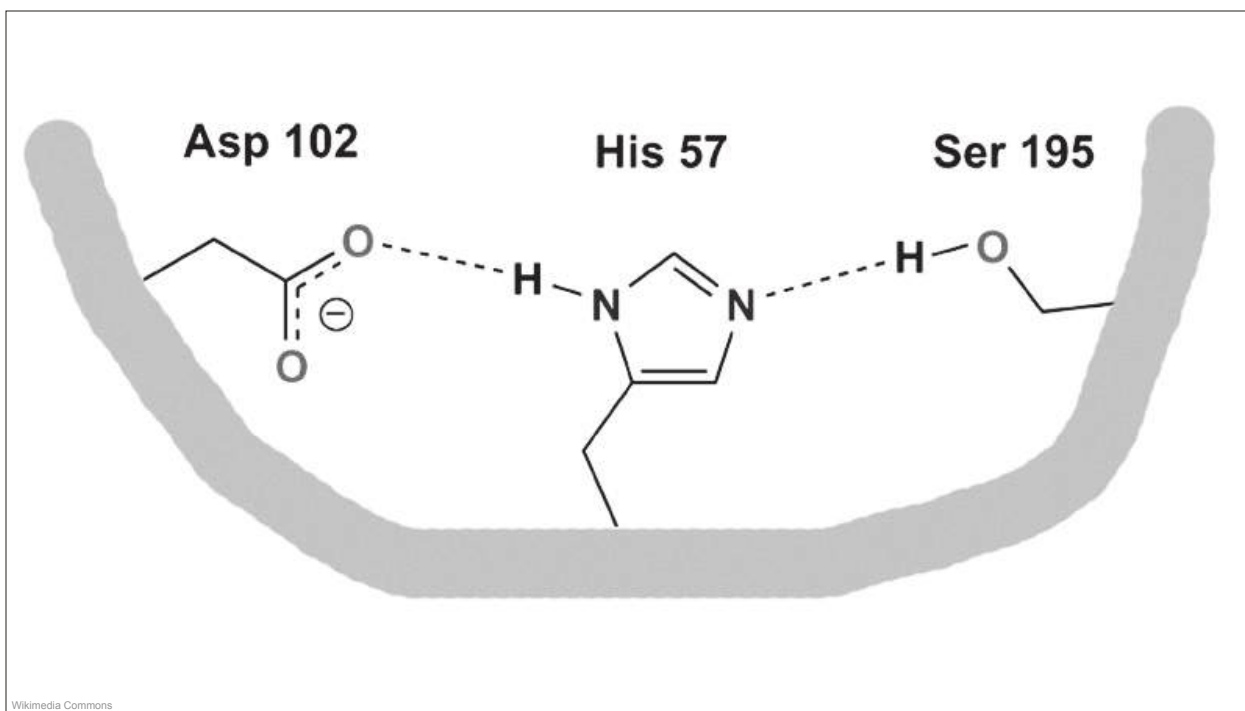




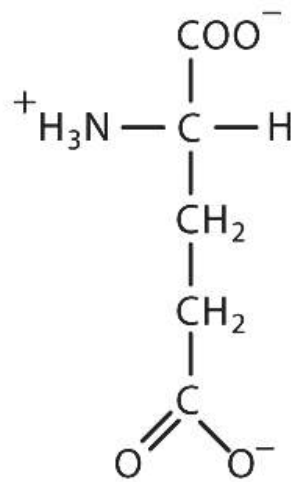
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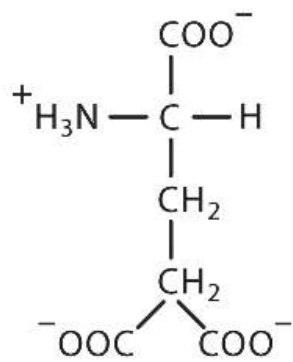
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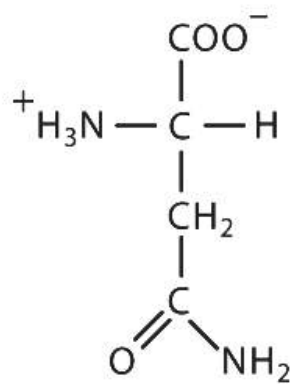
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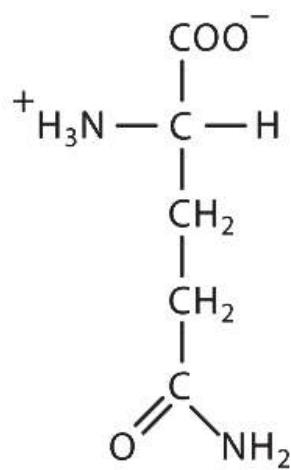
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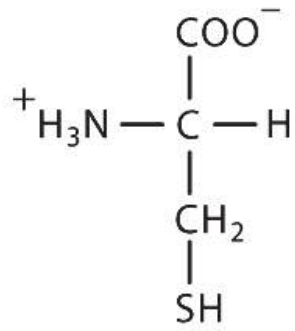
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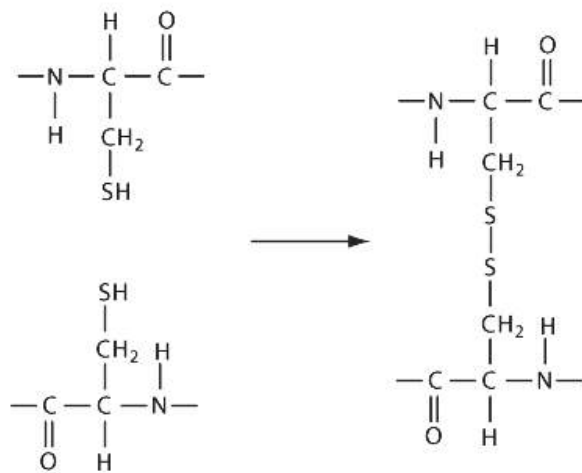
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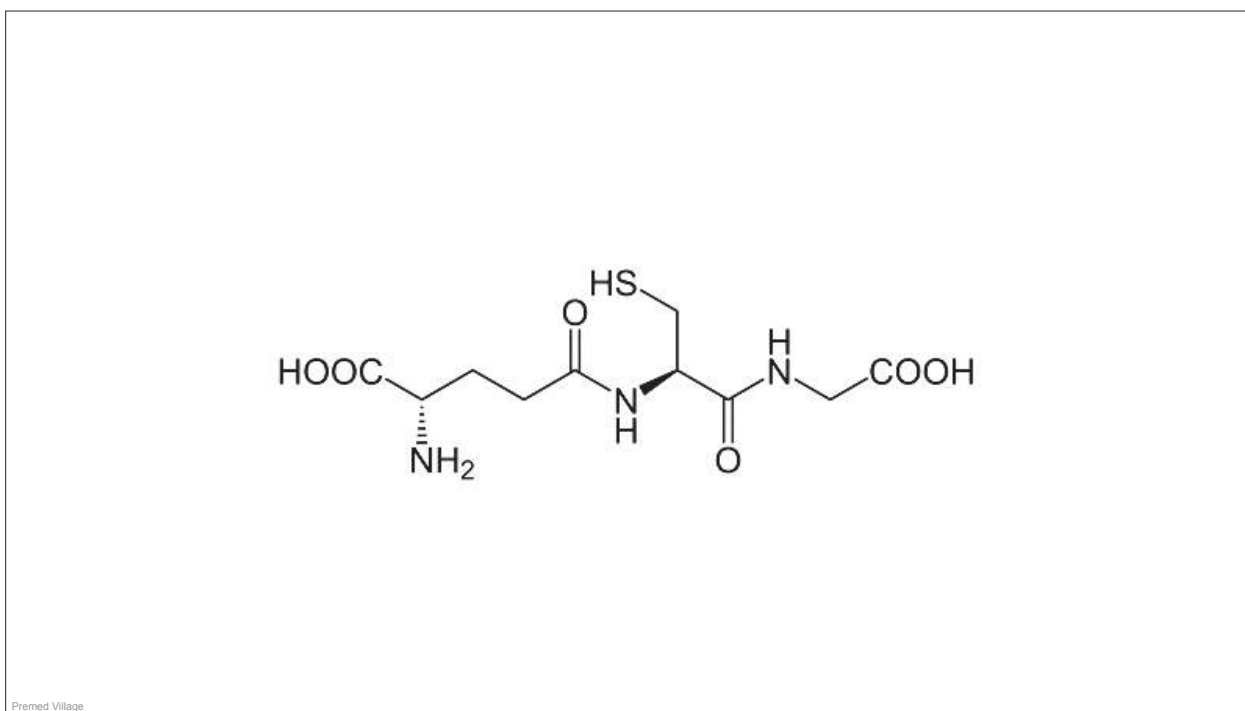
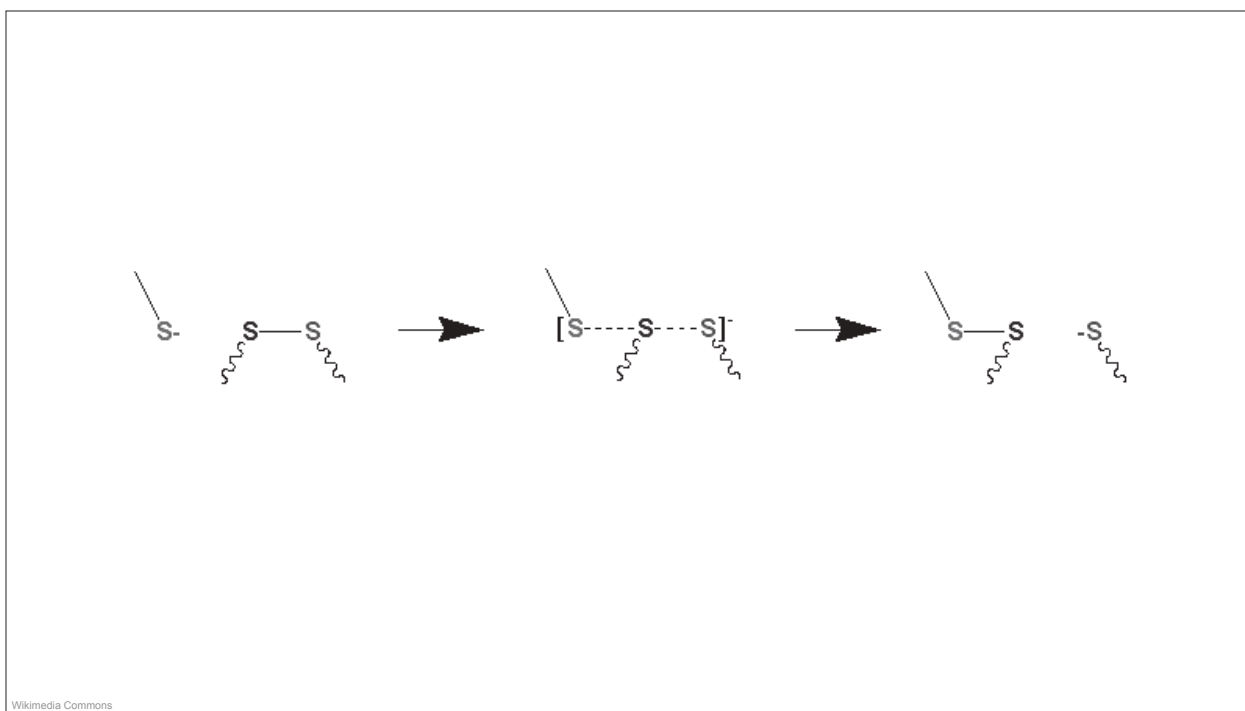
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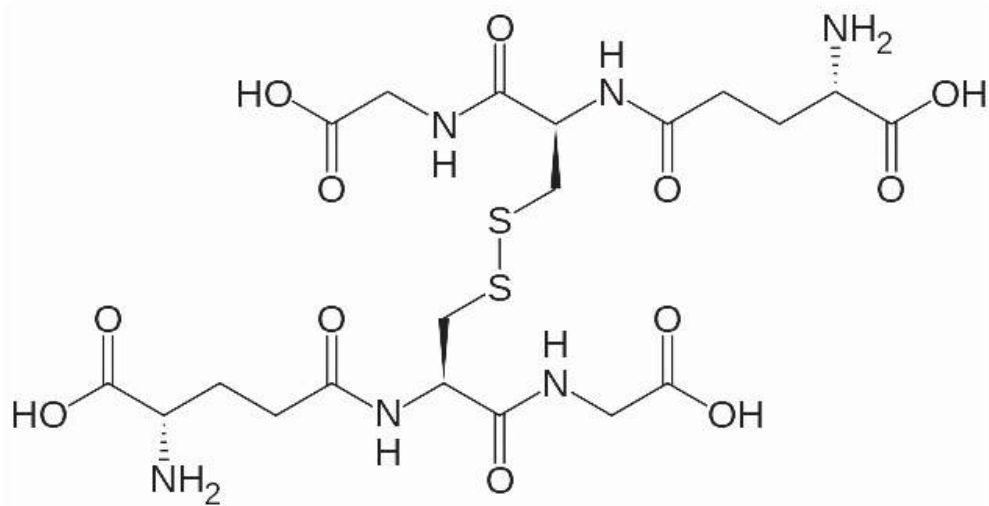


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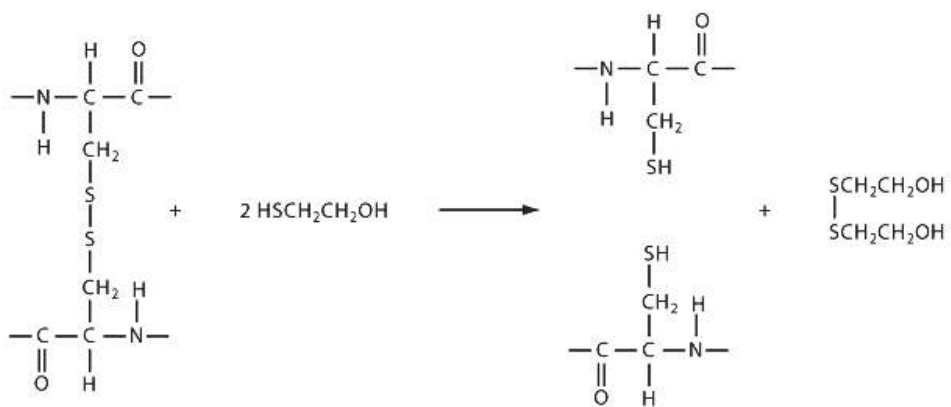


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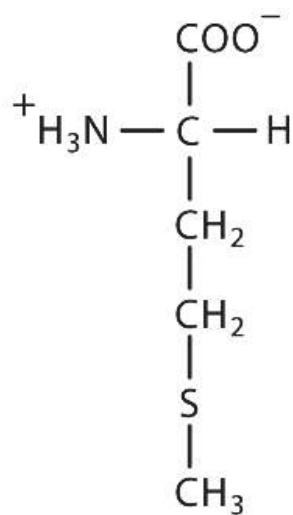




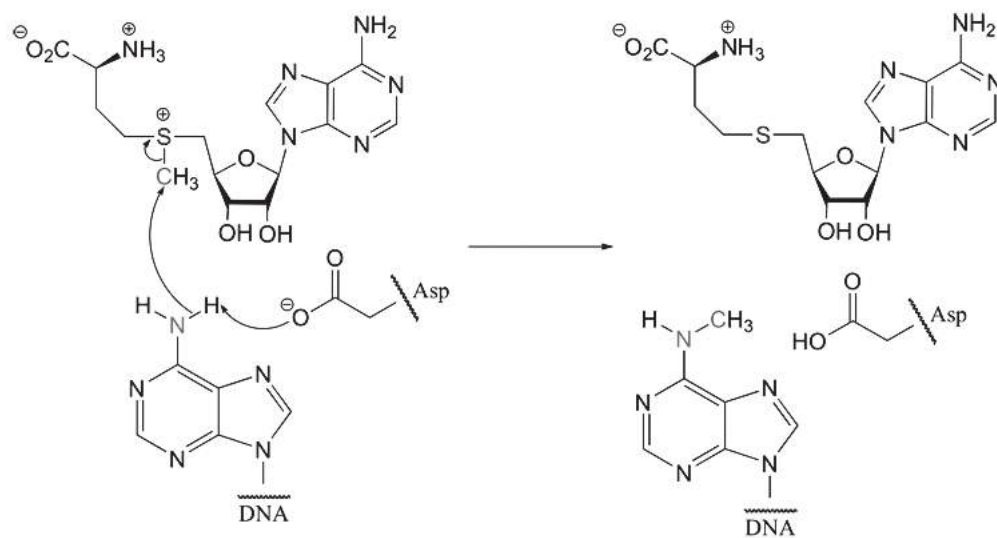
Premed Village



Premed Village

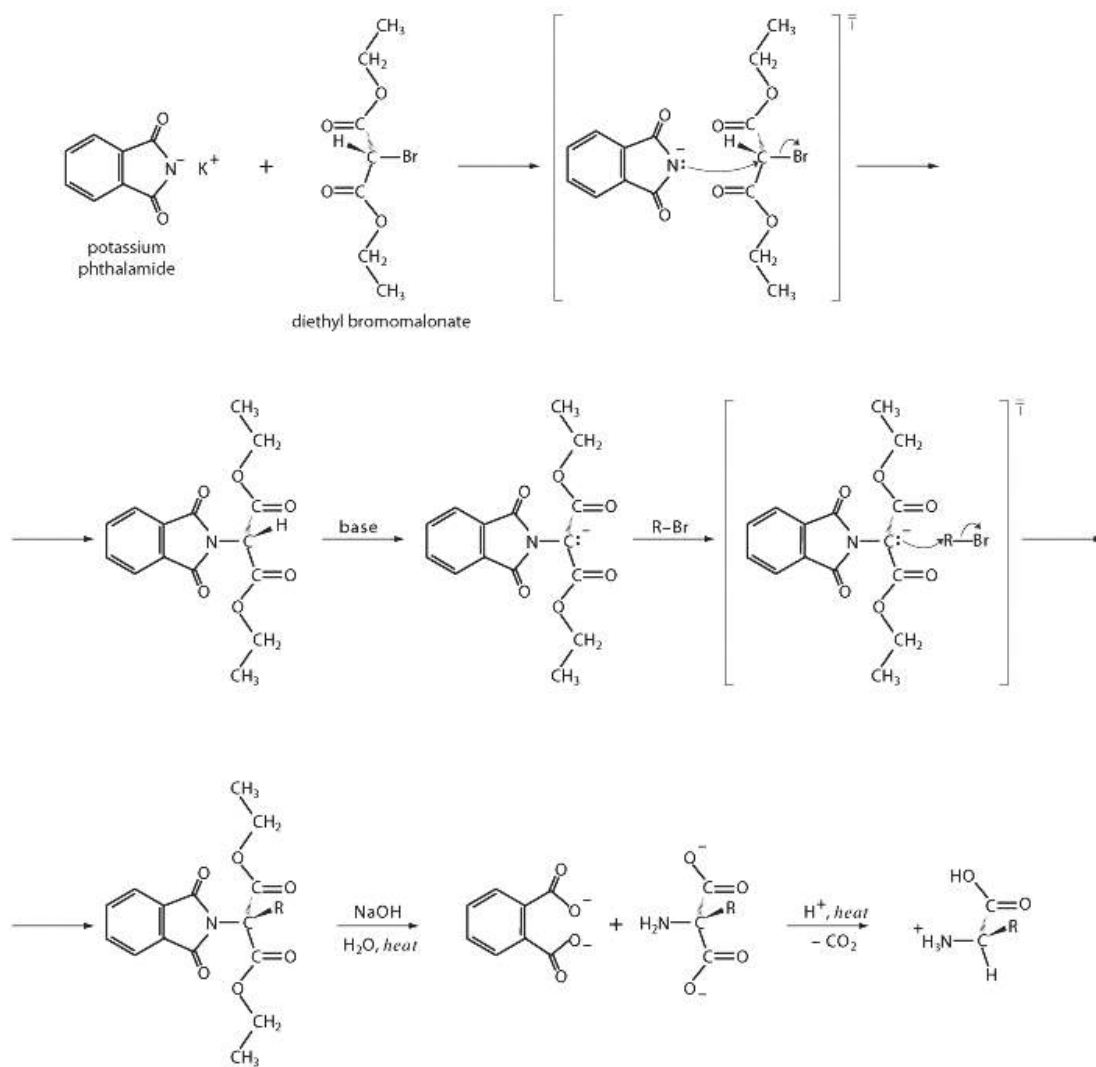


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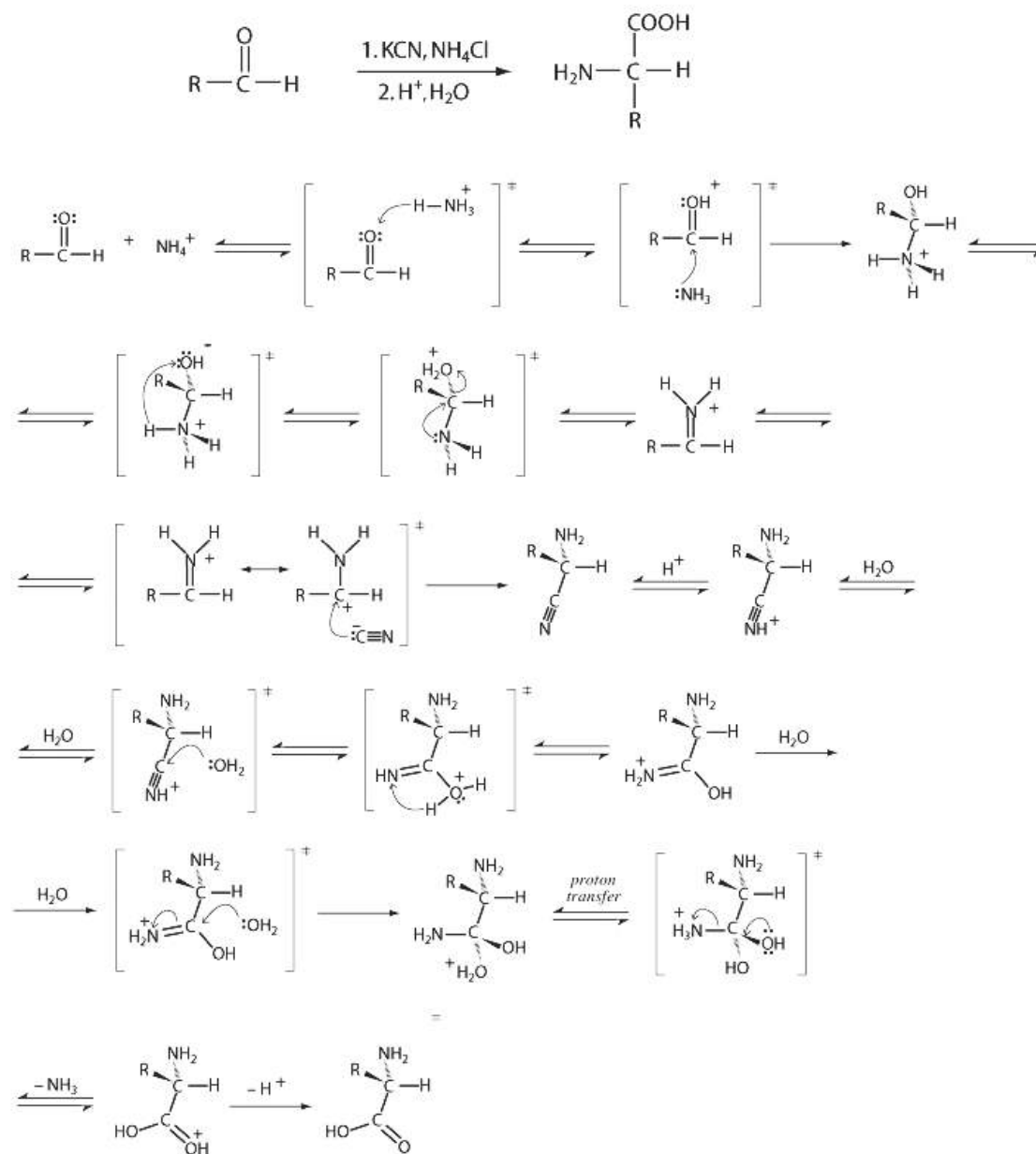
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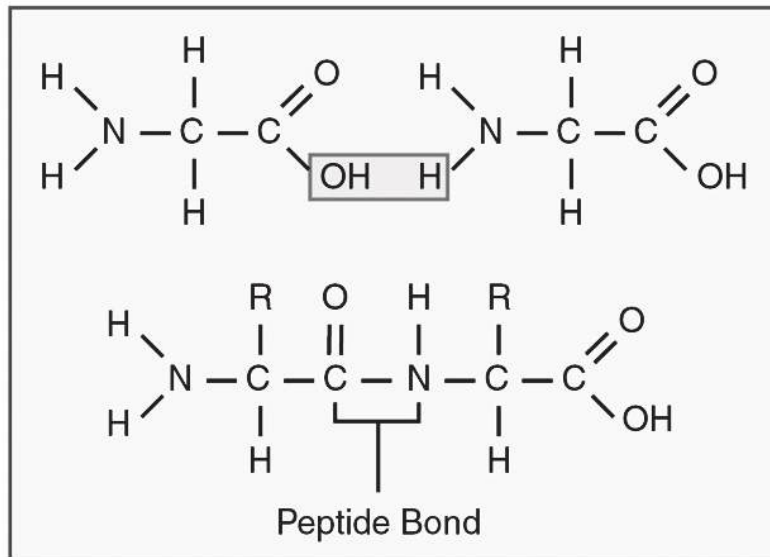
Gabriel Synthesis



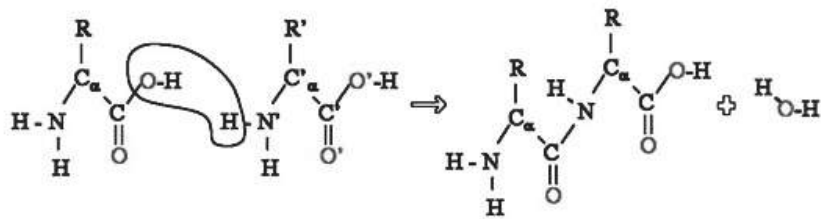
Premed Village

Strecker Synthesis

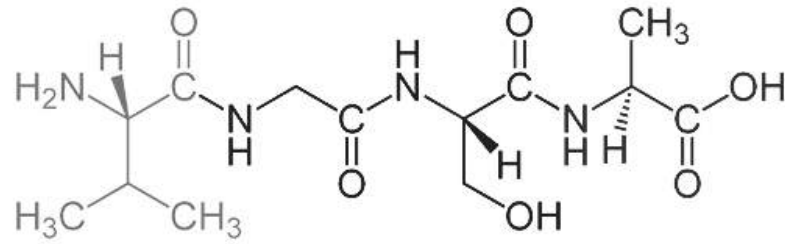




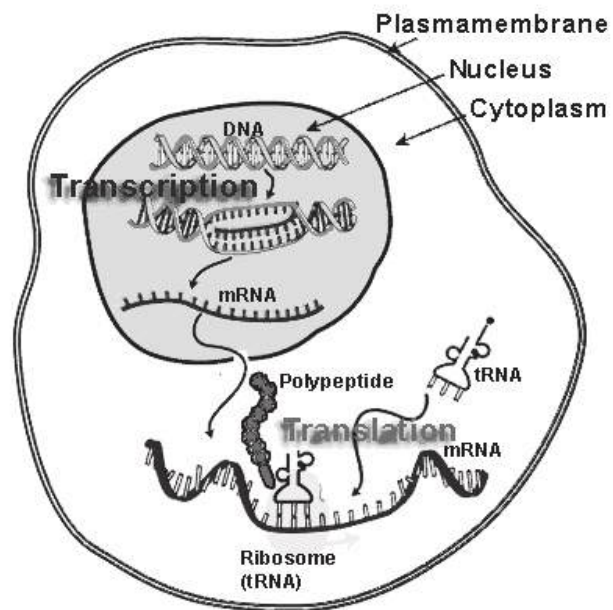
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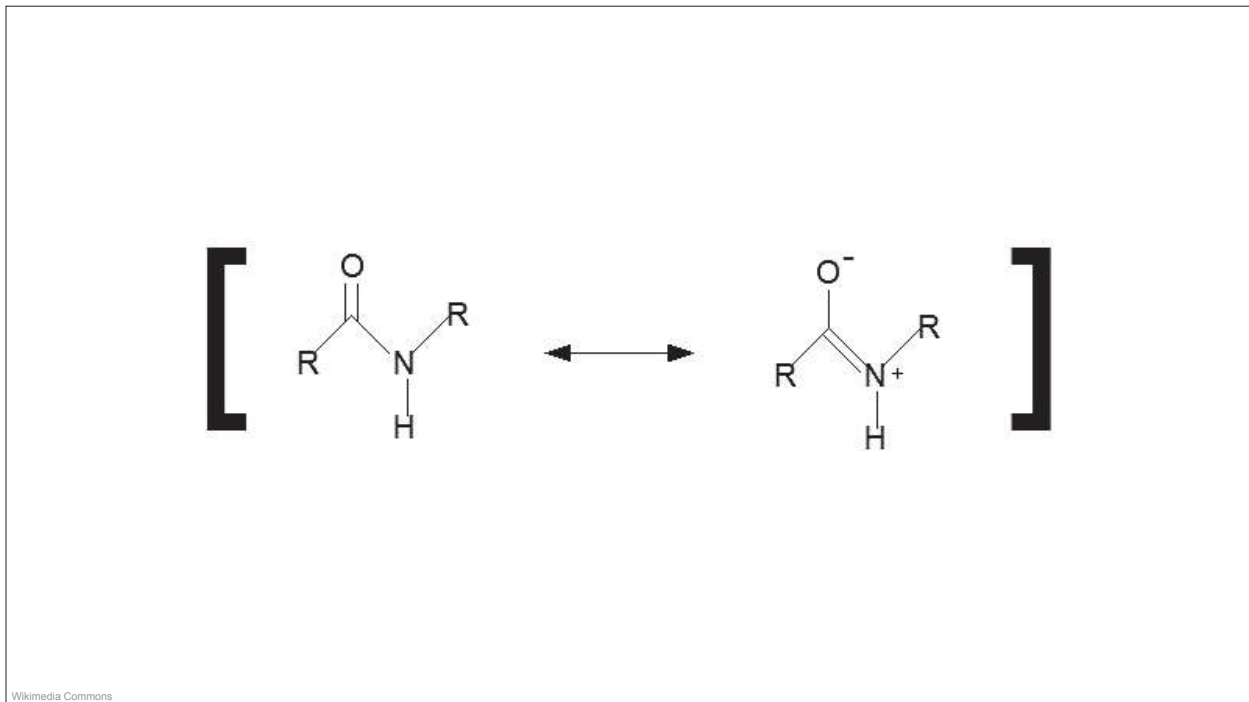
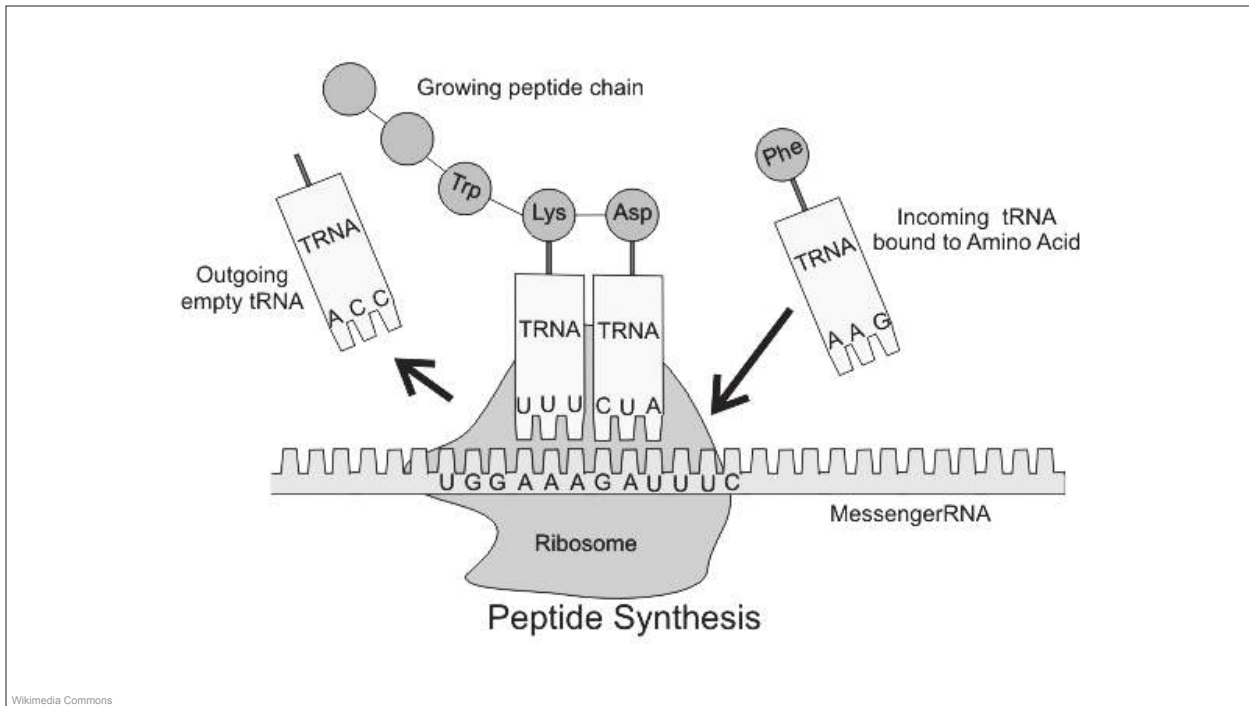
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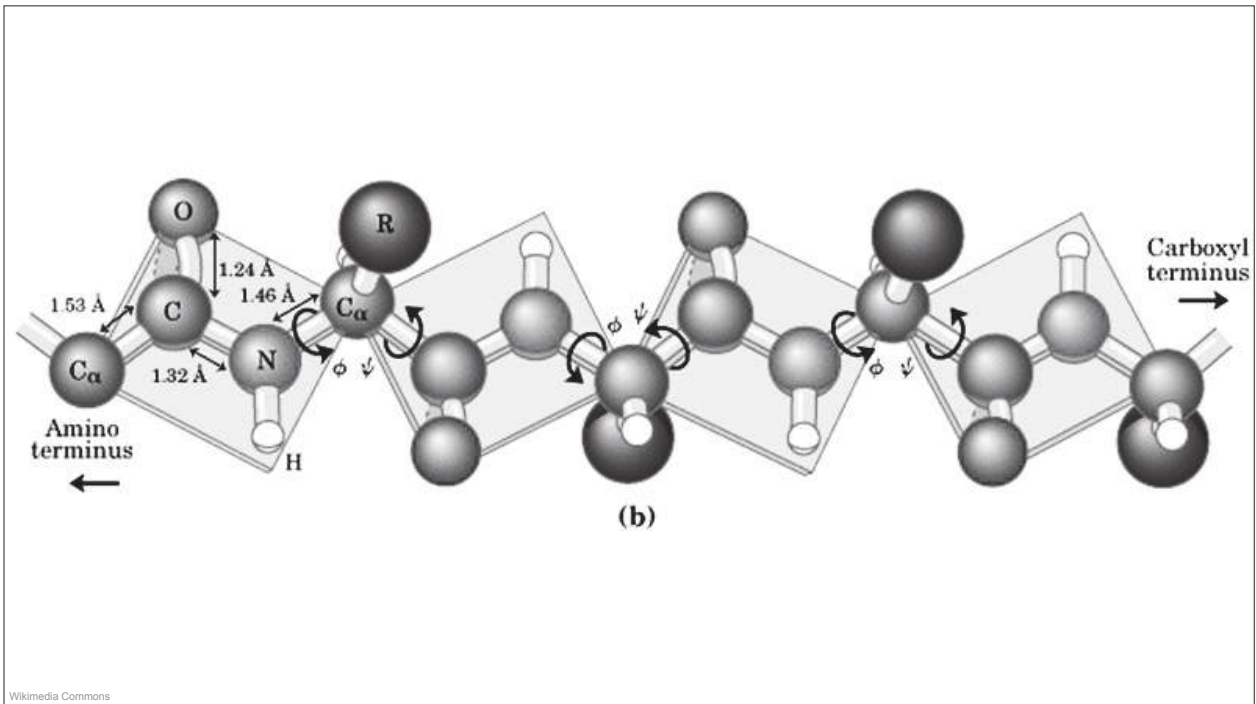
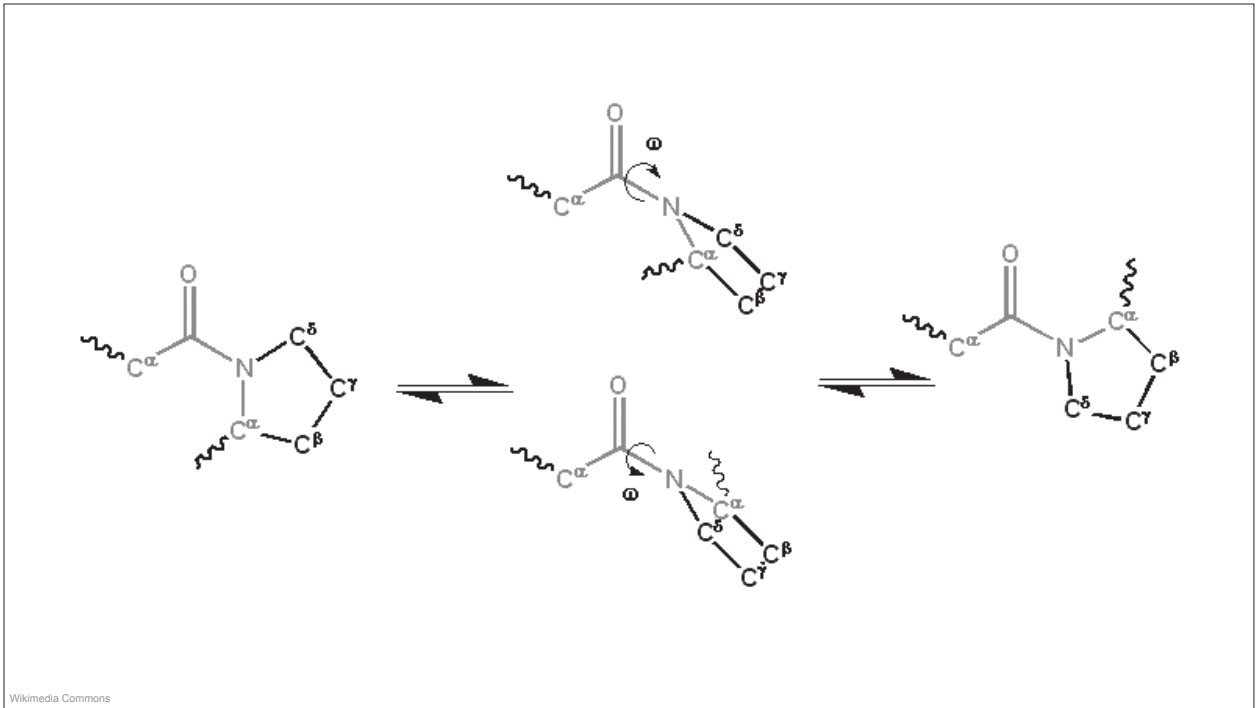


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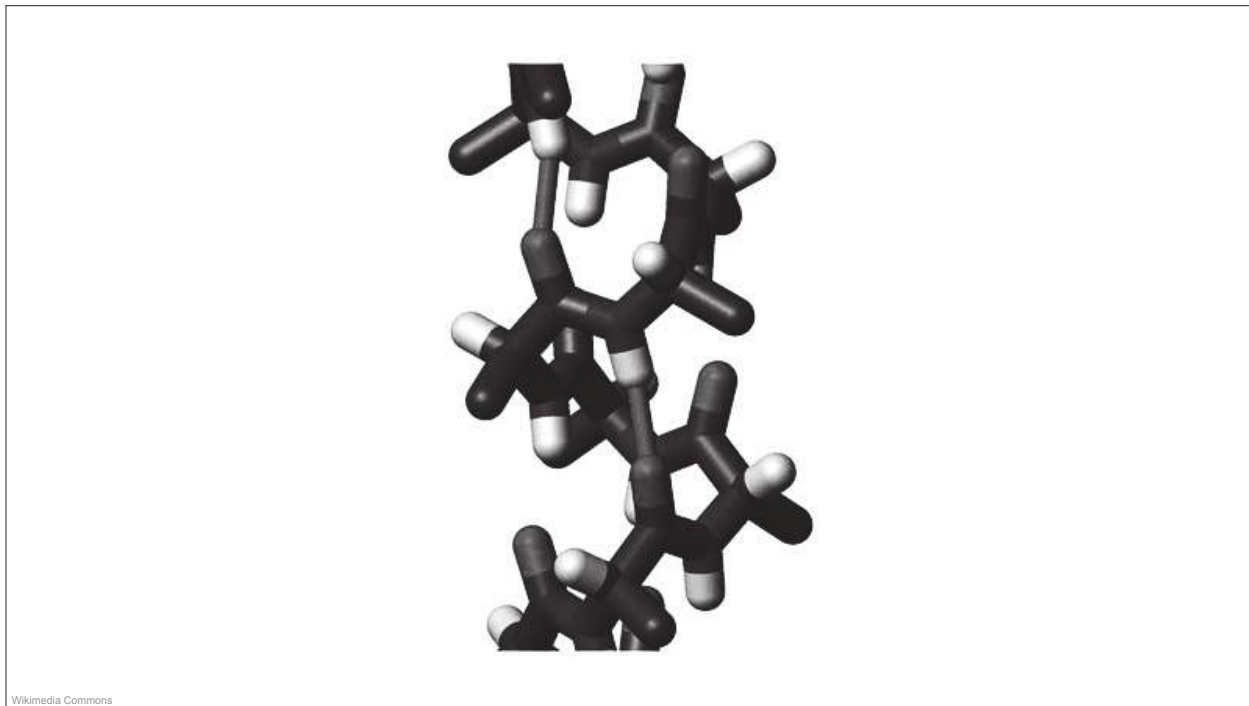
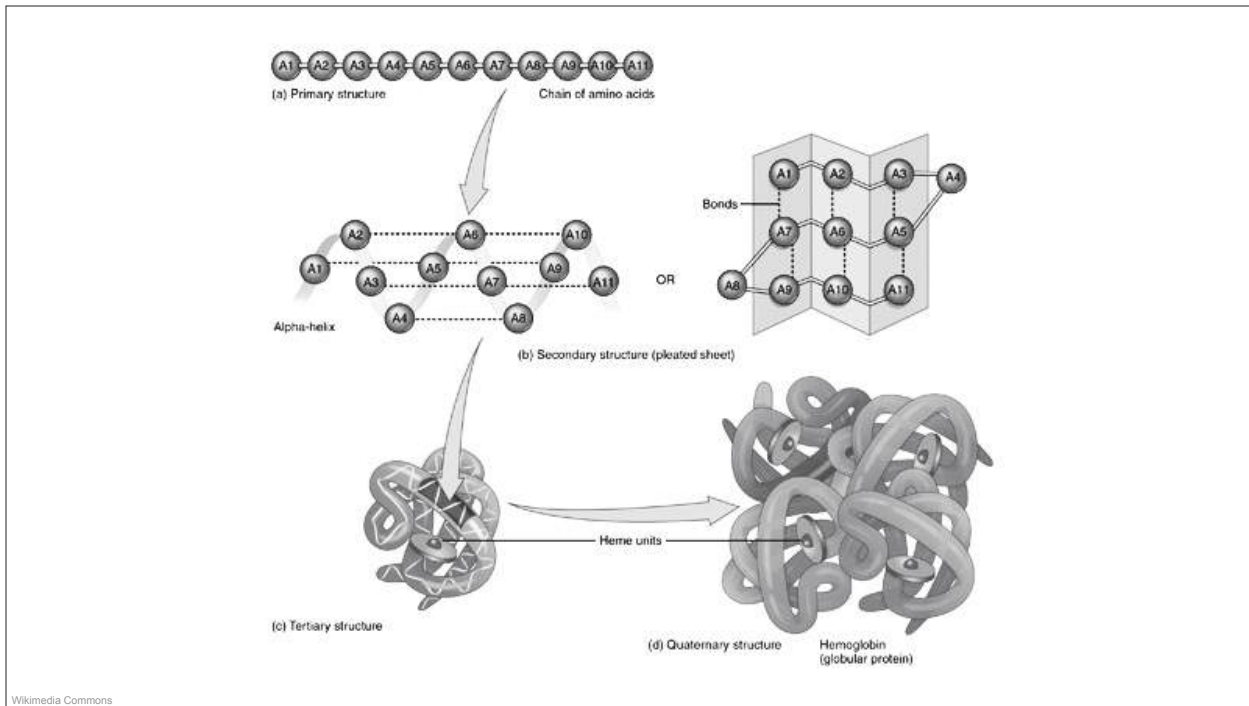


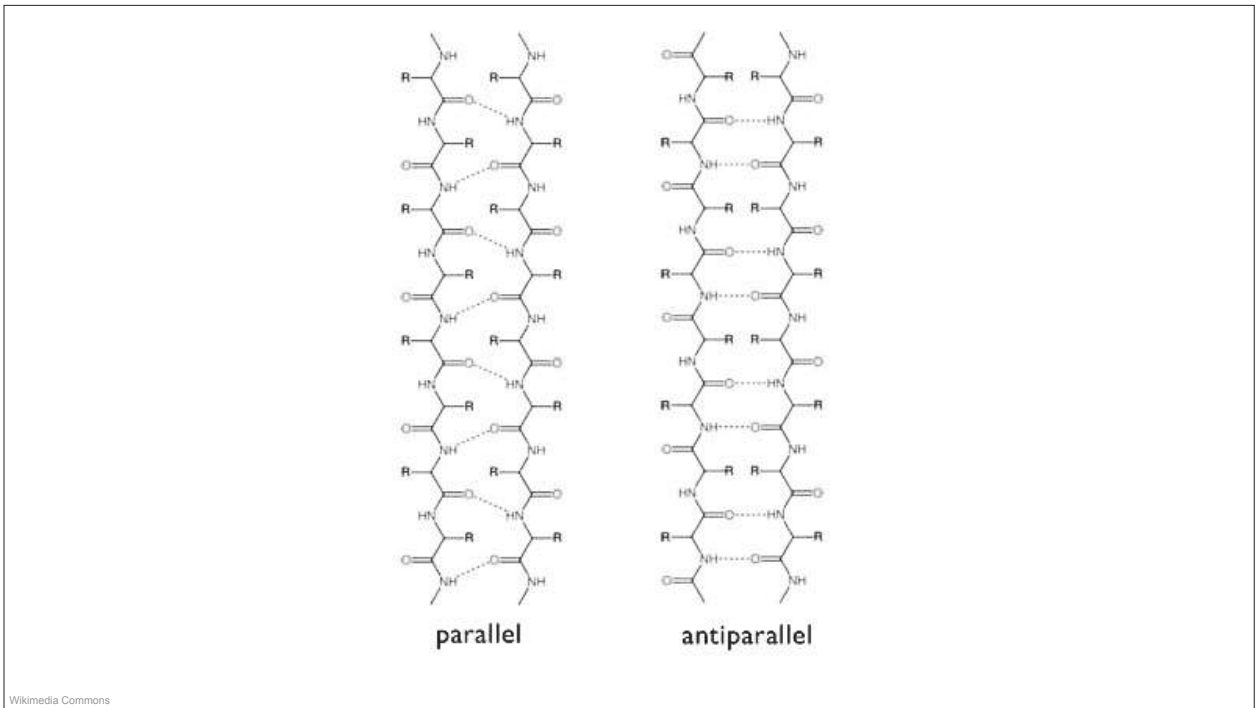
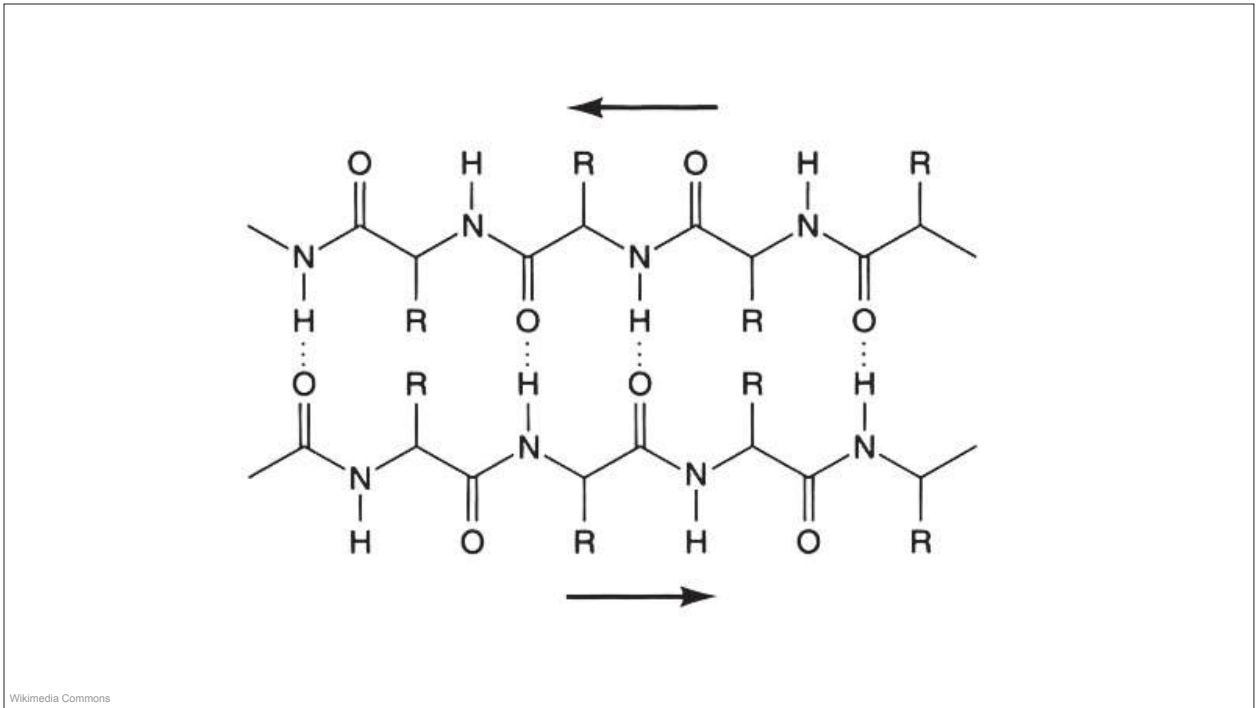
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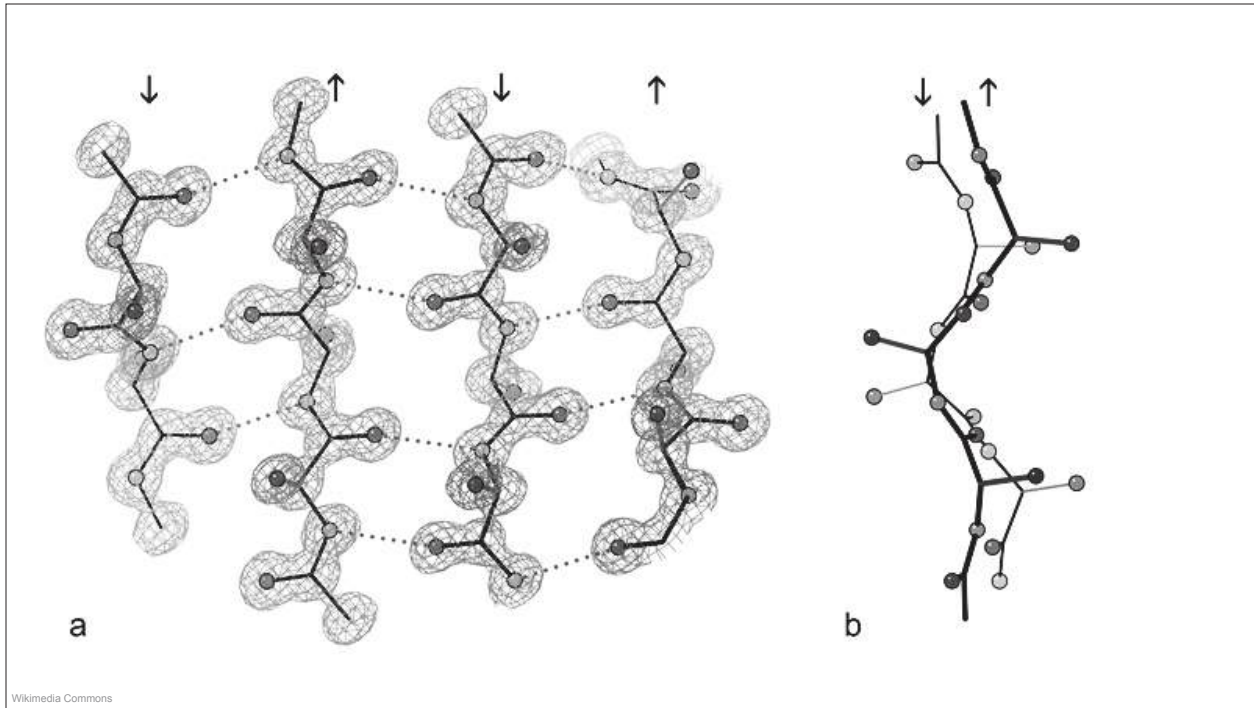


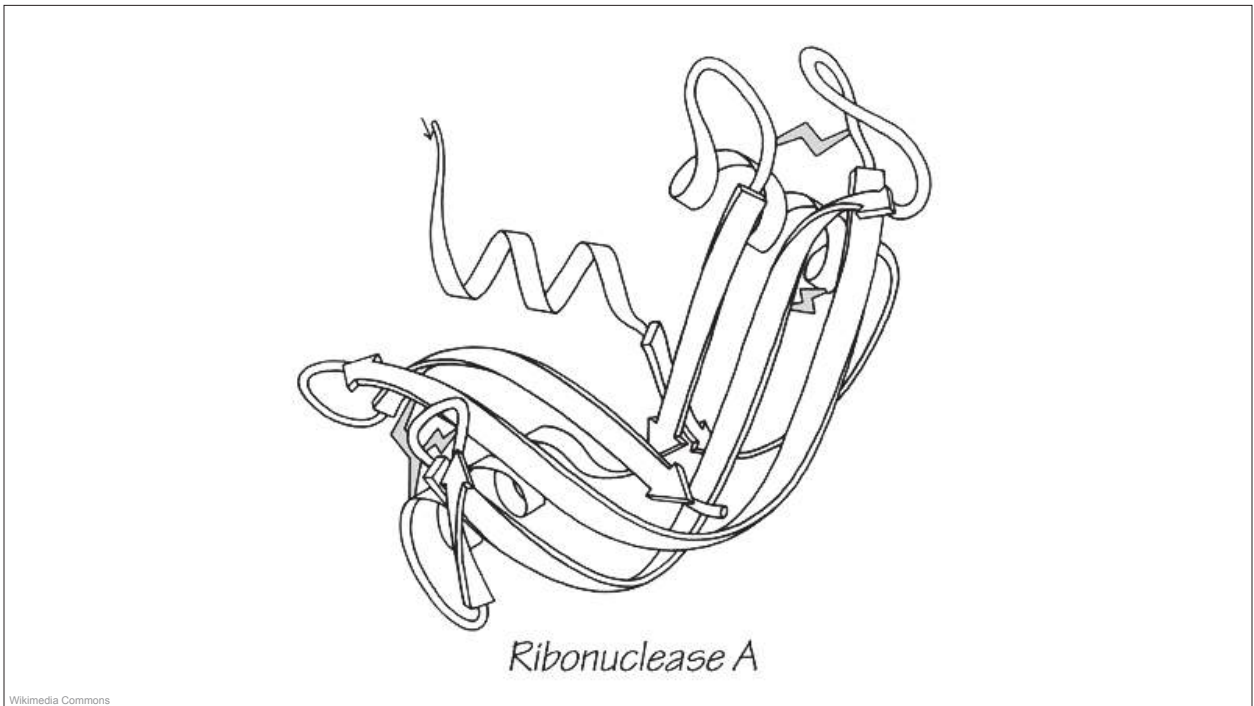
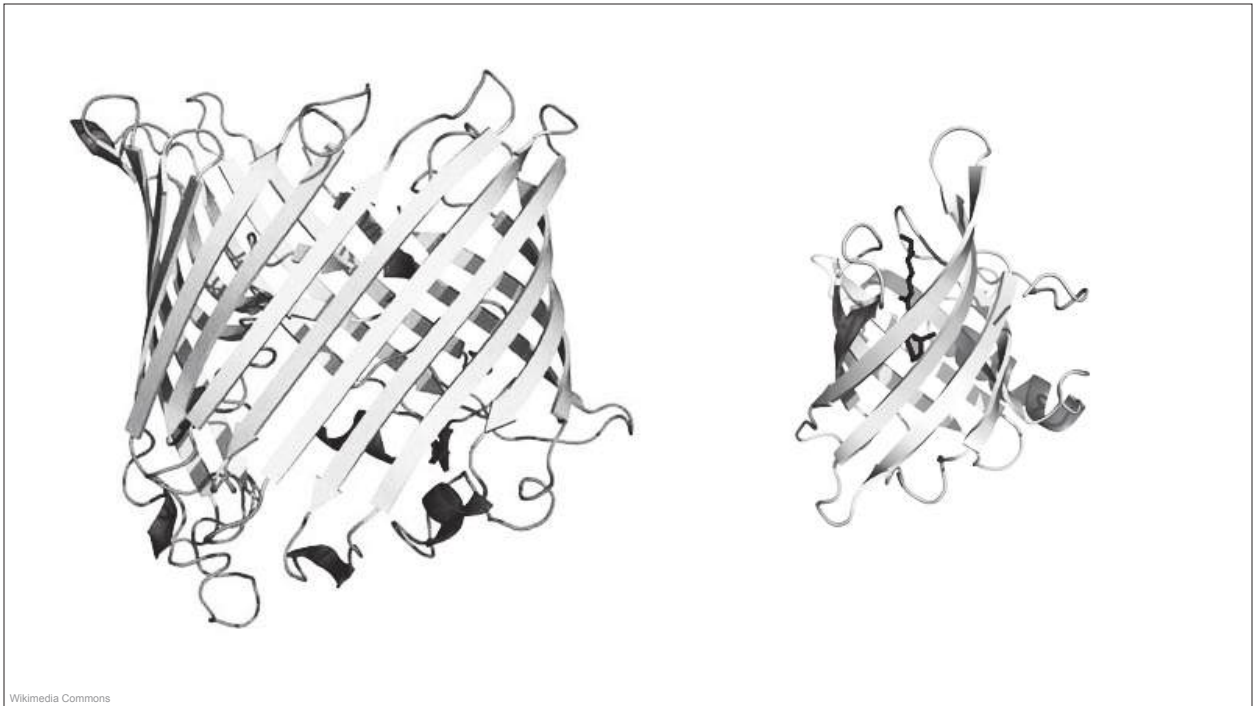


Protein Structure

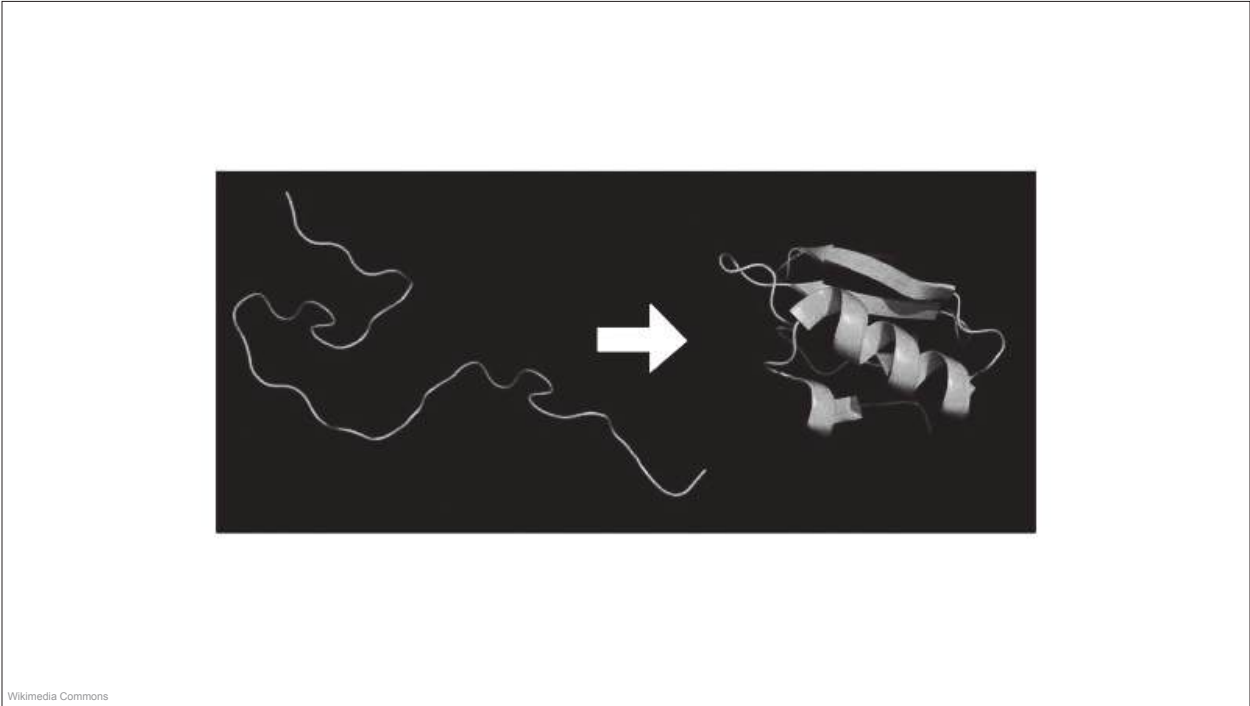
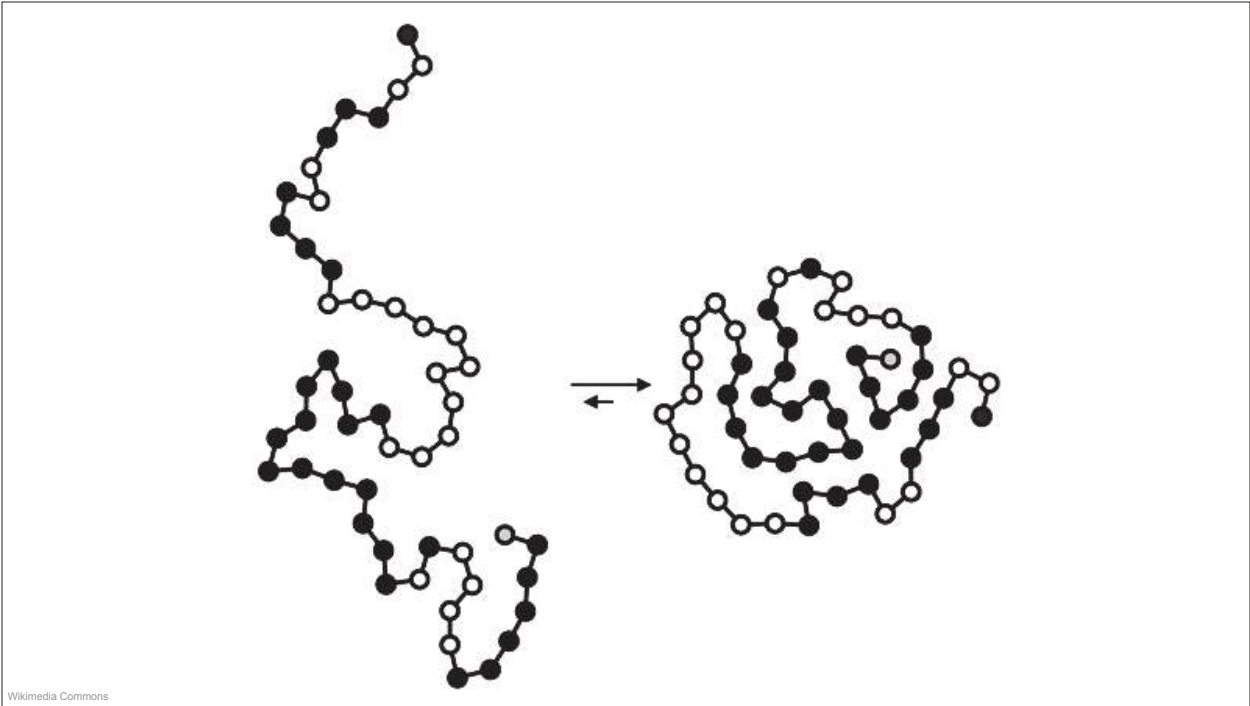


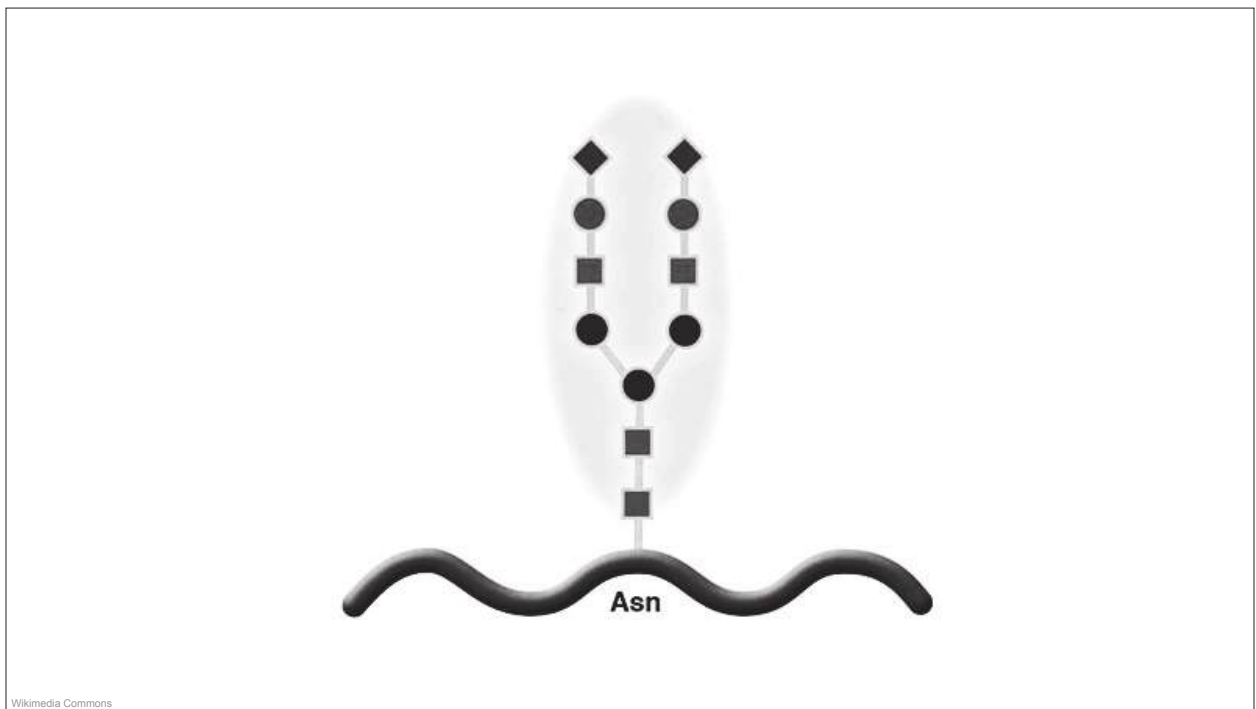
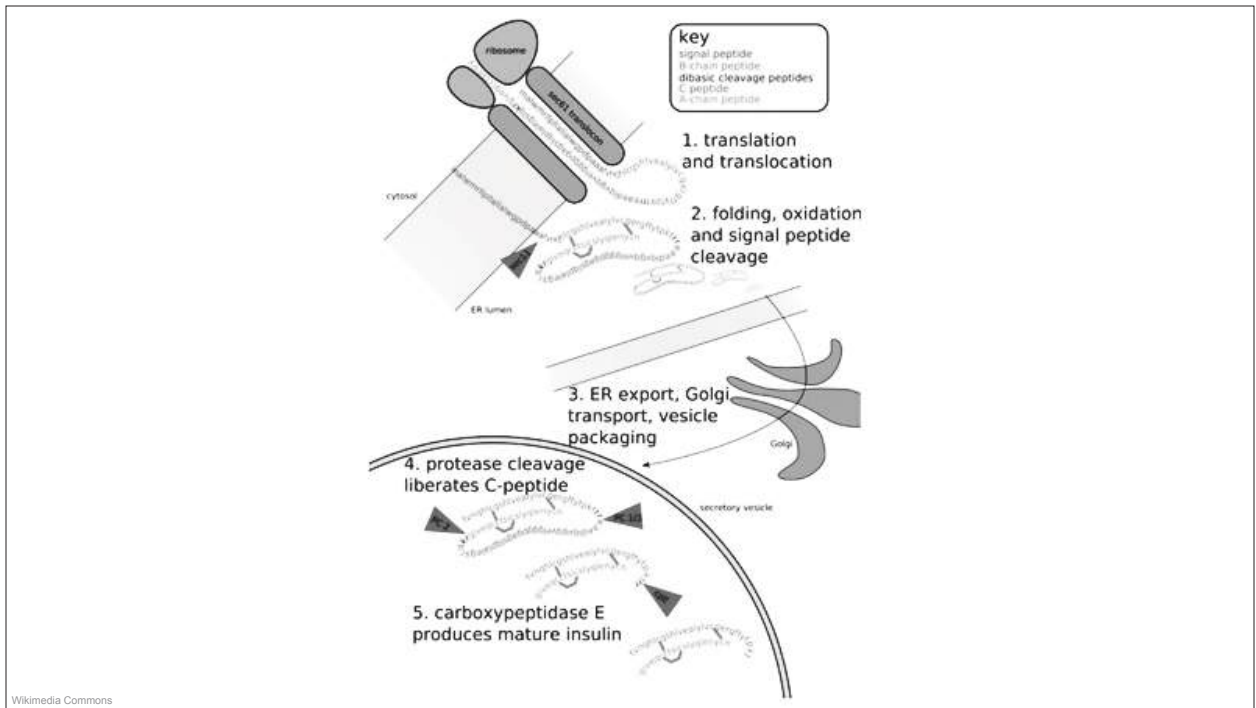


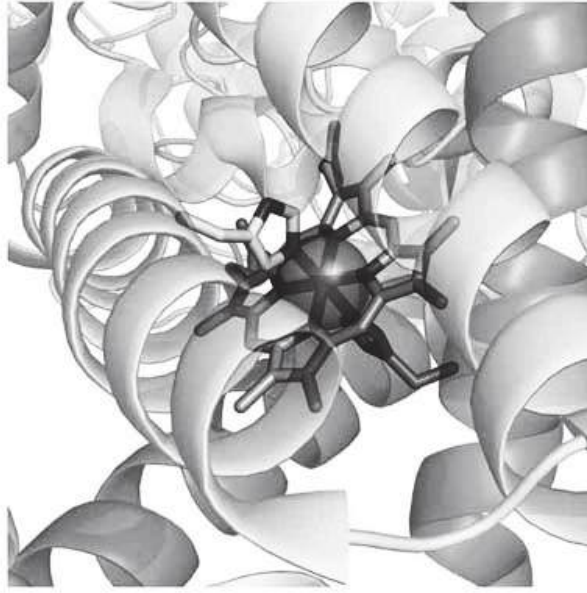




Protein Structure



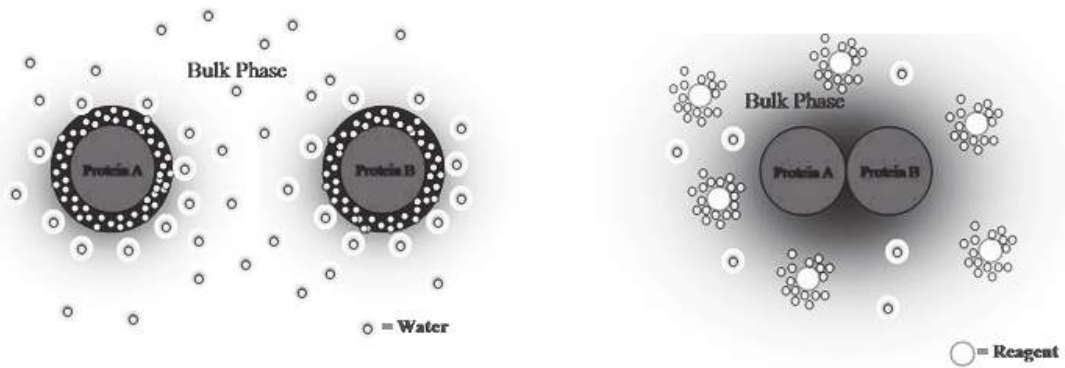




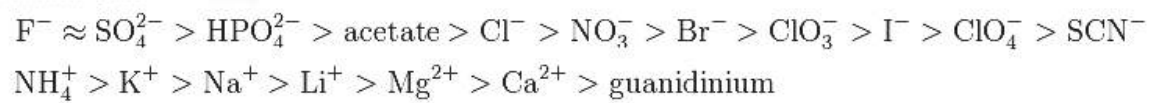
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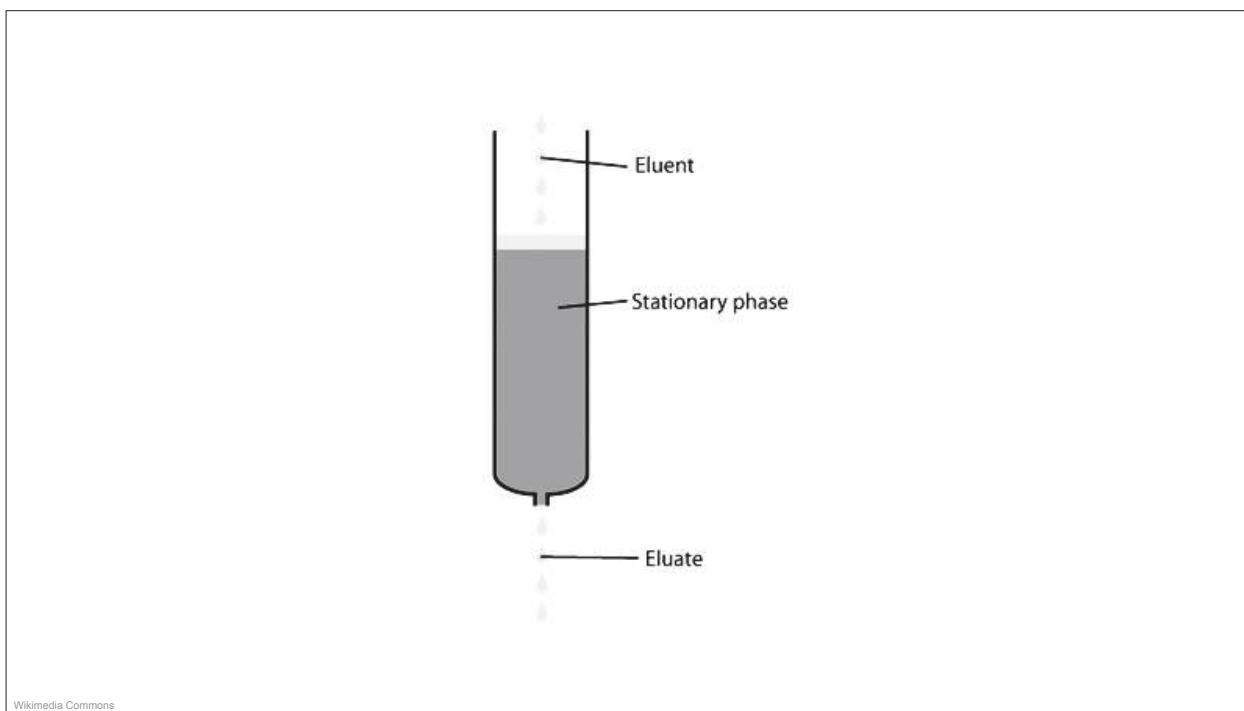
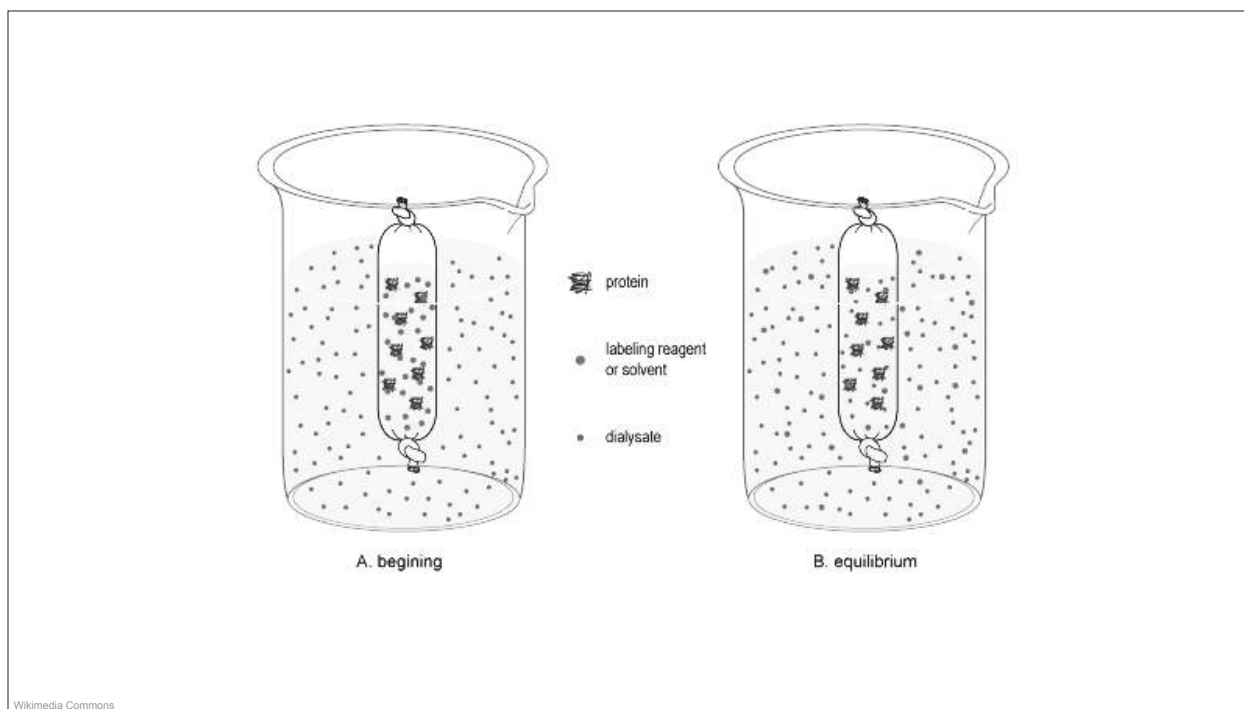
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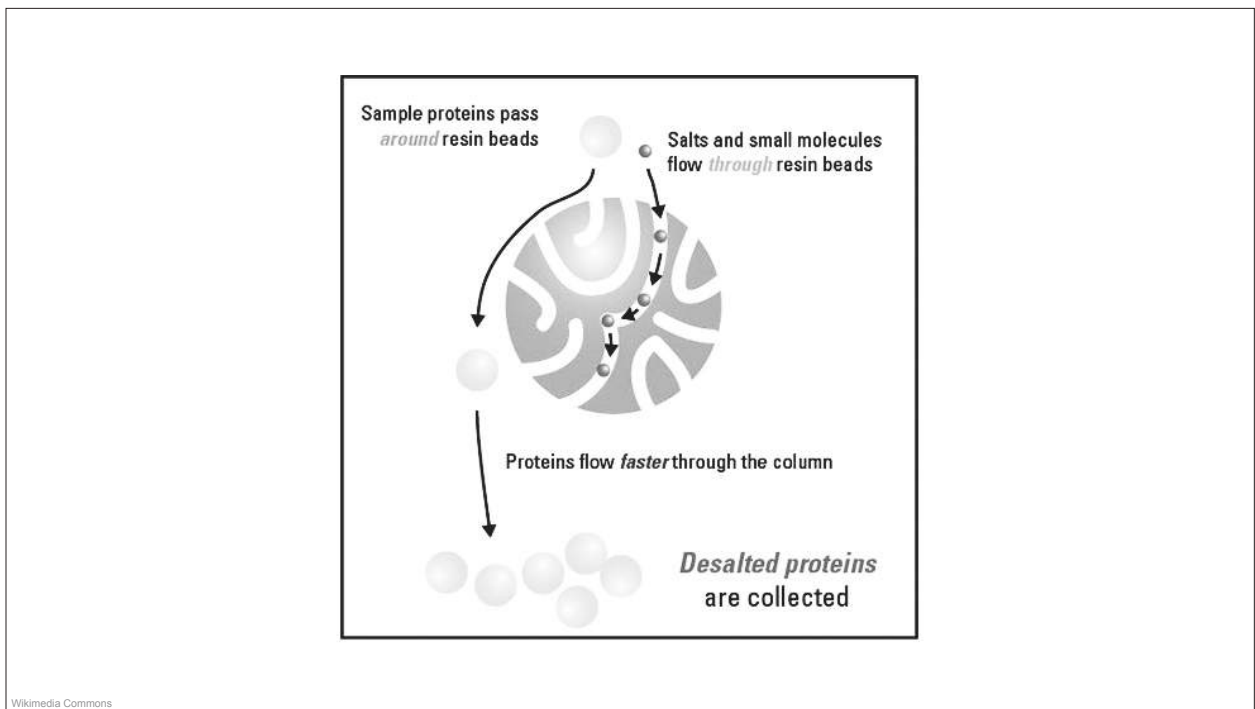
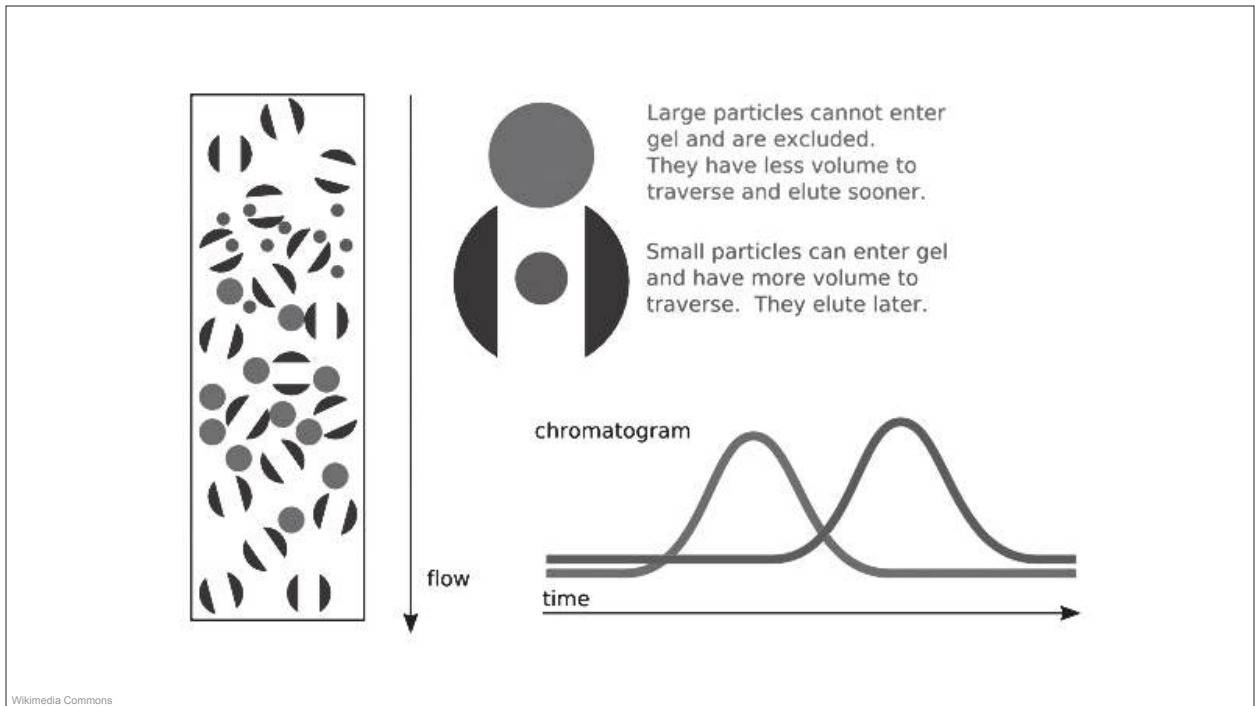


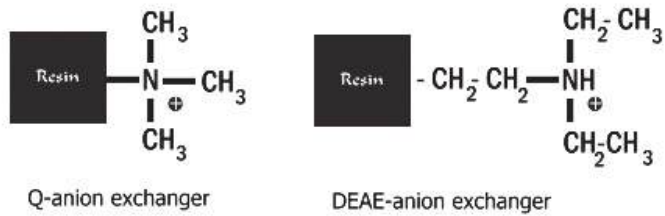
Hofmeister Series



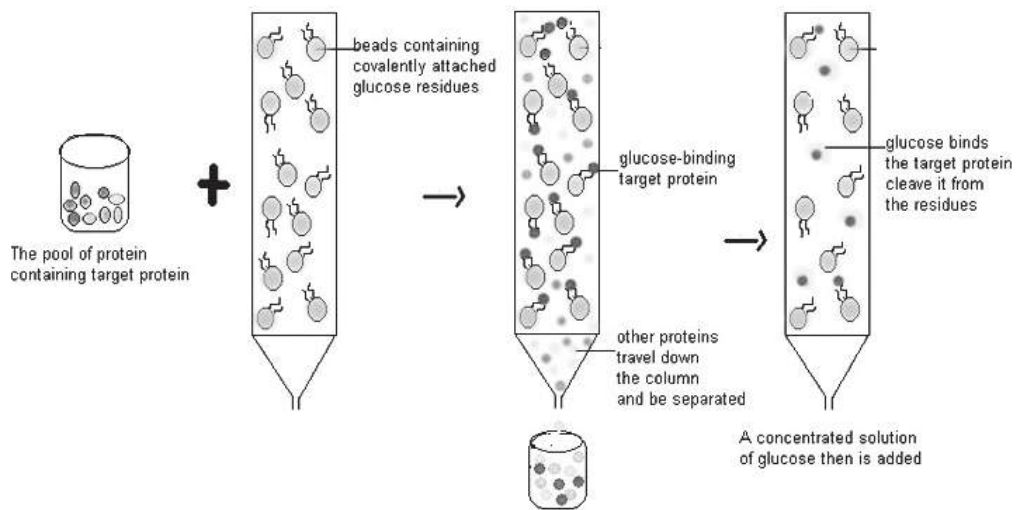
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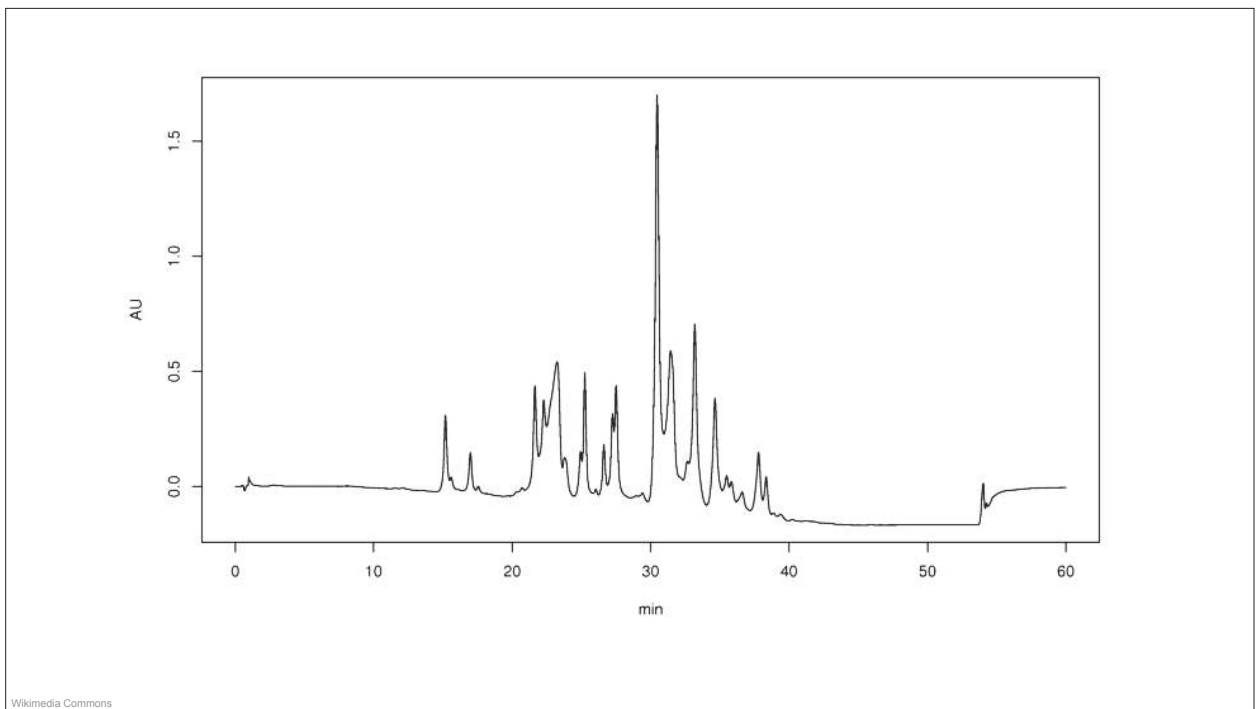
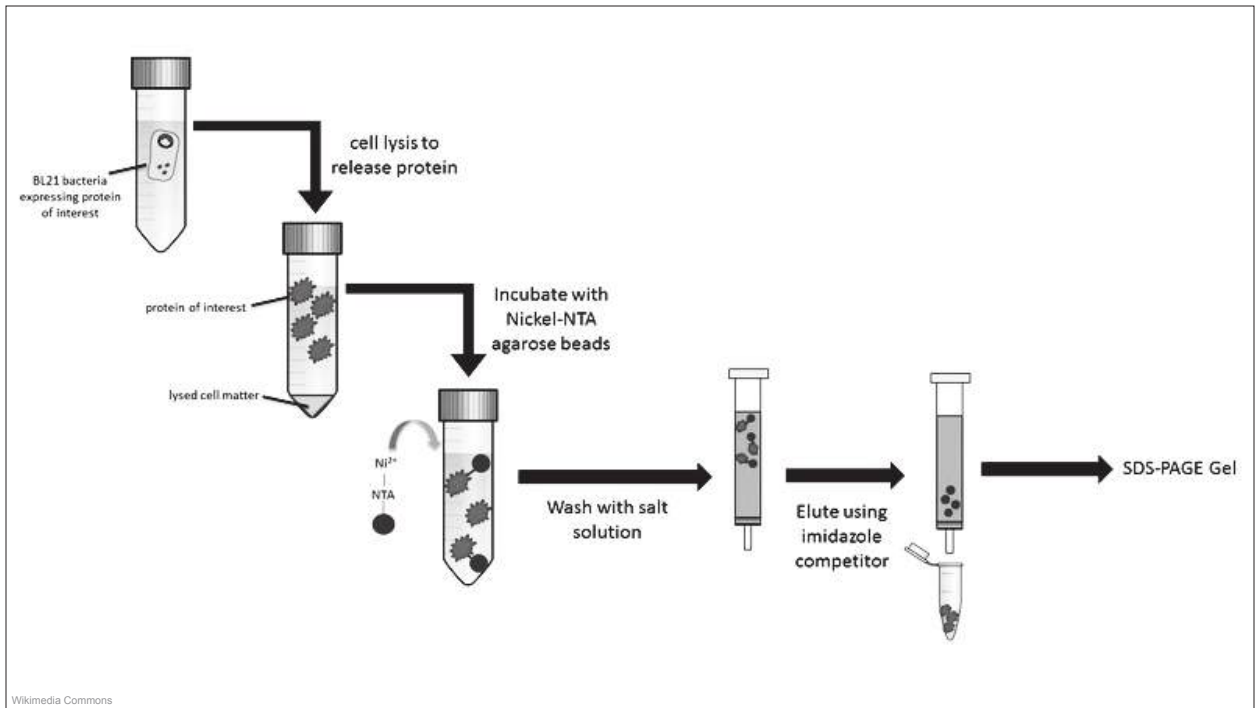


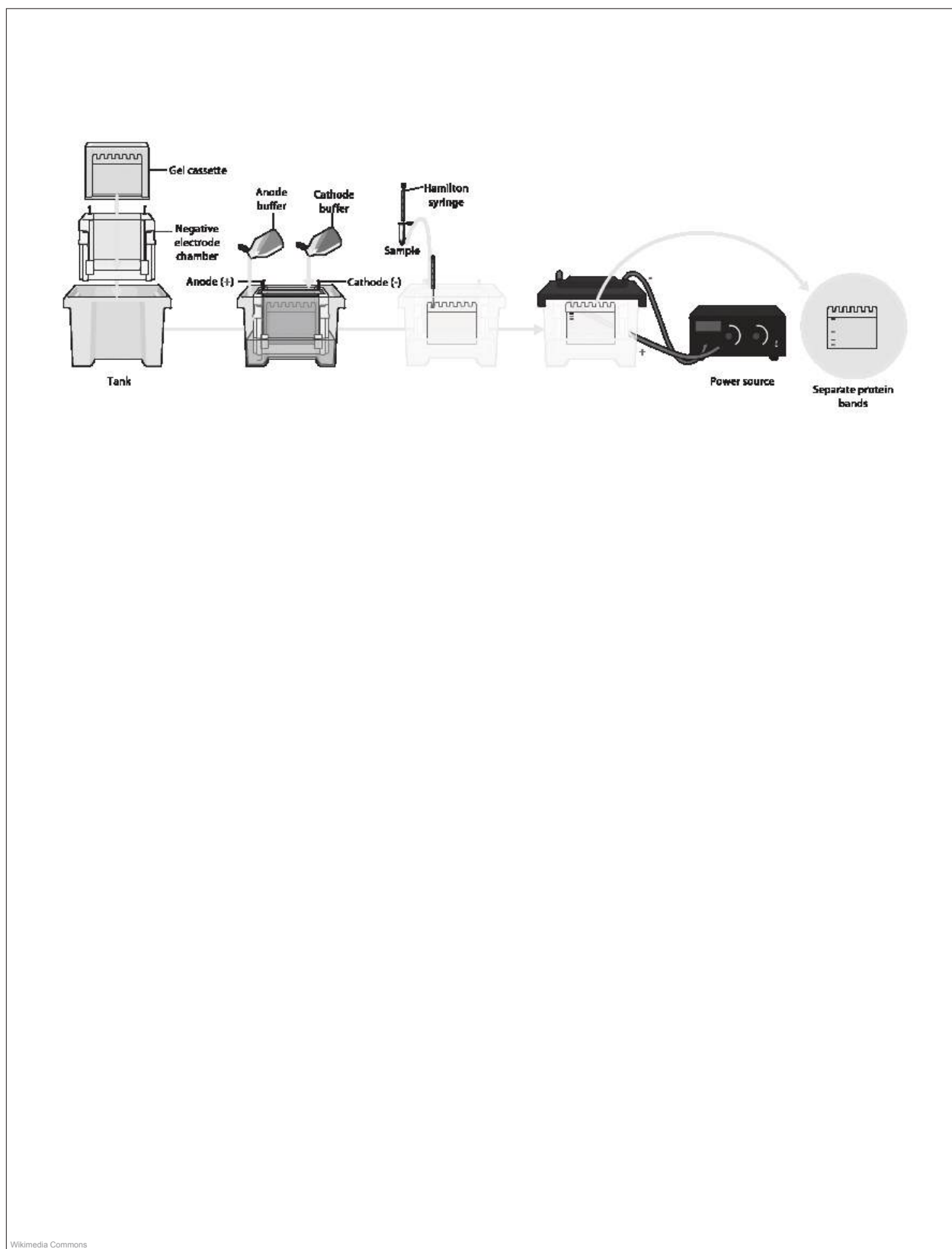
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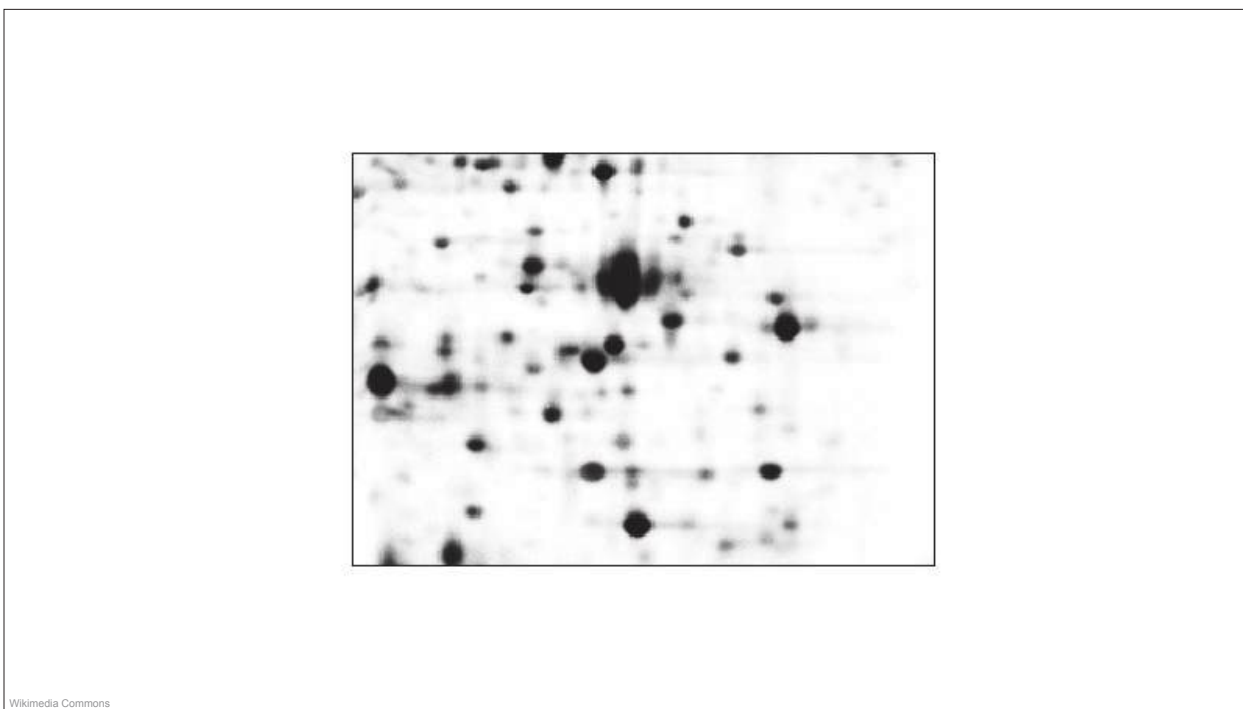
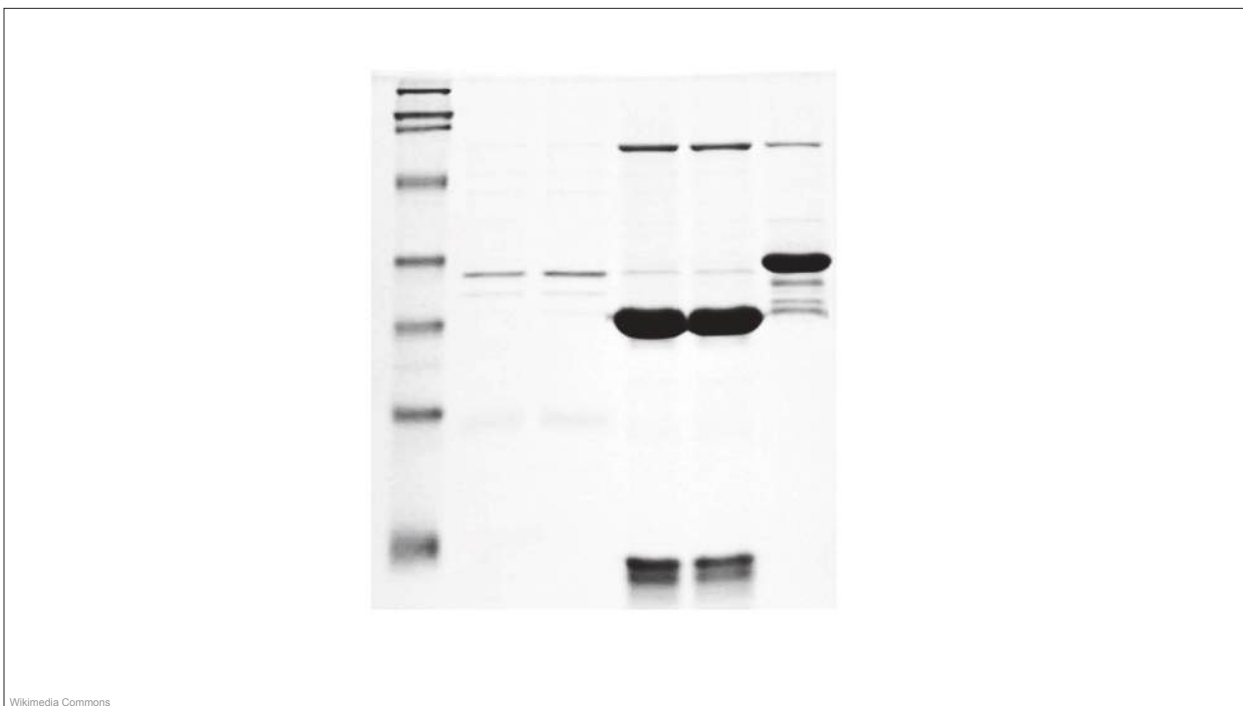


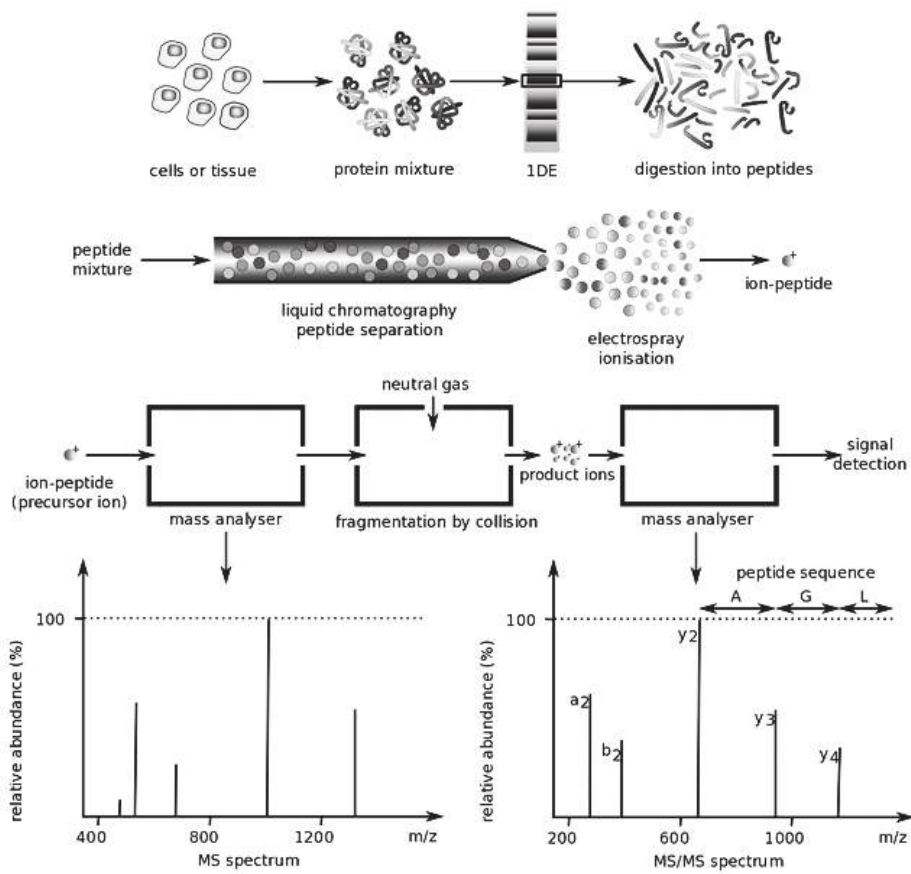
The demonstration of the steps in Affinity Chromatography

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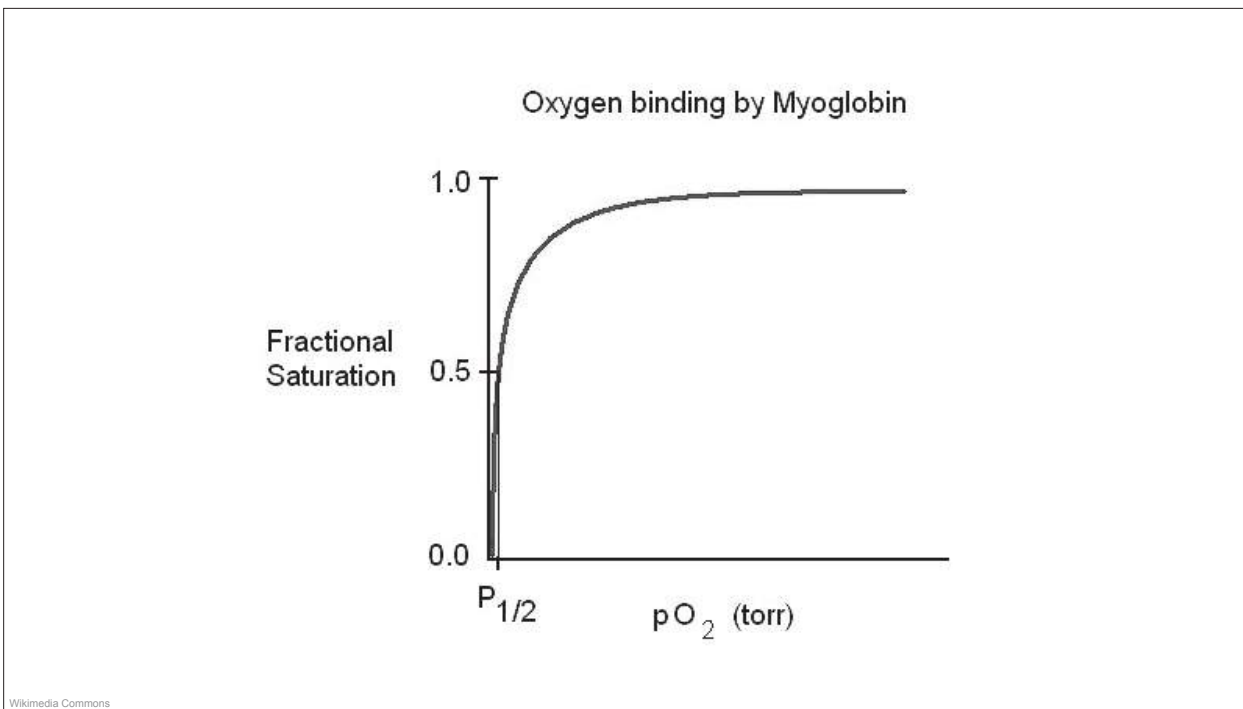
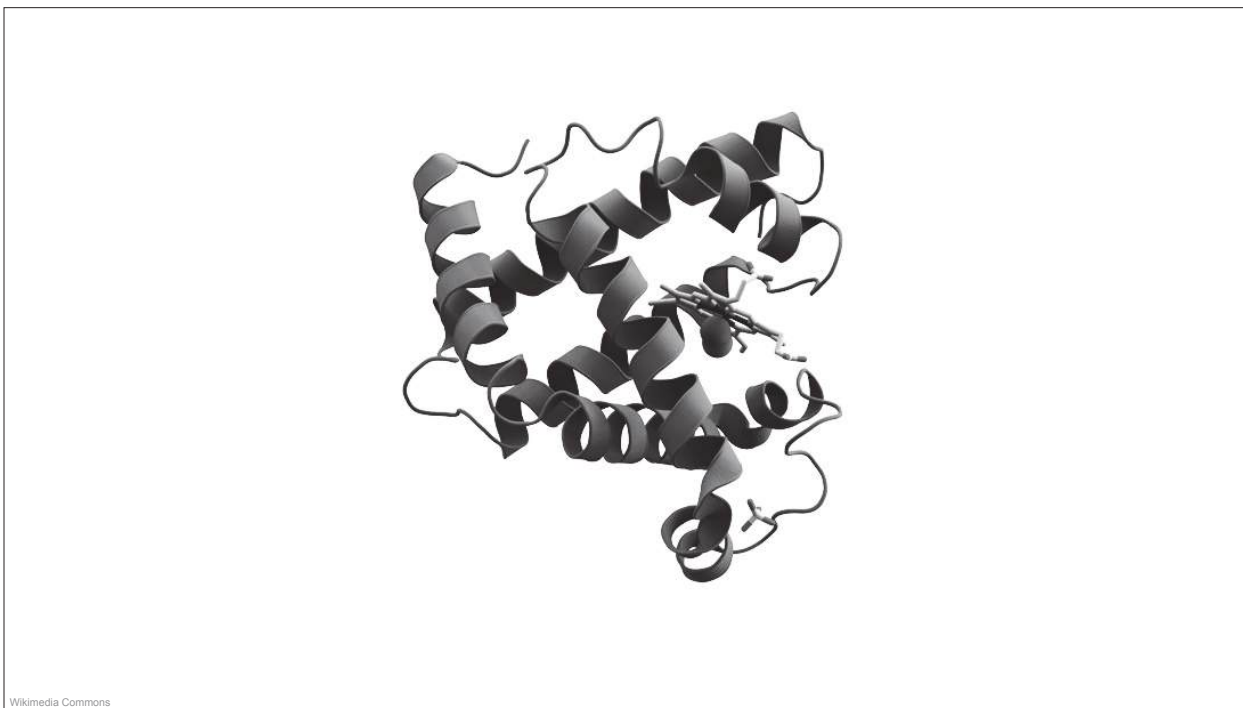




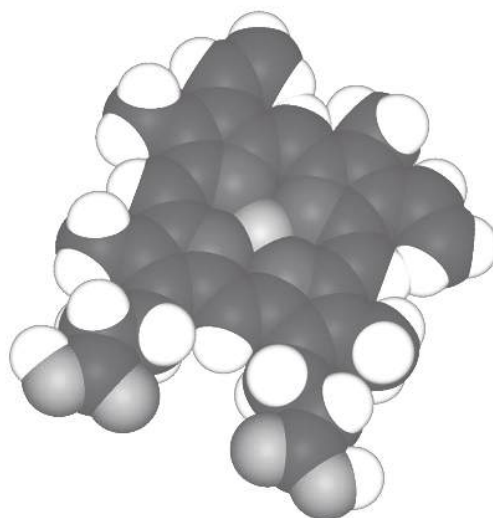




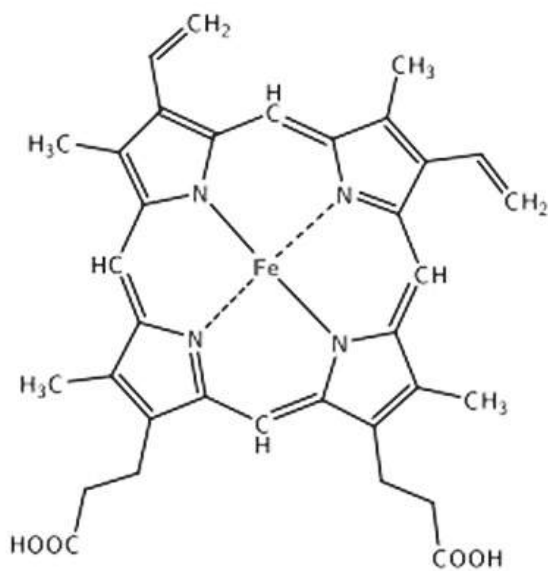
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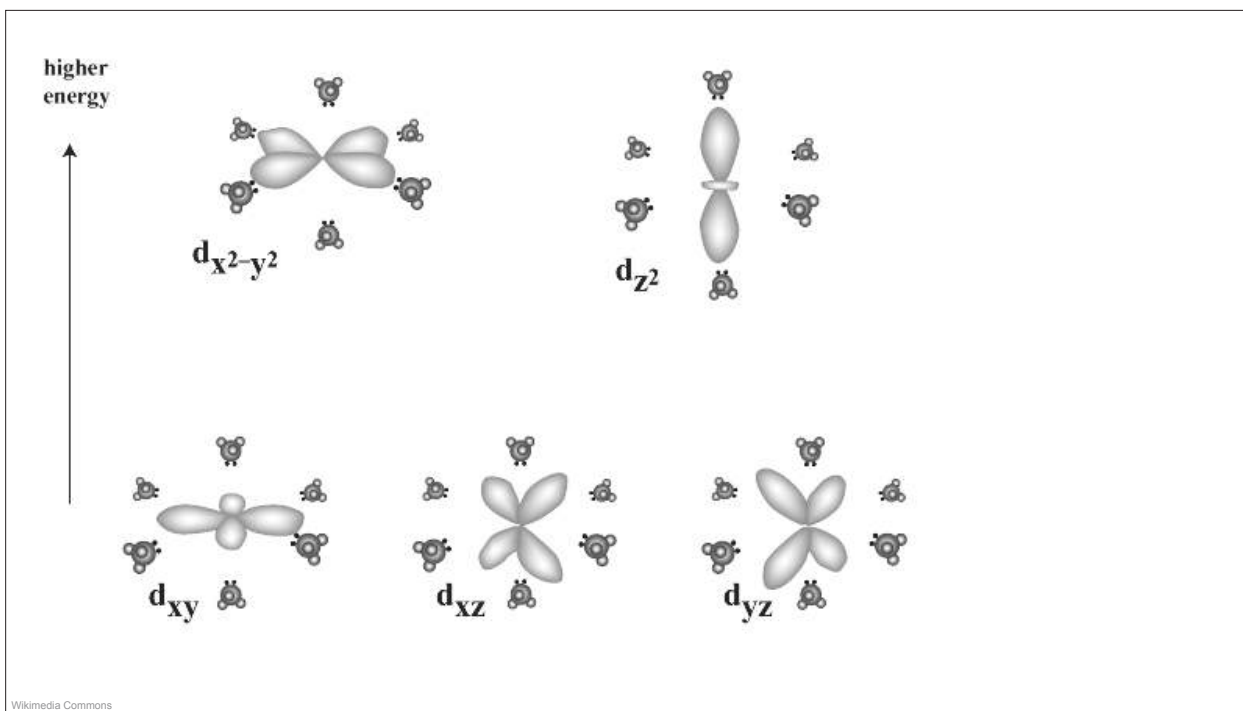
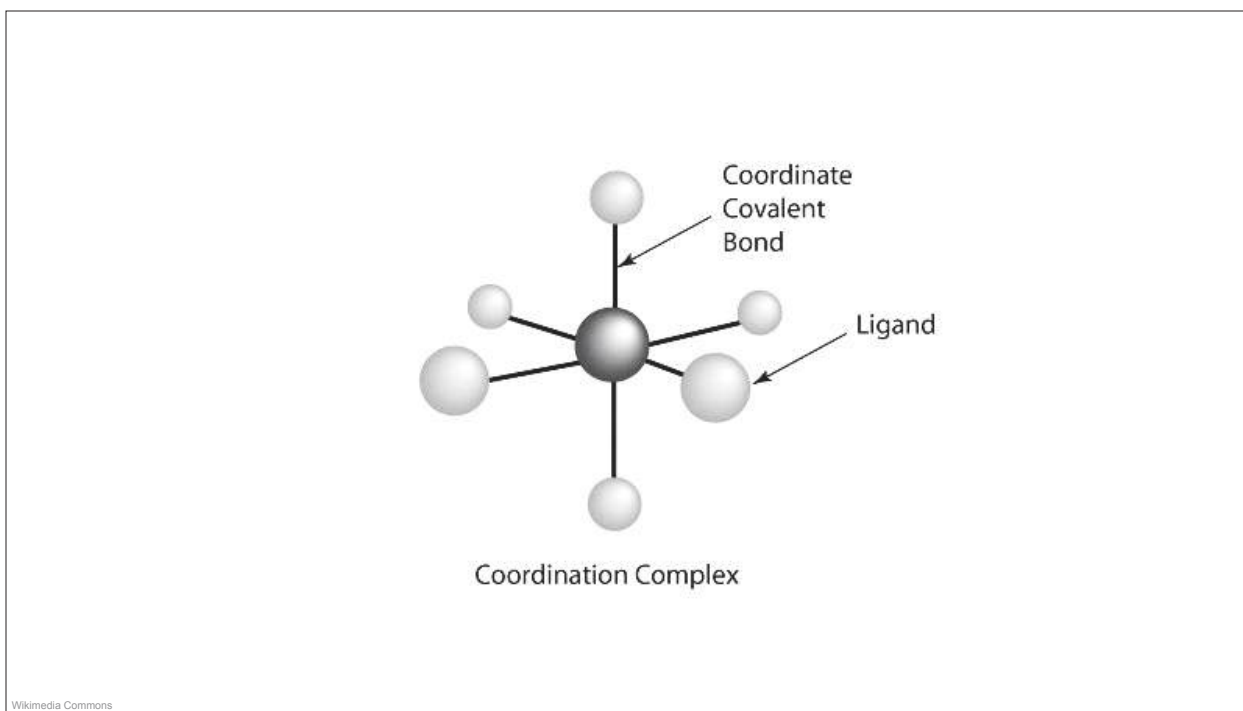
Hemoglobin (& Coordination Chemistry)



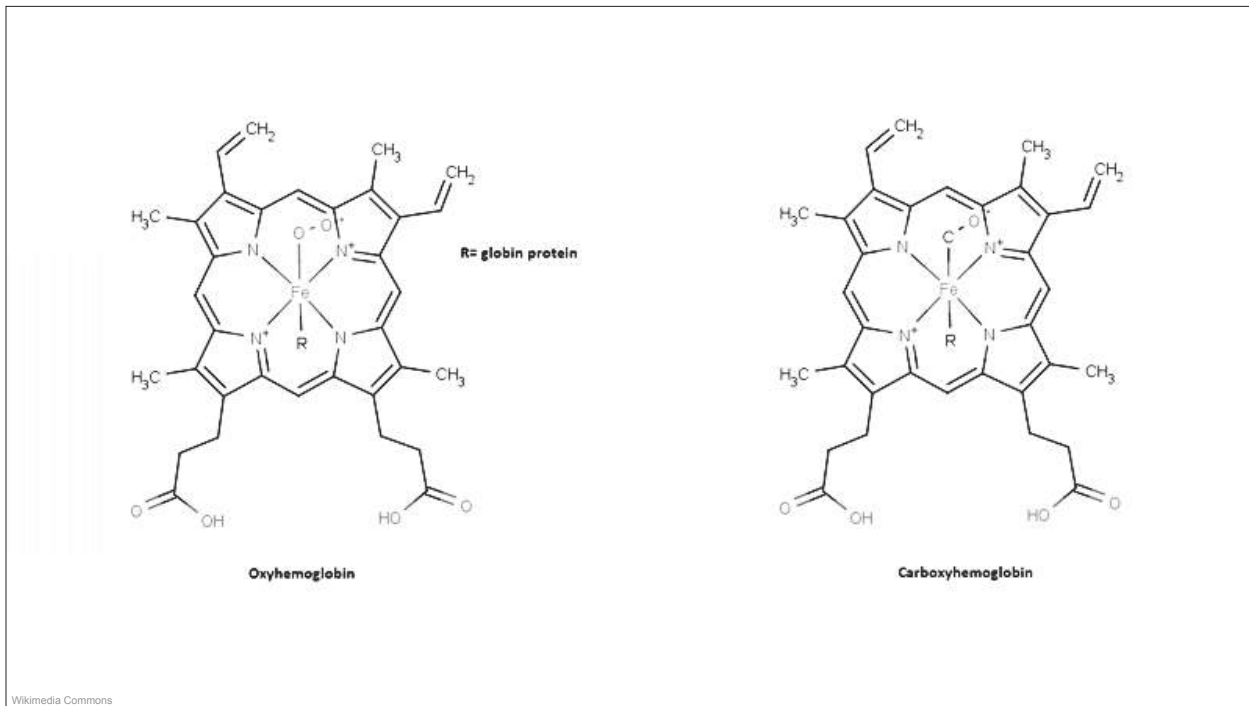
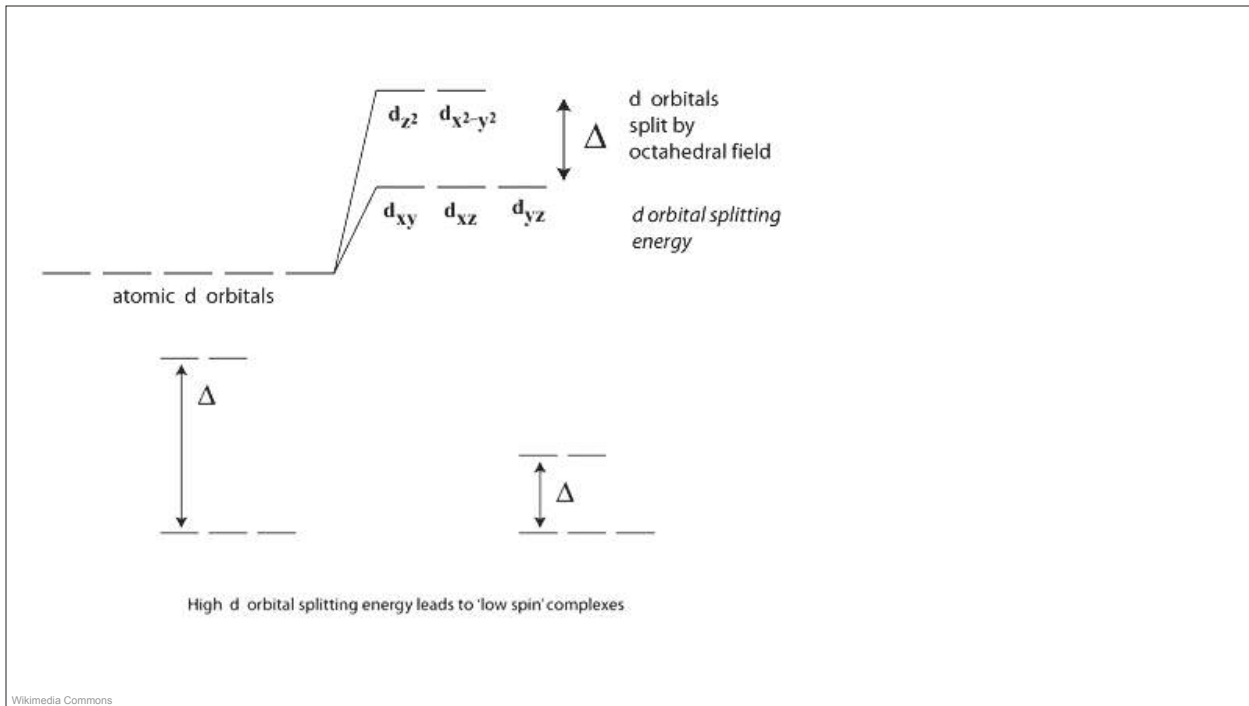
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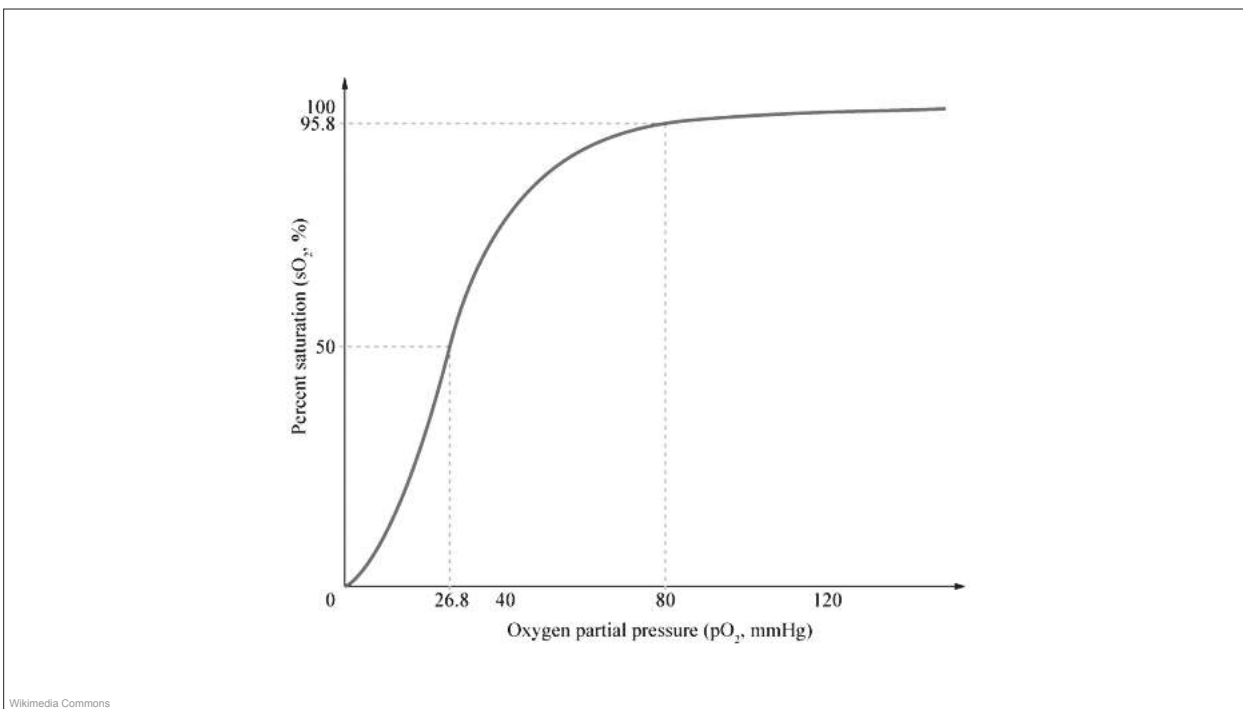
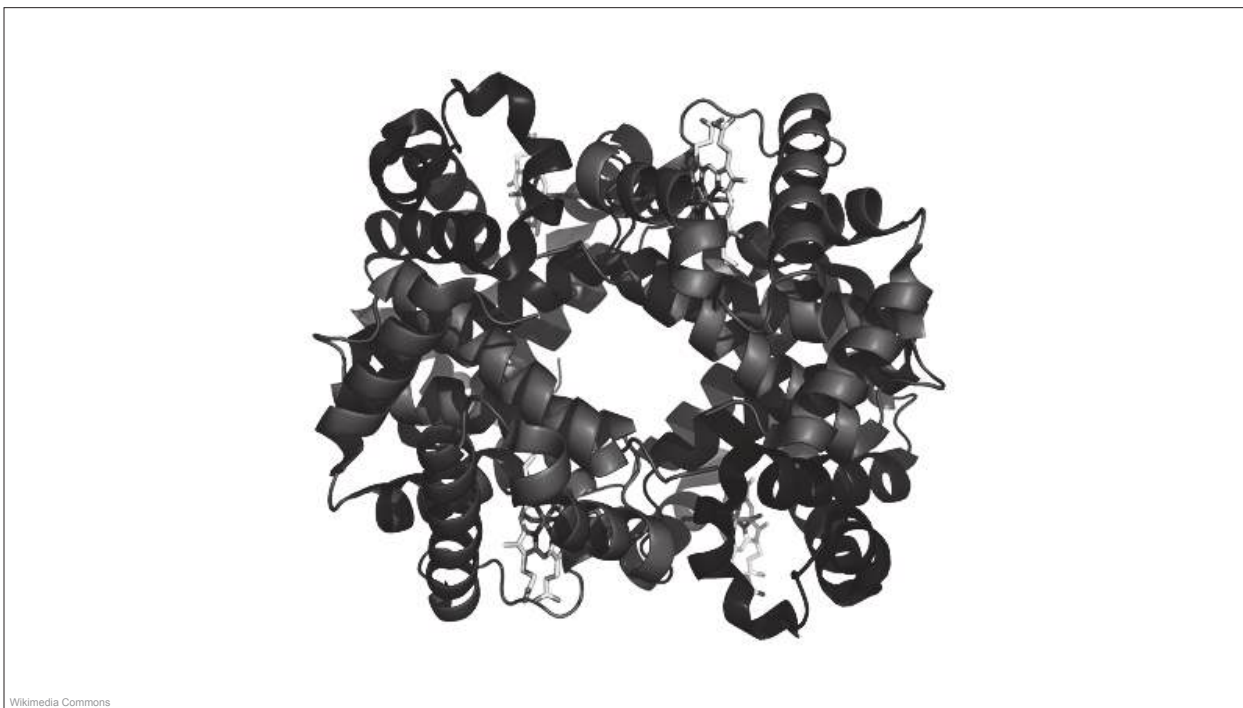


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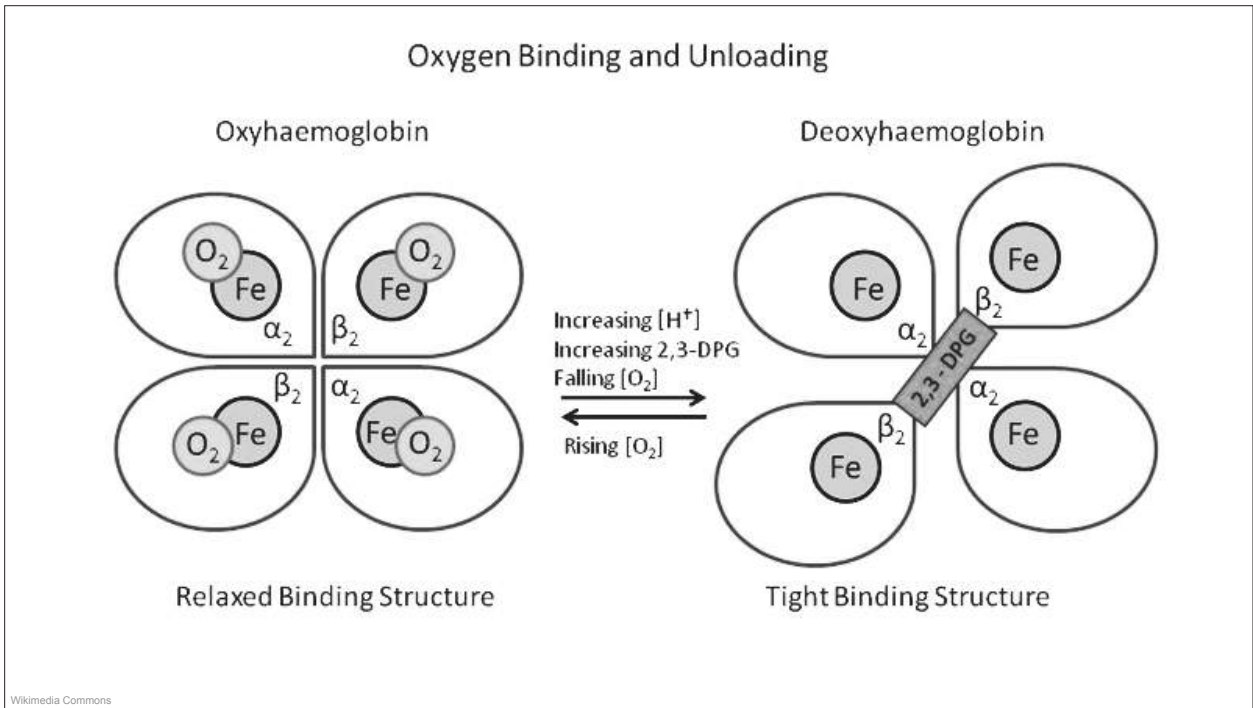
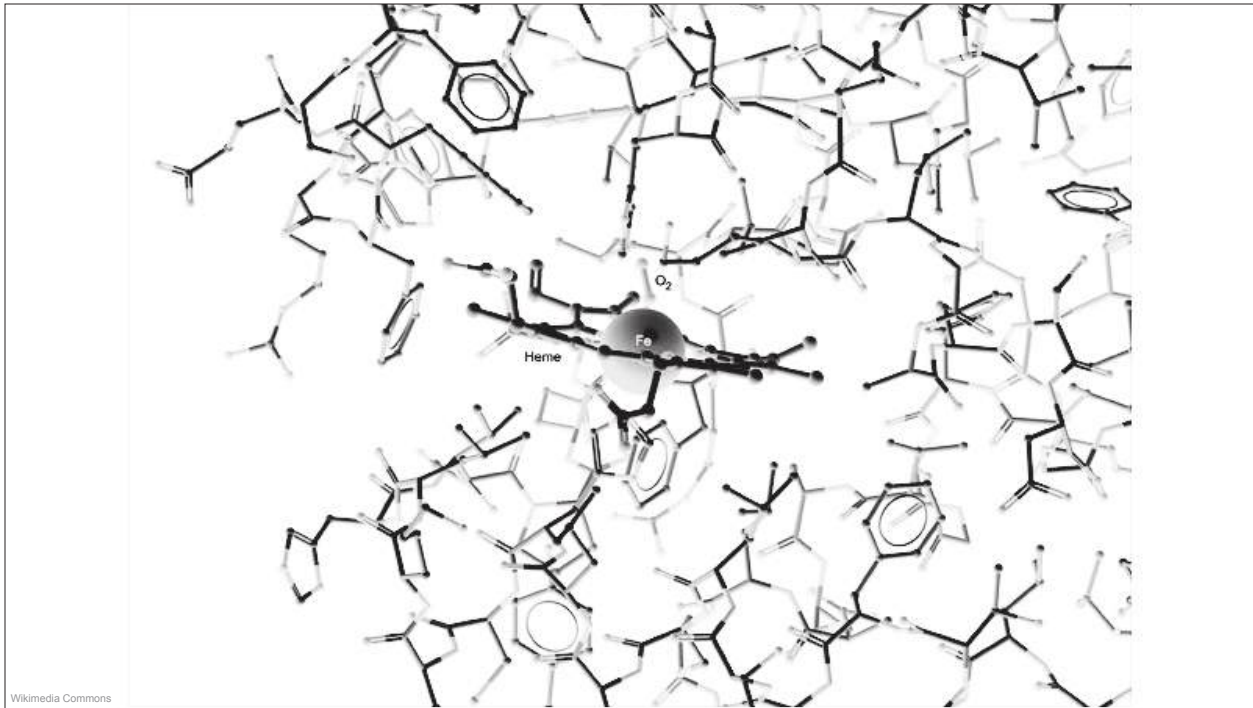


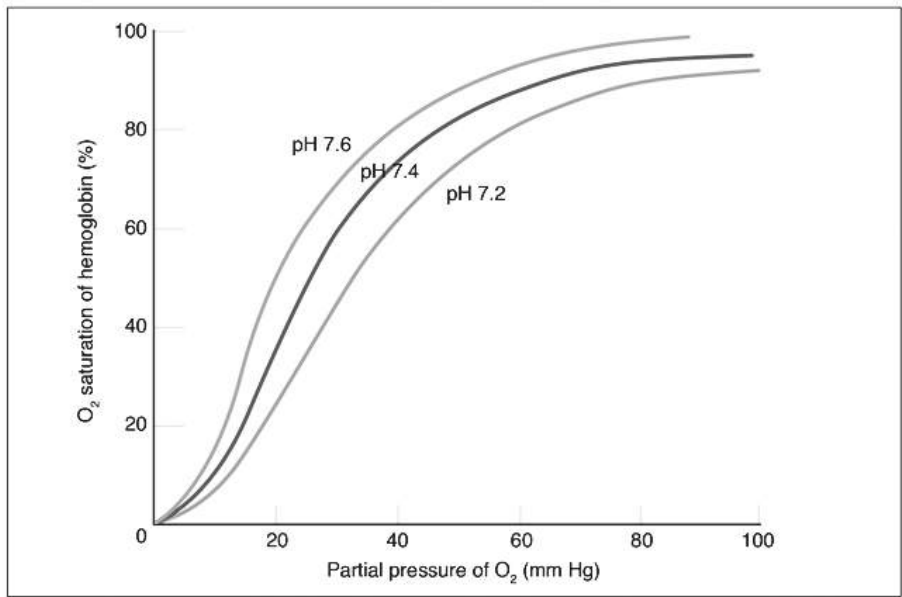
Hemoglobin (& Coordination Chemistry)





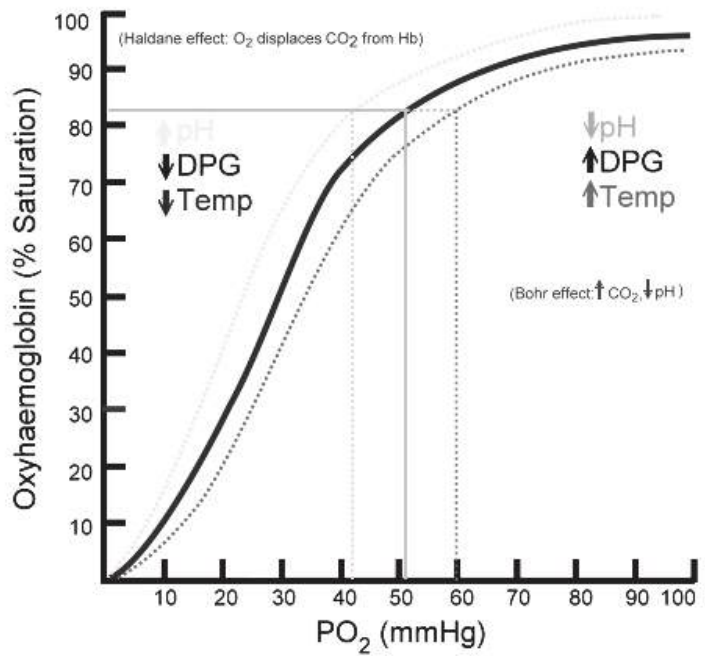
Hemoglobin (& Coordination Chemistry)



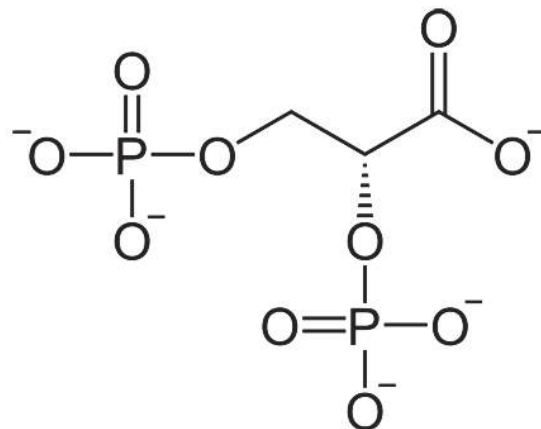


(b) Effect of pH

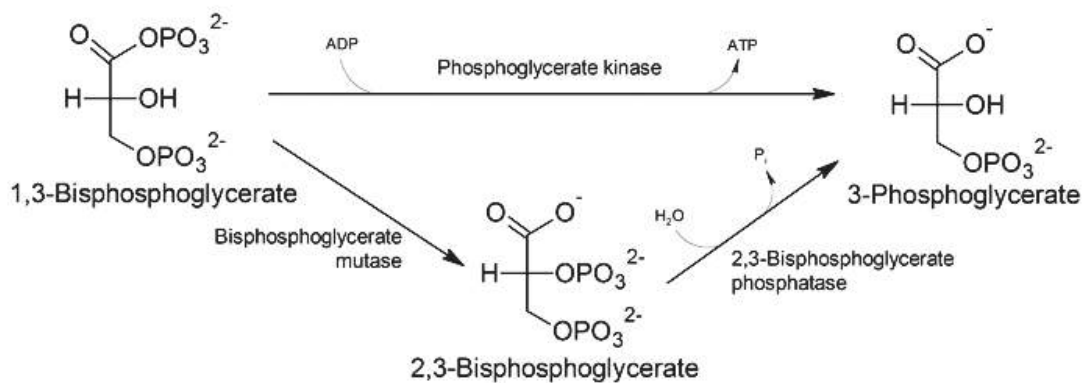
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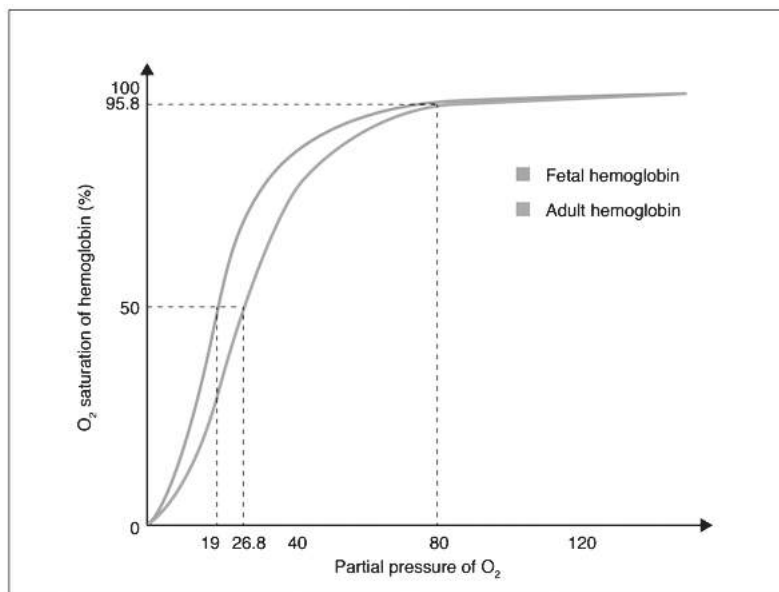
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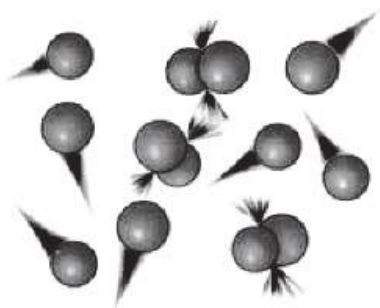
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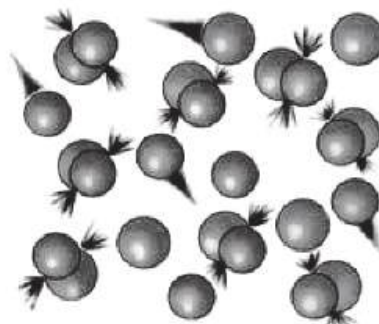
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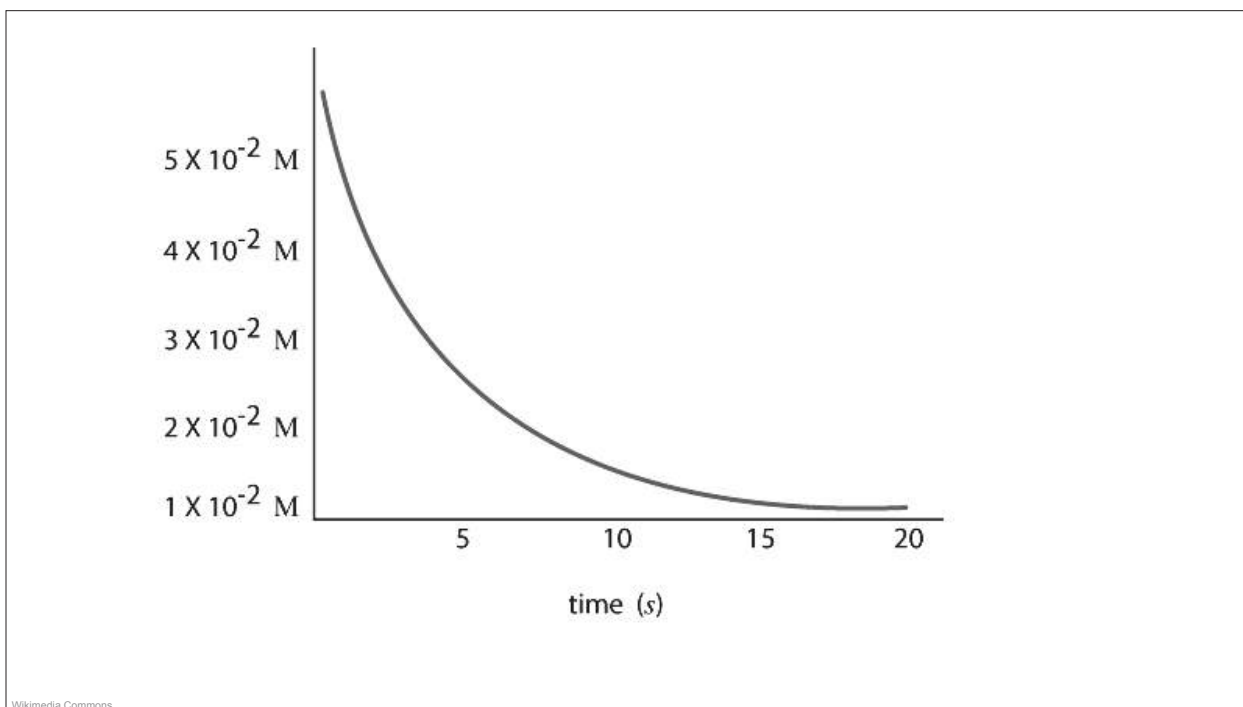


Low concentration = Few collisions



High concentration = More collisions

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$$\text{Rate} = \frac{\text{concentration change}}{\text{time interval}}$$

$$v = \frac{-1}{n_a} \frac{\Delta[A]}{\Delta t} = \frac{-1}{n_b} \frac{\Delta[B]}{\Delta t} = \frac{1}{n_p} \frac{\Delta[P]}{\Delta t} = \frac{1}{n_q} \frac{\Delta[Q]}{\Delta t}$$

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$$v = \frac{-1}{n_a} \frac{\Delta[A]}{\Delta t} = \frac{-1}{n_b} \frac{\Delta[B]}{\Delta t} = \frac{1}{n_p} \frac{\Delta[P]}{\Delta t} = \frac{1}{n_q} \frac{\Delta[Q]}{\Delta t}$$

$$v = k f([A], [B], \dots)$$

$$v = k [A]^a [B]^b$$

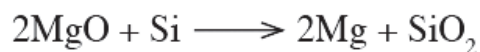
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$$\frac{\Delta[\text{I}_2]}{\Delta t} = k [\text{HI}]^2$$

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Choose the correct rate expression for the reaction below



- A. rate = $k [\text{MgO}] [\text{Si}]$
- B. rate = $k [\text{MgO}]^2 [\text{Si}]$
- C. rate = $2k [\text{MgO}][\text{Si}]$
- D. impossible to determine from given information

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If the reaction rate is quadrupled by doubling the concentration of a reactant, the order of the reaction with respect to that reactant is

- A. 1
- B. 2
- C. 4
- D. cannot be determined except by experiment

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$$\text{Rate} = k [\text{CH}_3\text{CH}_2\text{Br}] [\text{NaOCH}_3]$$

Total order: 2



$$\text{Rate} = k [\text{CH}_3\text{CHBrCH}_3]$$

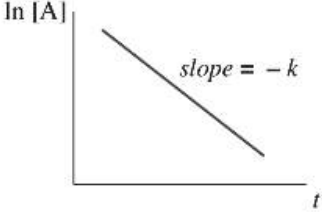
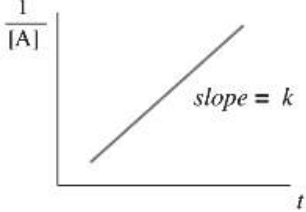
Total order: 1

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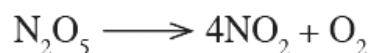
Experiment	1	2	3	4
[A]	0.5 M	1.0 M	1.0 M	0.5 M
[B]	0.5 M	0.5 M	1.0 M	0.5 M
[C]	0.5 M	0.5 M	0.5 M	1.0 M
<i>rate</i>	0.2 M/s	1.6 M/s	1.6 M/s	0.4 M/s

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<i>1st Order</i>	$-\frac{\Delta[A]}{\Delta t} = k[A]$ $[A] = [A]_0 e^{(-k t)}$ $\ln [A] = \ln[A]_0 - k t$		$t_{\text{half life}} = \frac{\ln(2)}{k}$
<i>2nd Order</i>	$-\frac{\Delta[A]}{\Delta t} = k[A]^2$ $\frac{1}{[A]} - \frac{1}{[A]_0} = k t$		$t_{\text{half life}} = \frac{1}{k [A]_0}$

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The decomposition of N_2O_5 in carbon tetrachloride can be represented

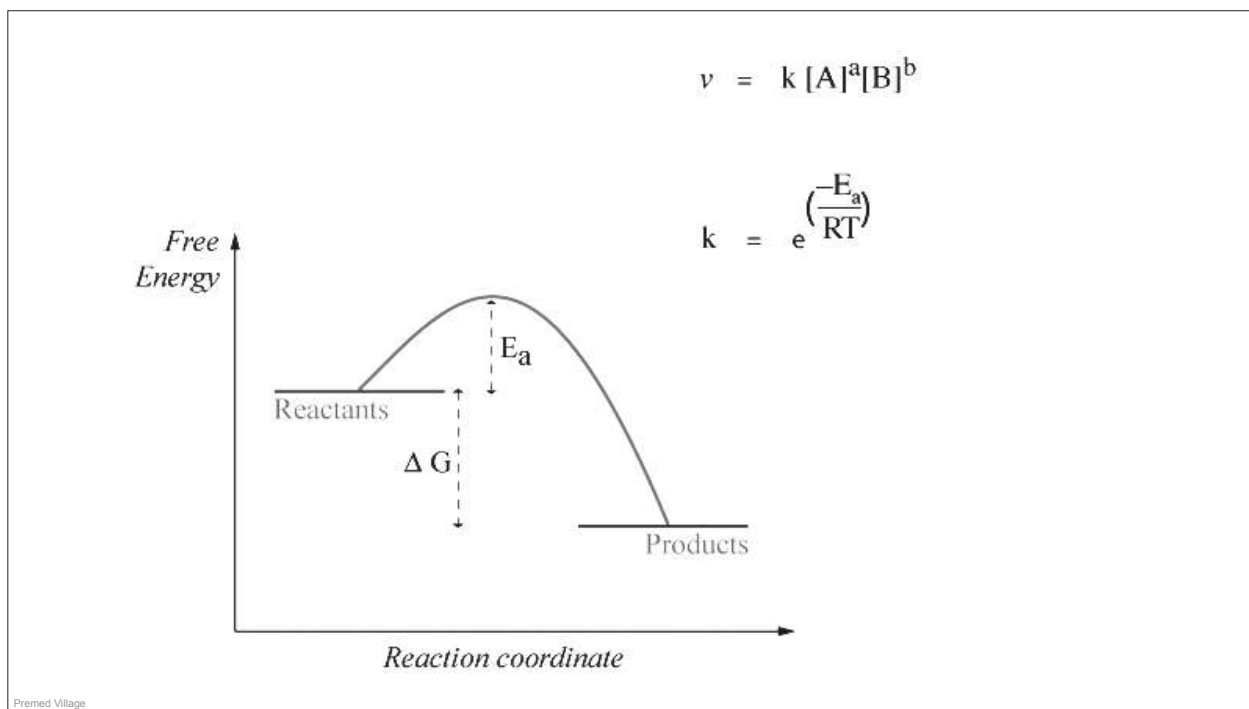
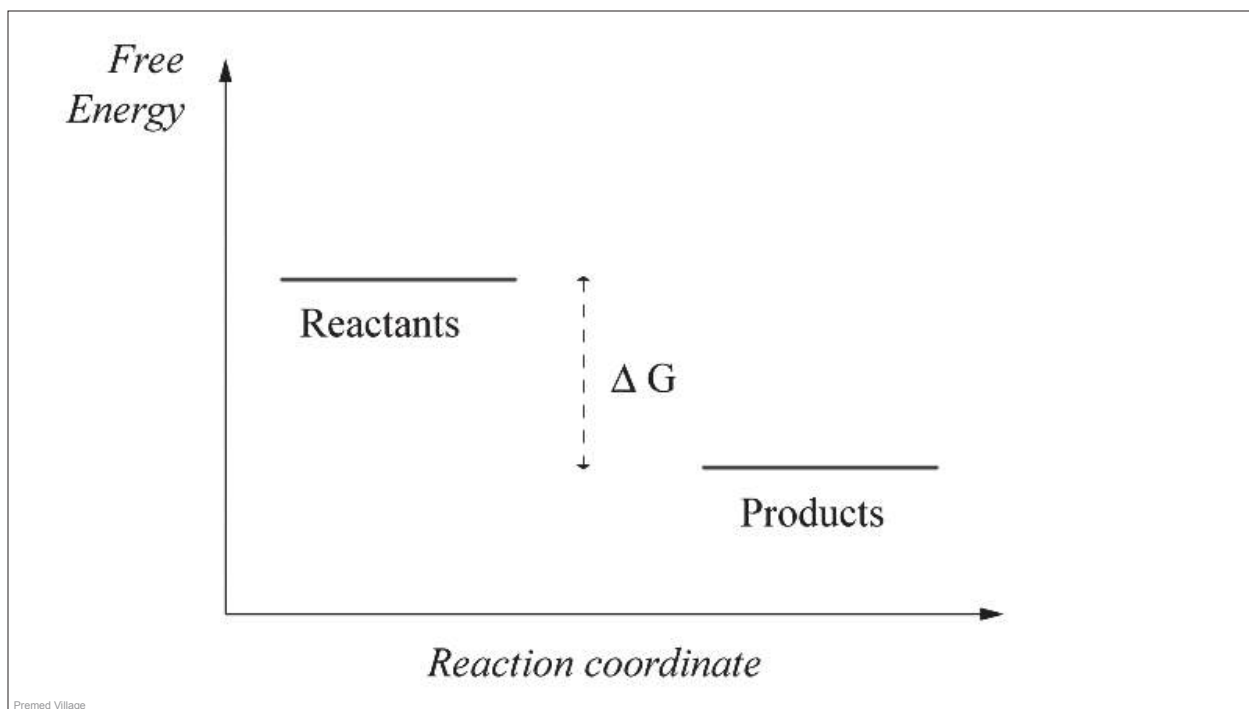


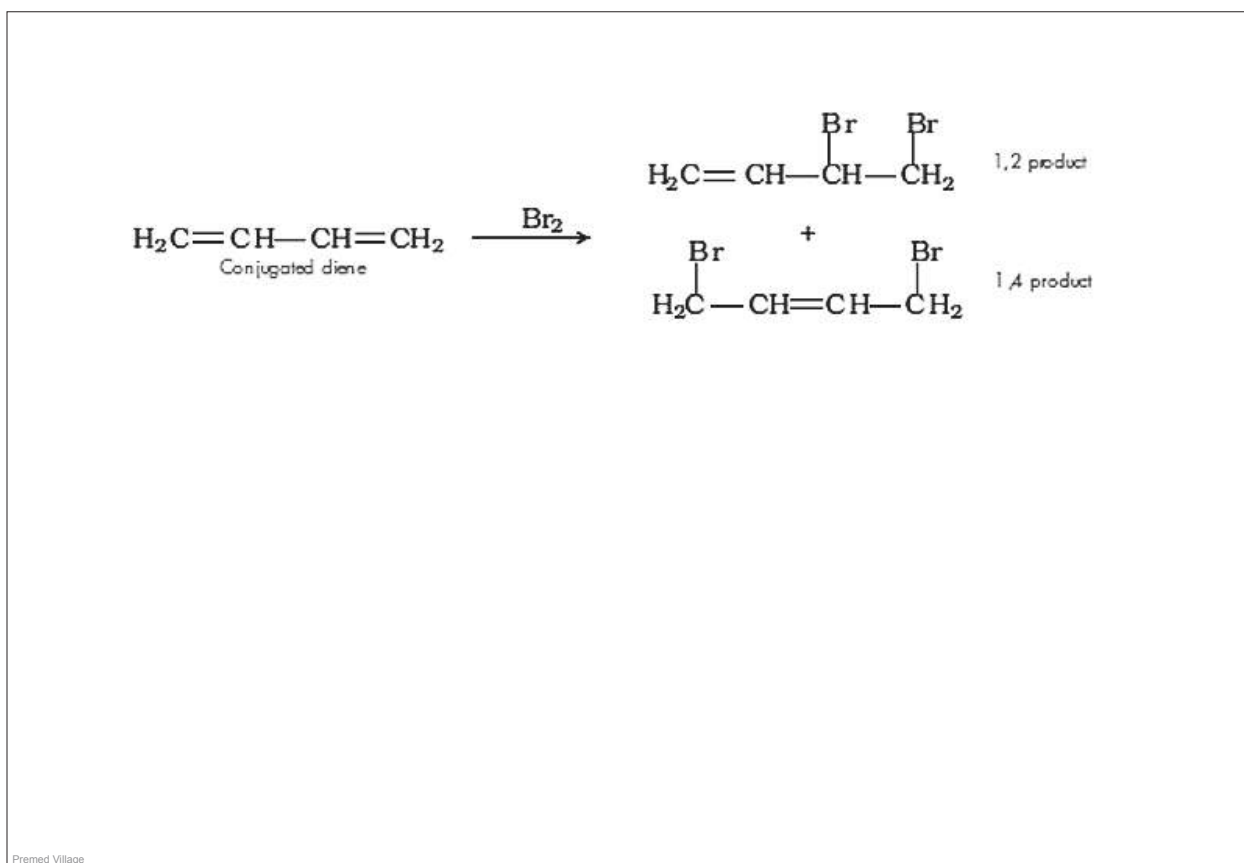
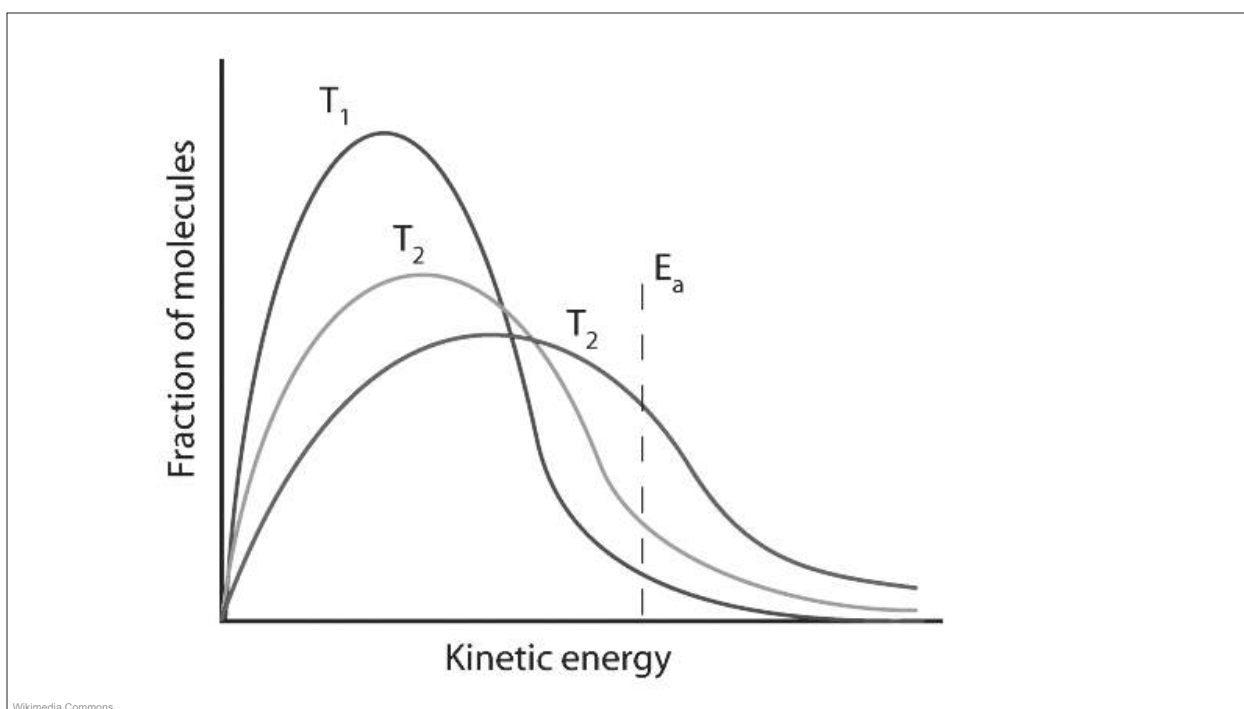
The reaction rate equation was found to be

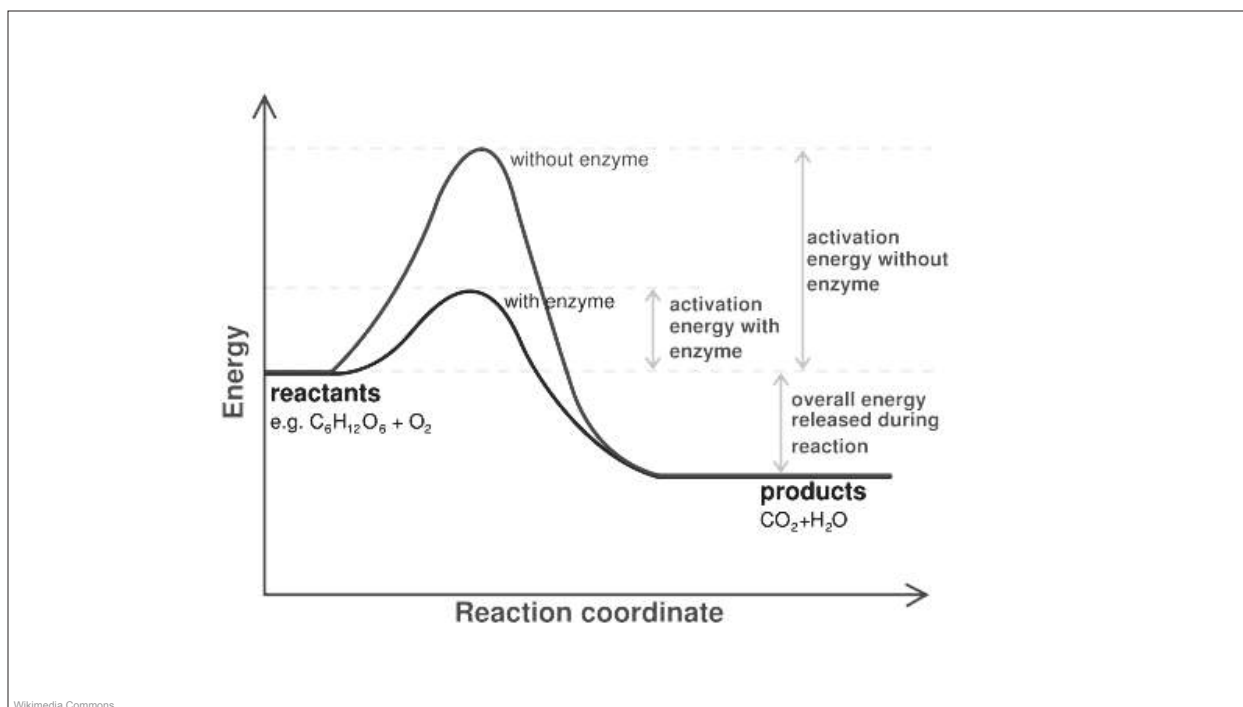
$$\text{rate} = (6.9 \times 10^{-4} \text{ M s}^{-1}) [\text{N}_2\text{O}_5]$$

If we begin with 30 g of N_2O_5 in solution, approximately how much time elapses before only 1 g remains?

- A.** $5.0 \times 10^3 \text{ s}$
- B.** $4.0 \times 10^4 \text{ s}$
- C.** $2.0 \times 10^4 \text{ s}$
- D.** $1.4 \times 10^4 \text{ s}$

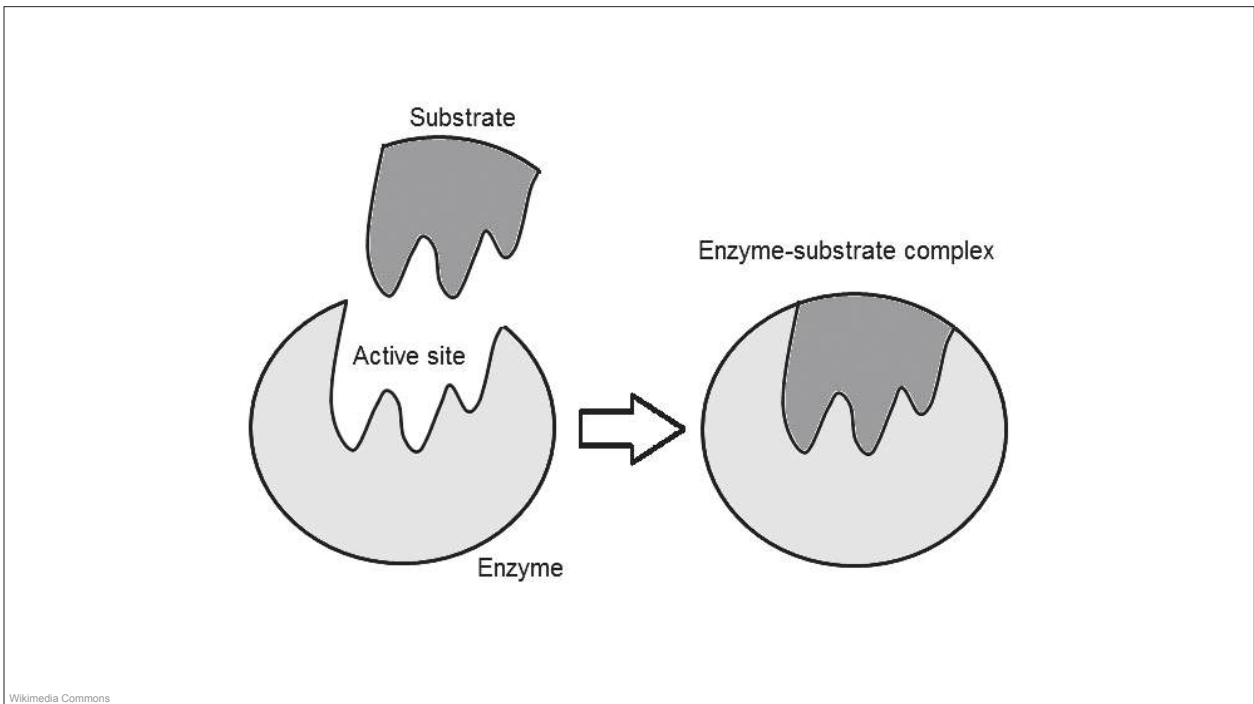
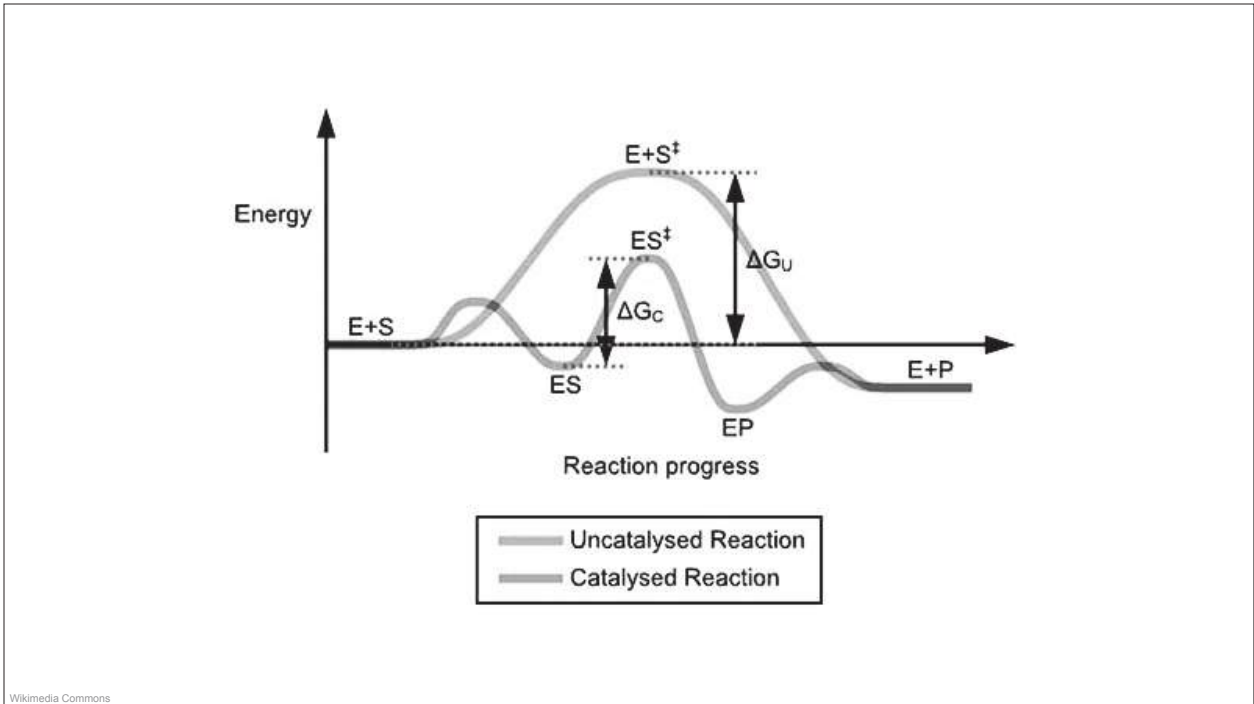




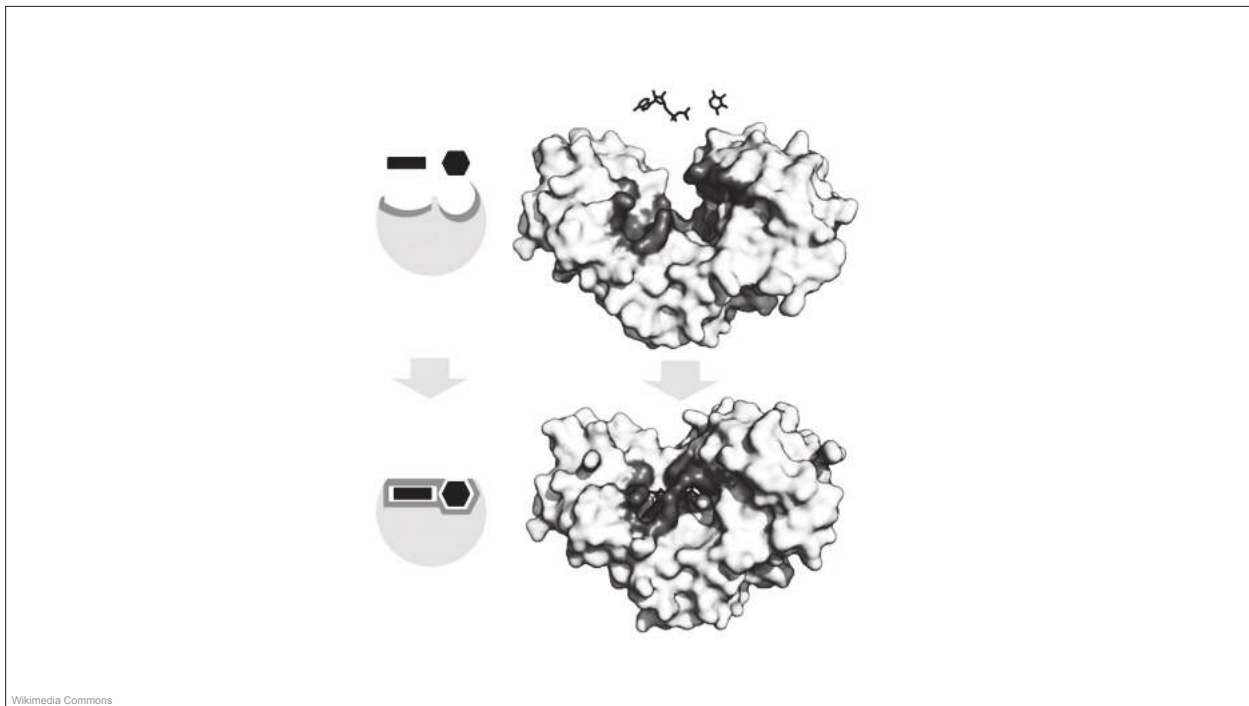
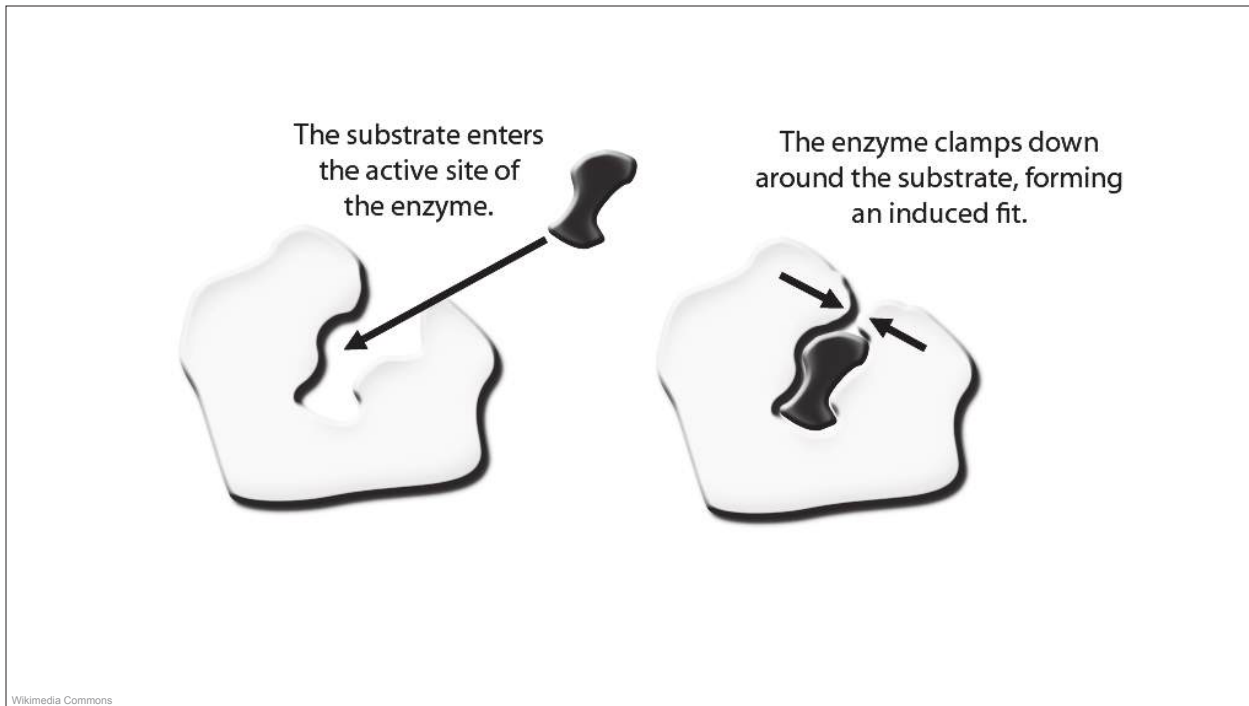


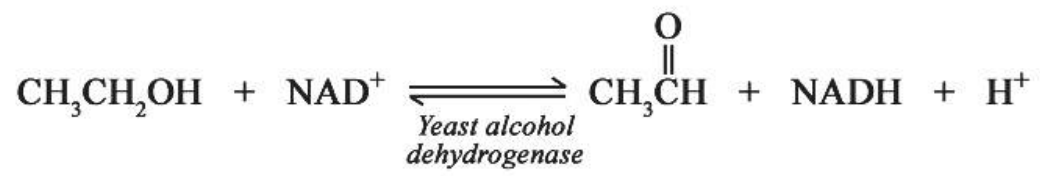
In the presence of a catalyst

- I. Effective collisions among reactant molecules become more likely to occur.
 - II. Chemical equilibrium will shift toward the products.
 - III. The activation energy for the reaction is lowered.
- A. I
 - B. I and III
 - C. II and III
 - D. I, II, and III

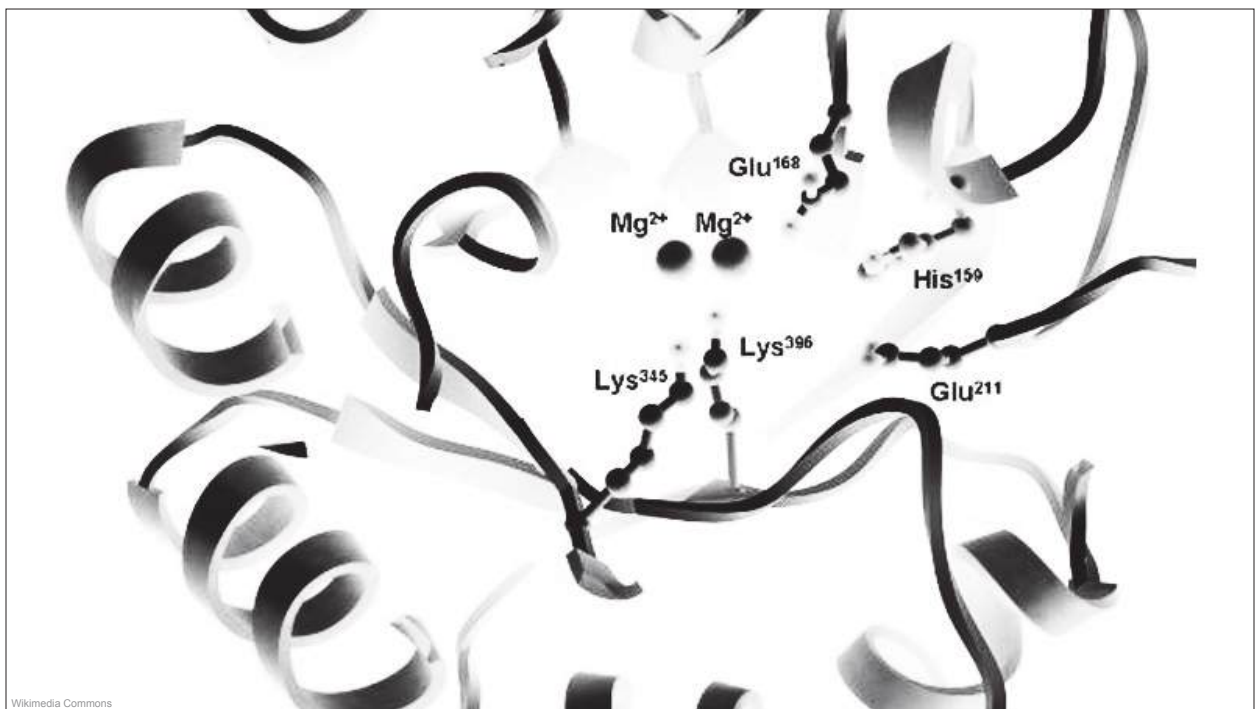


Enzyme Activity



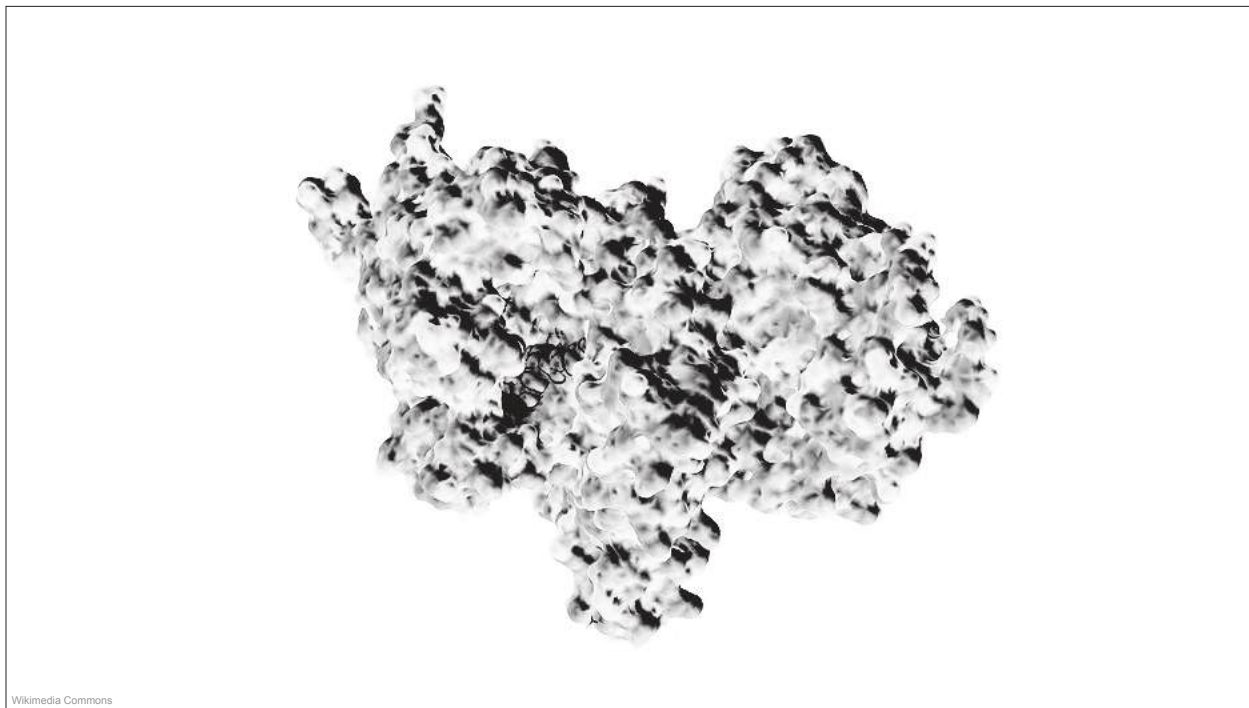
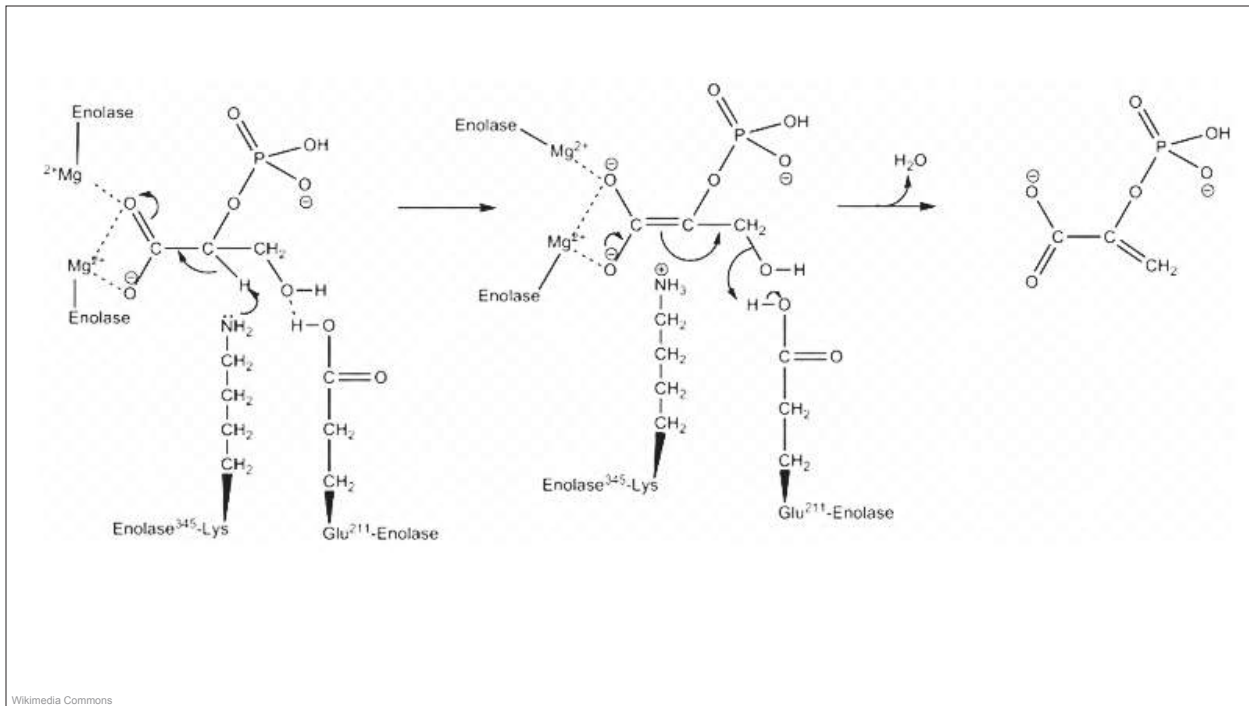


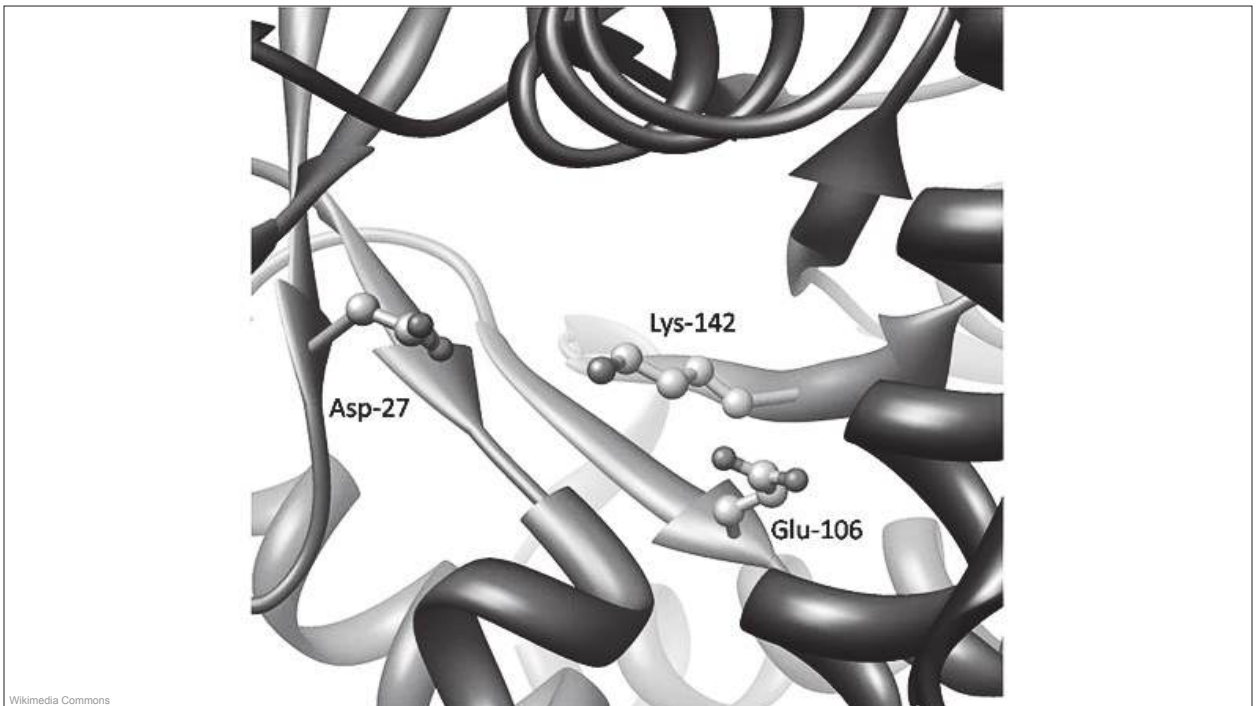
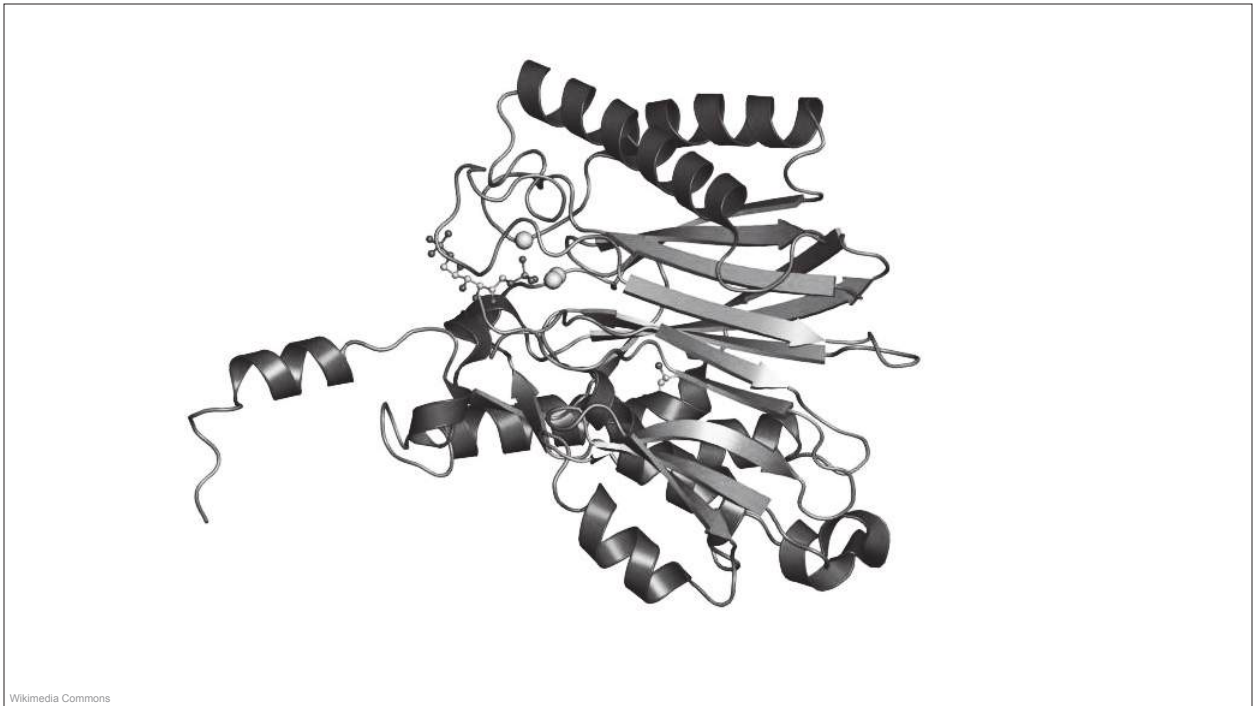
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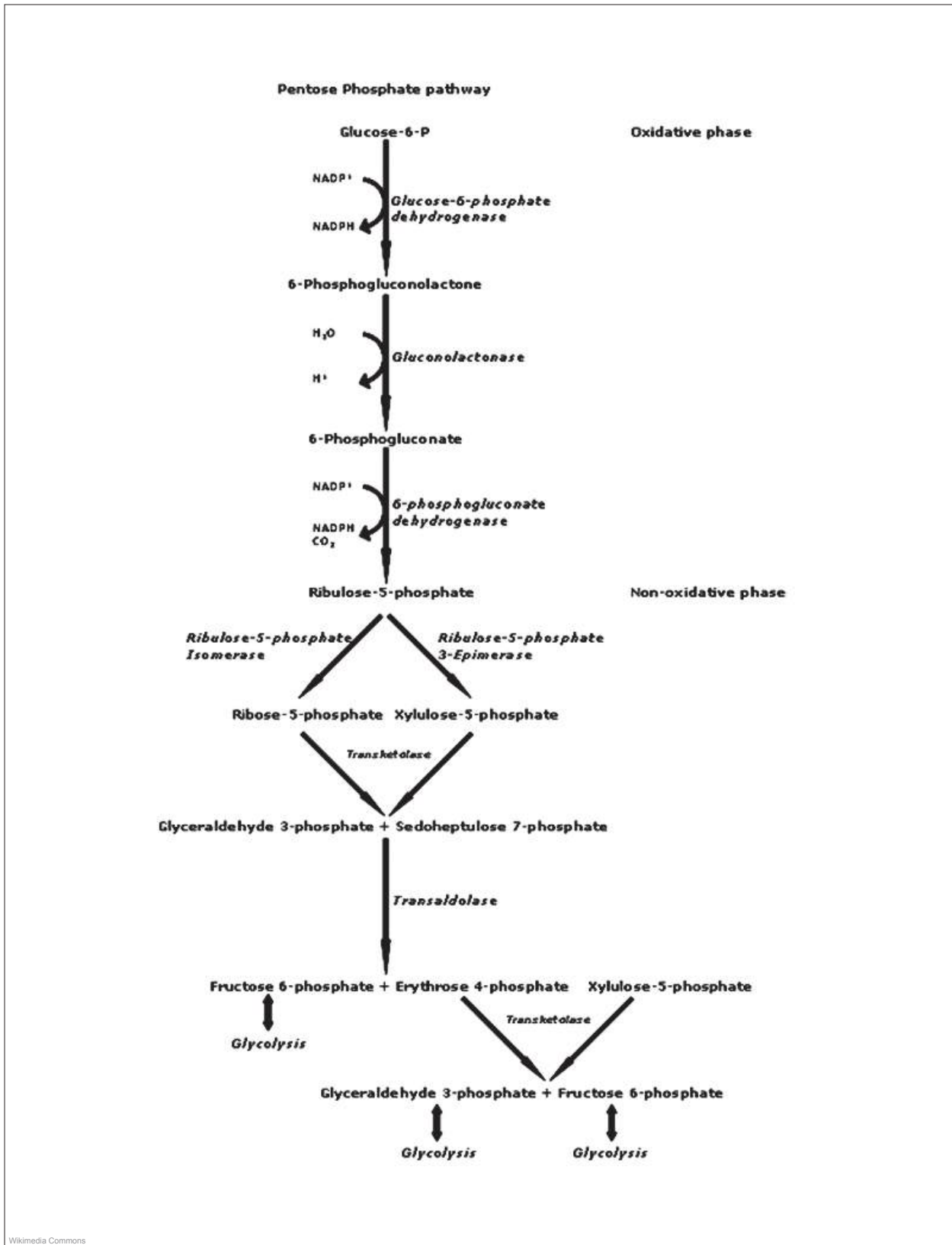


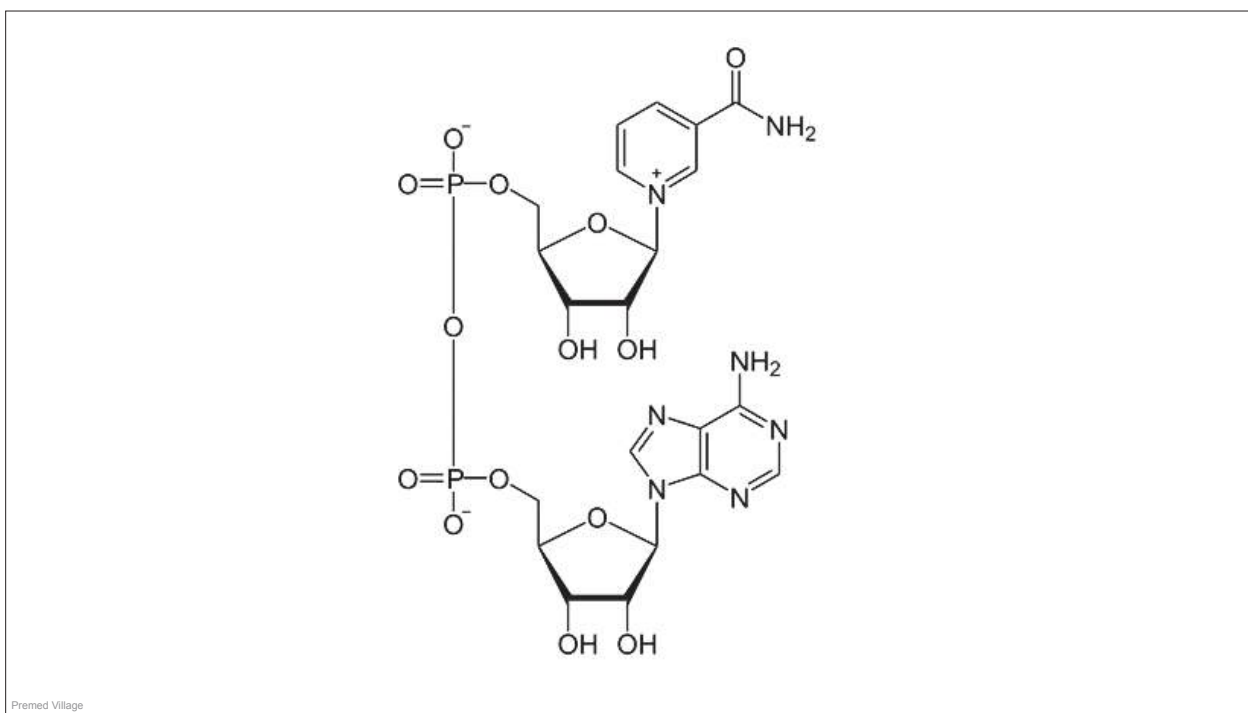
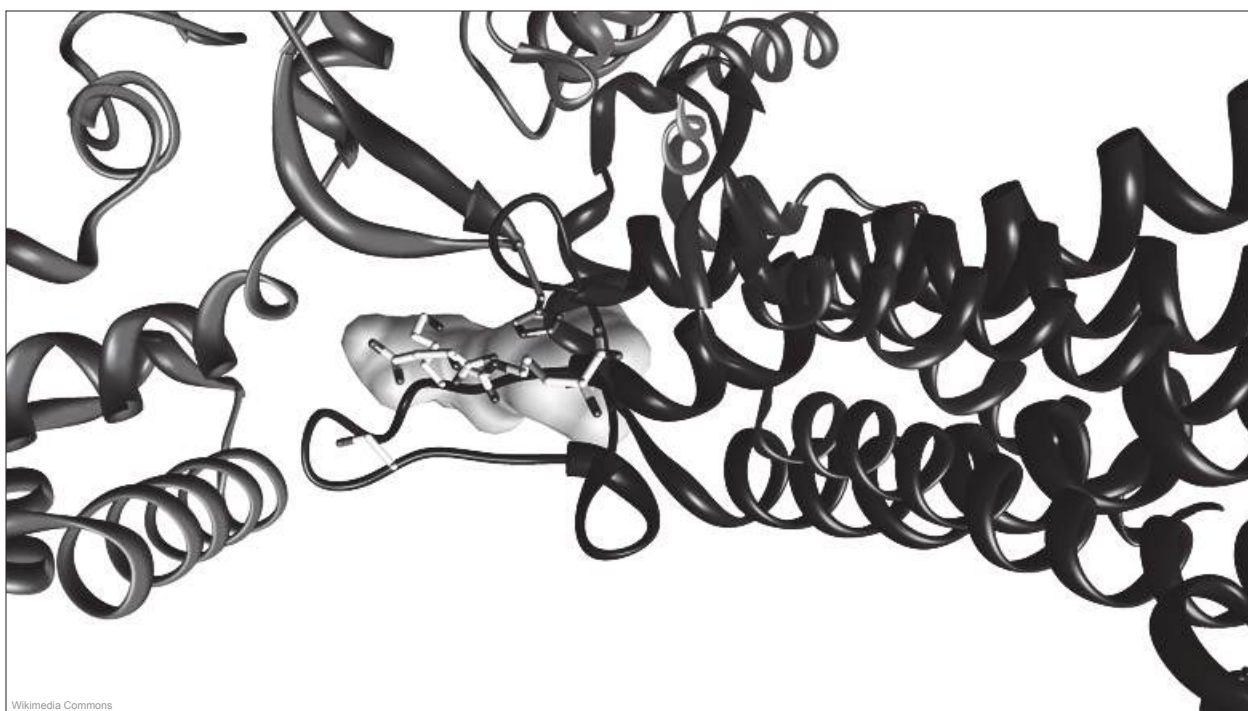
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Enzyme Activity

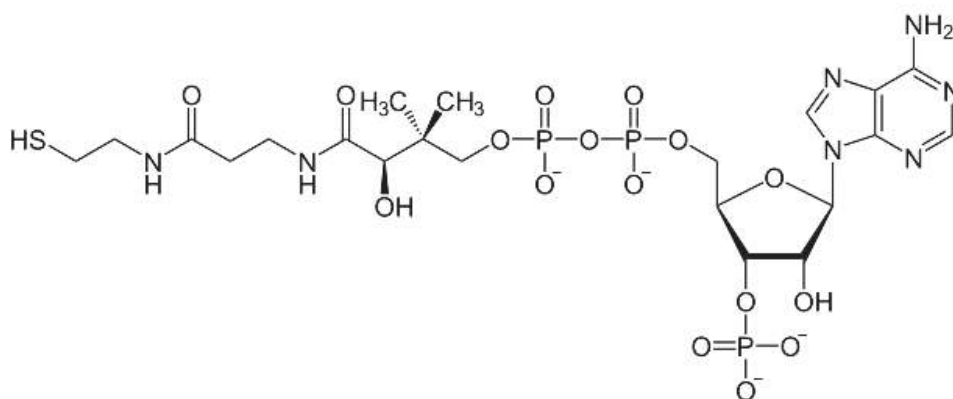




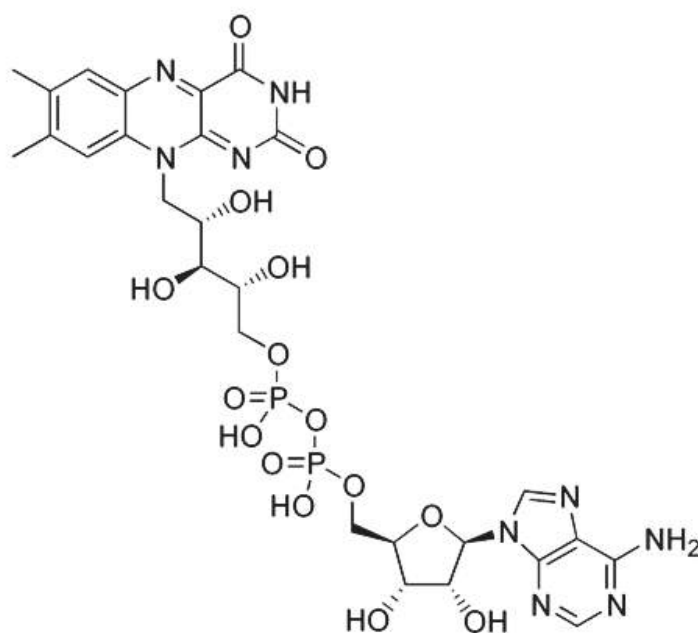




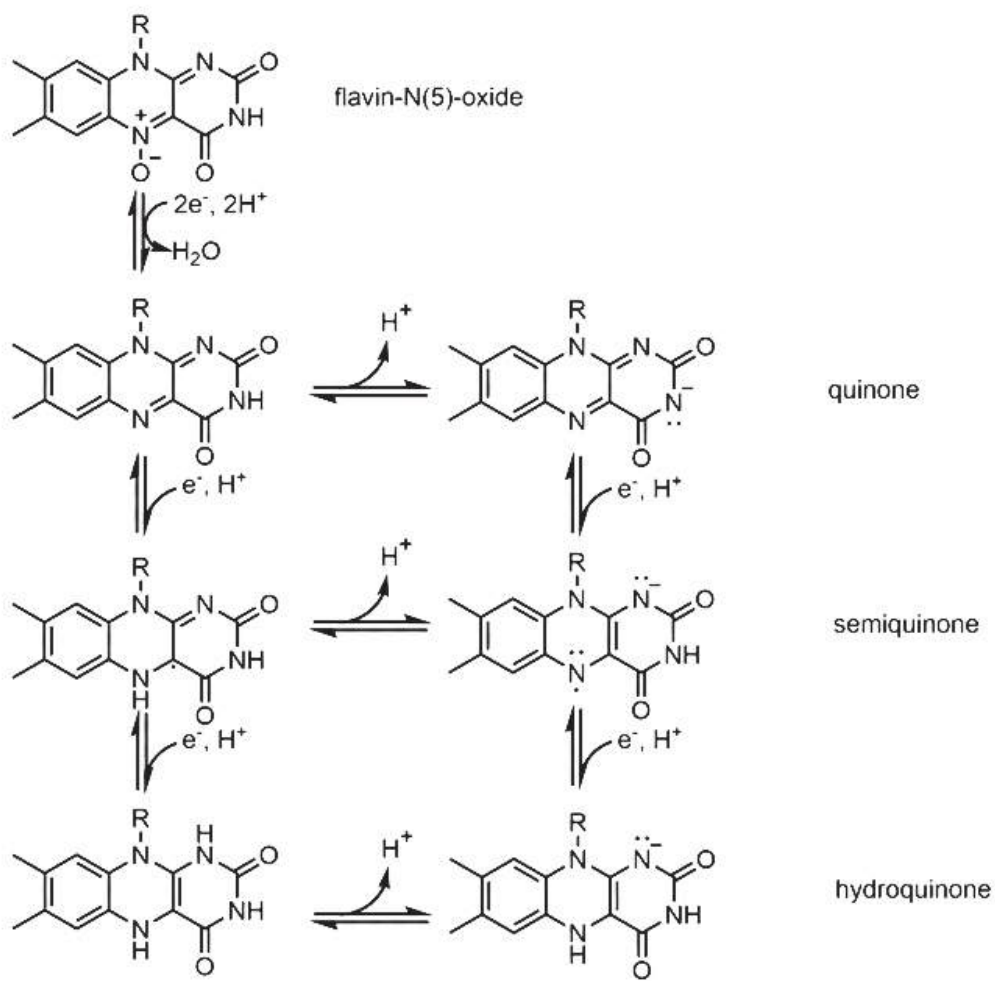
Enzyme Activity



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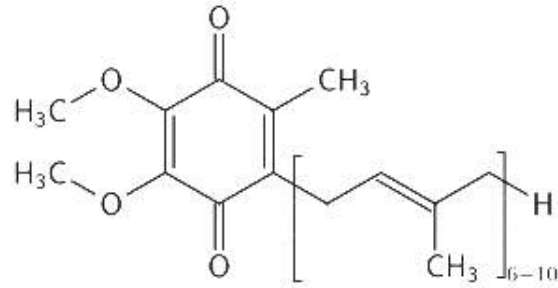


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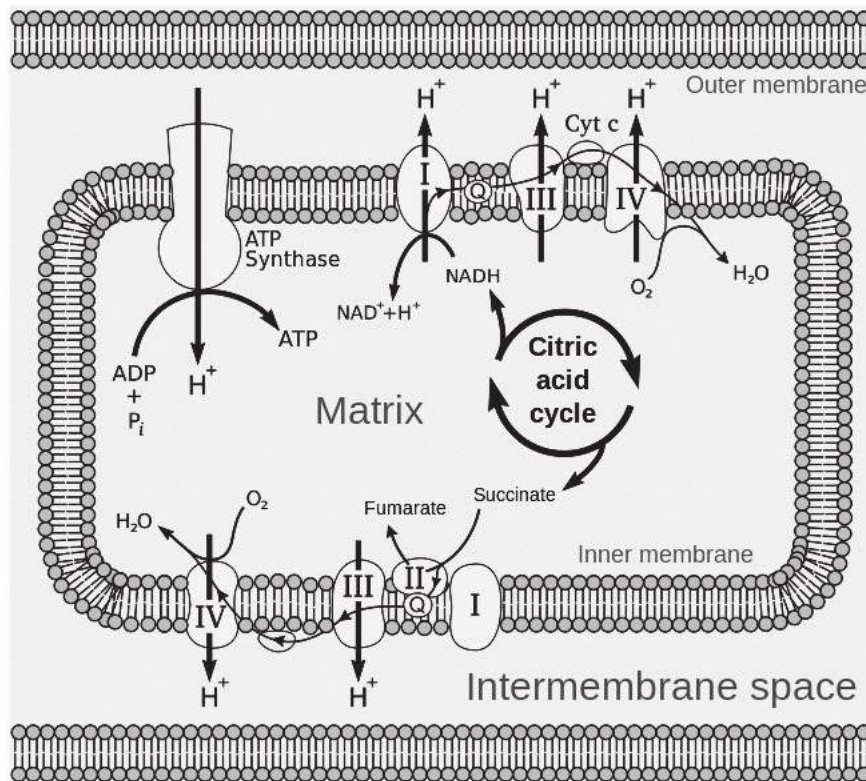


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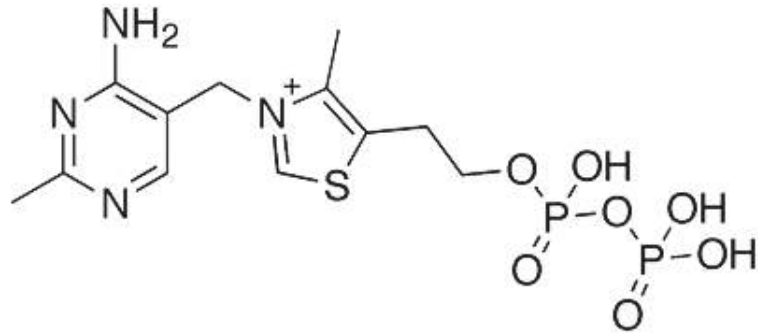
Enzyme Activity



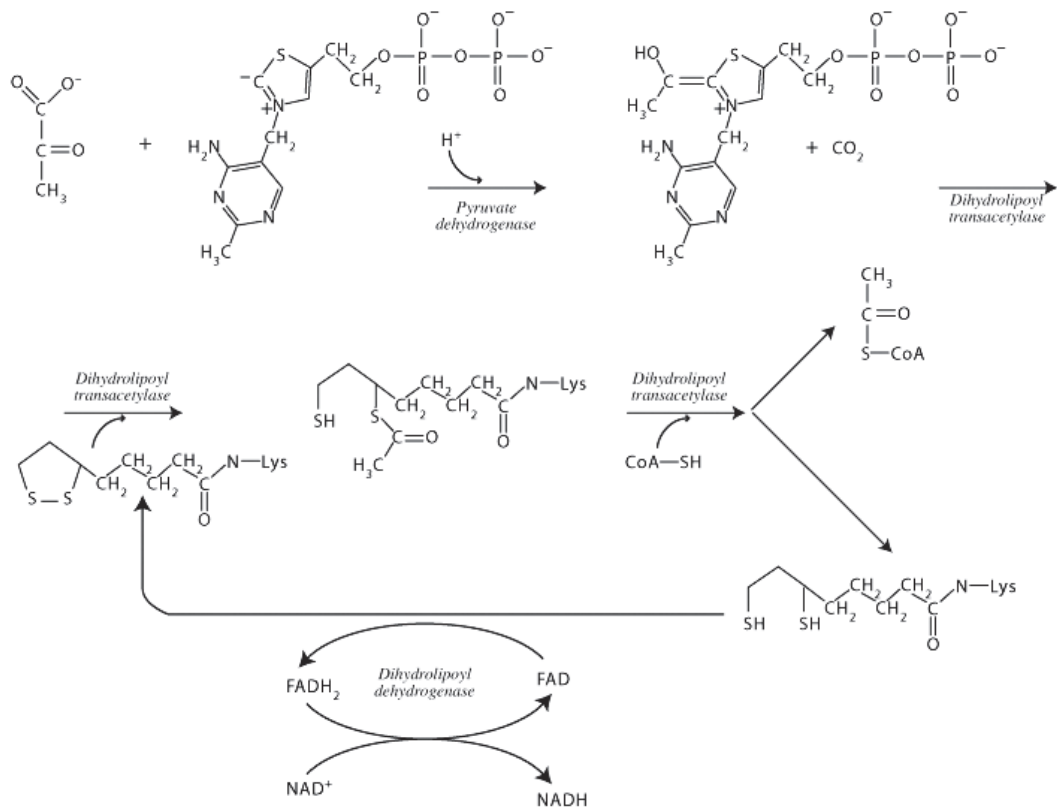
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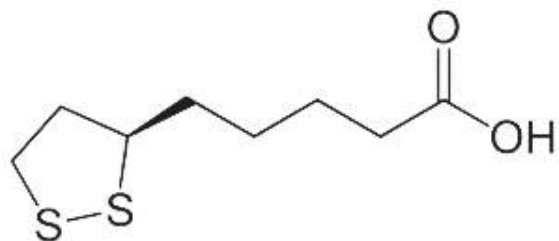
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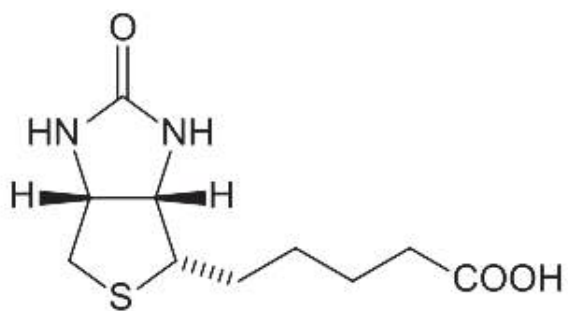
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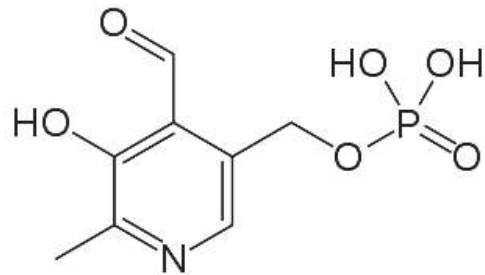
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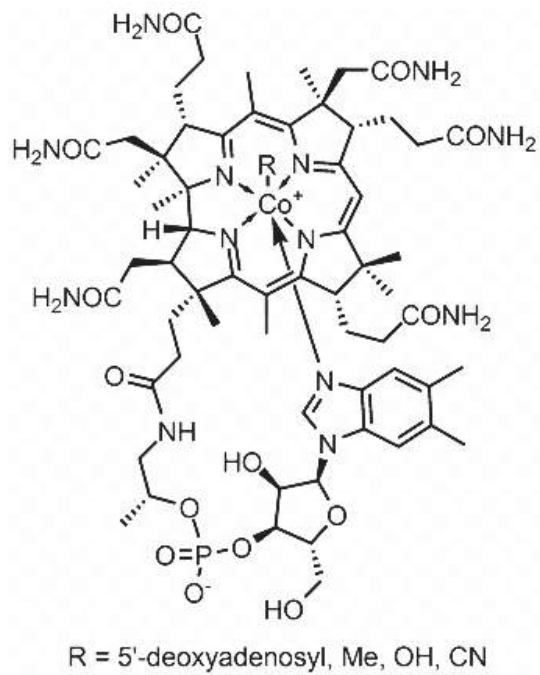
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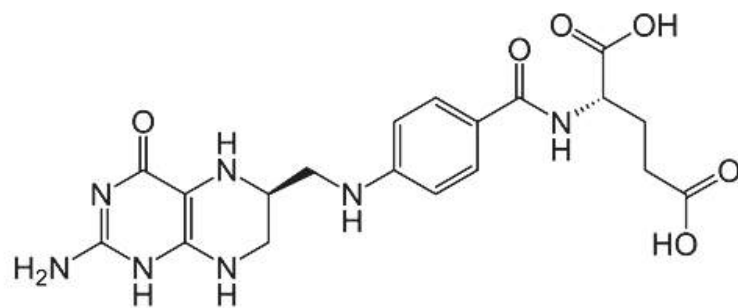
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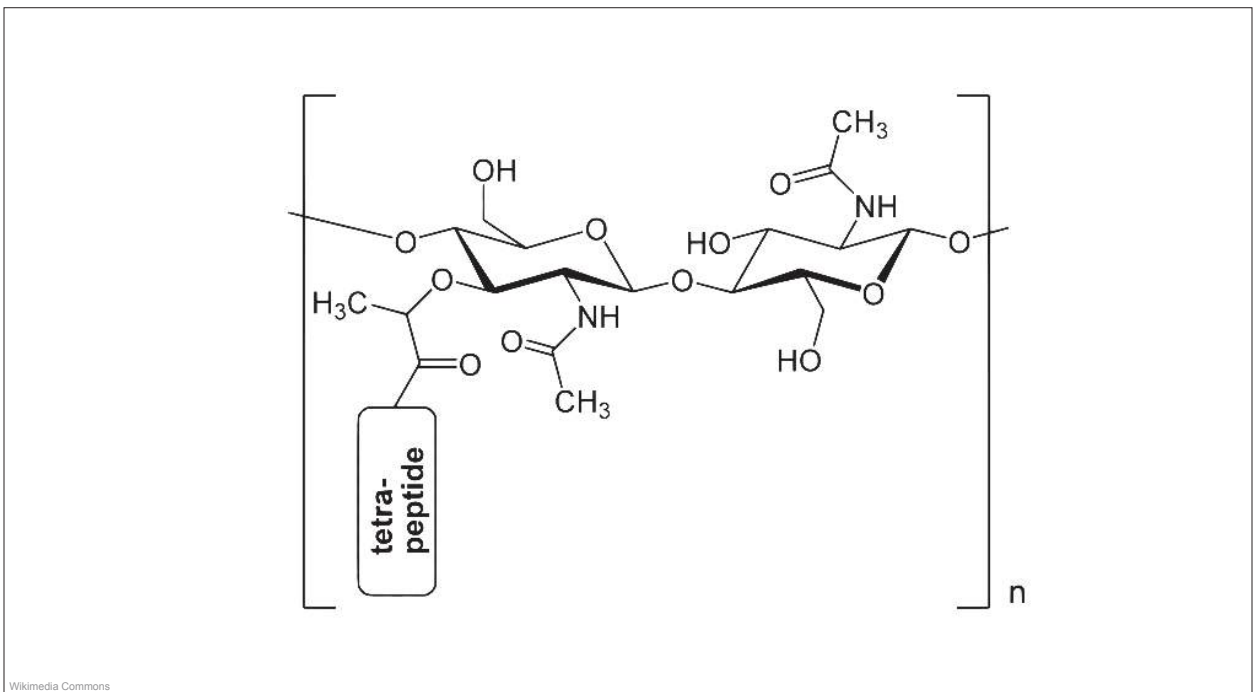
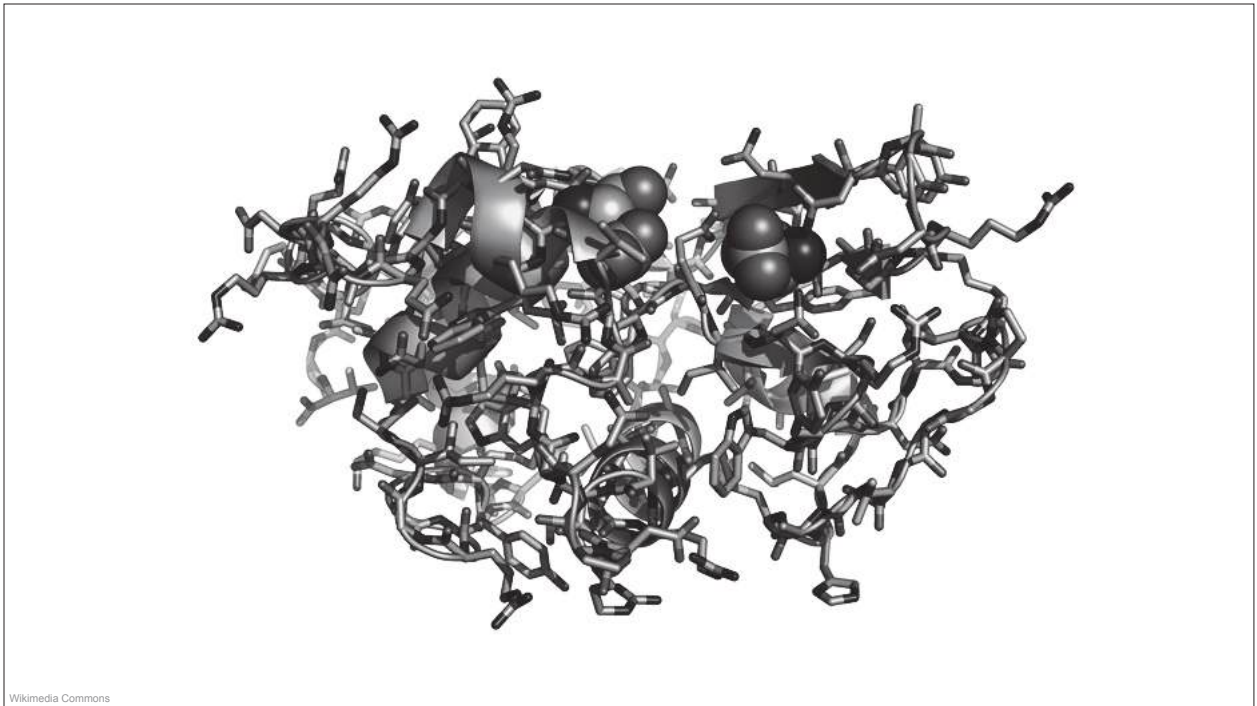
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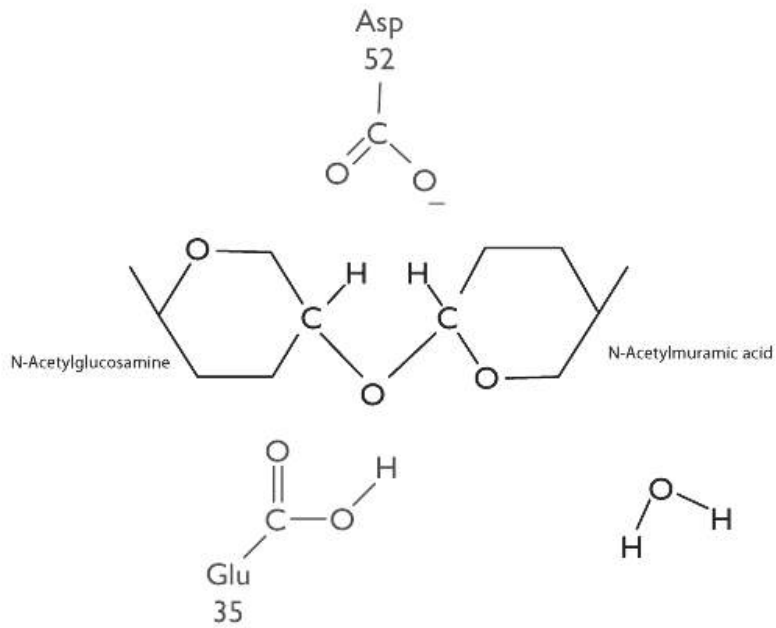
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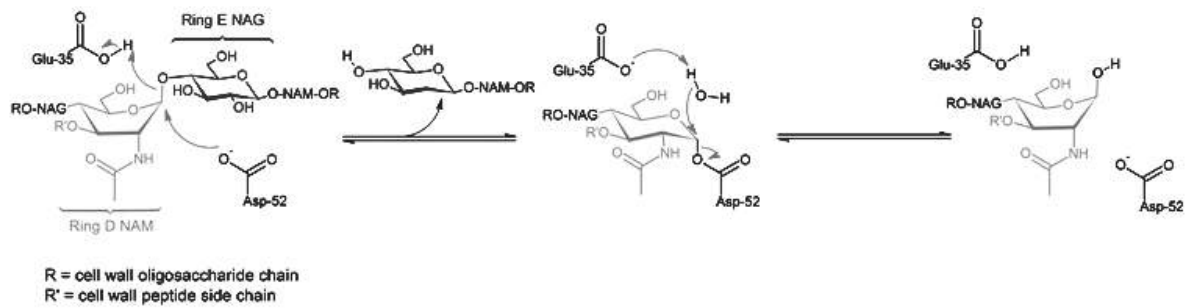
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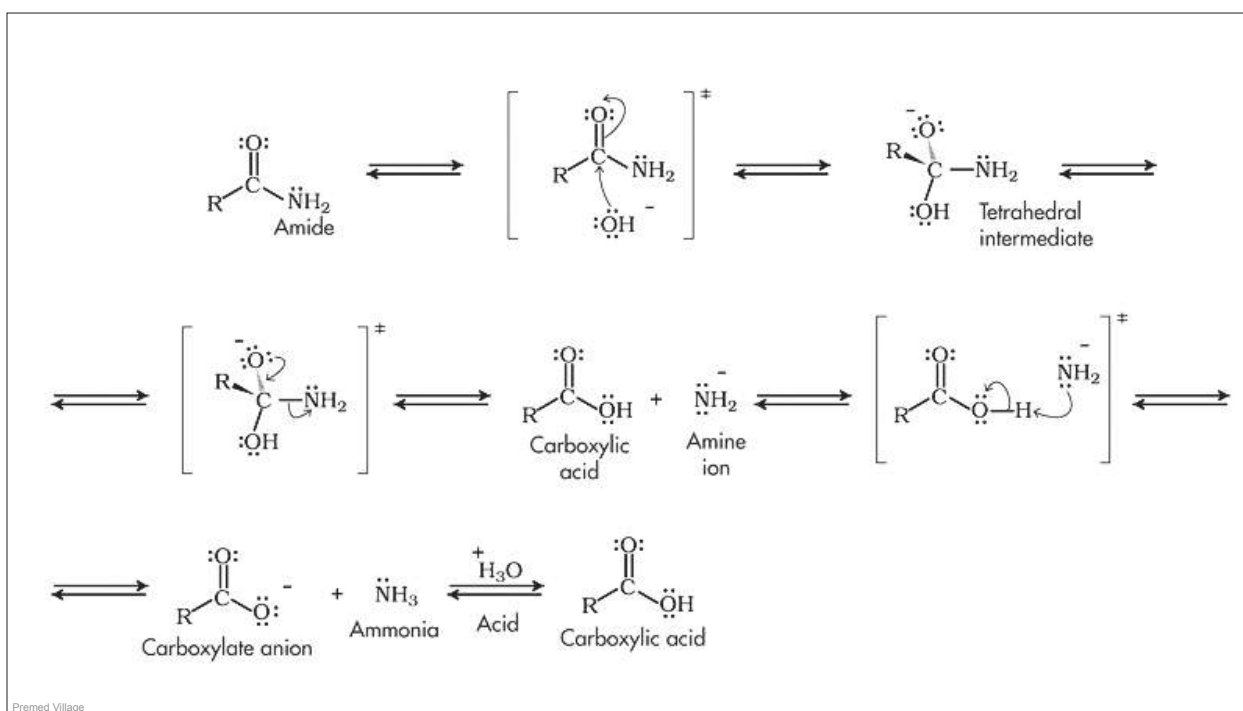
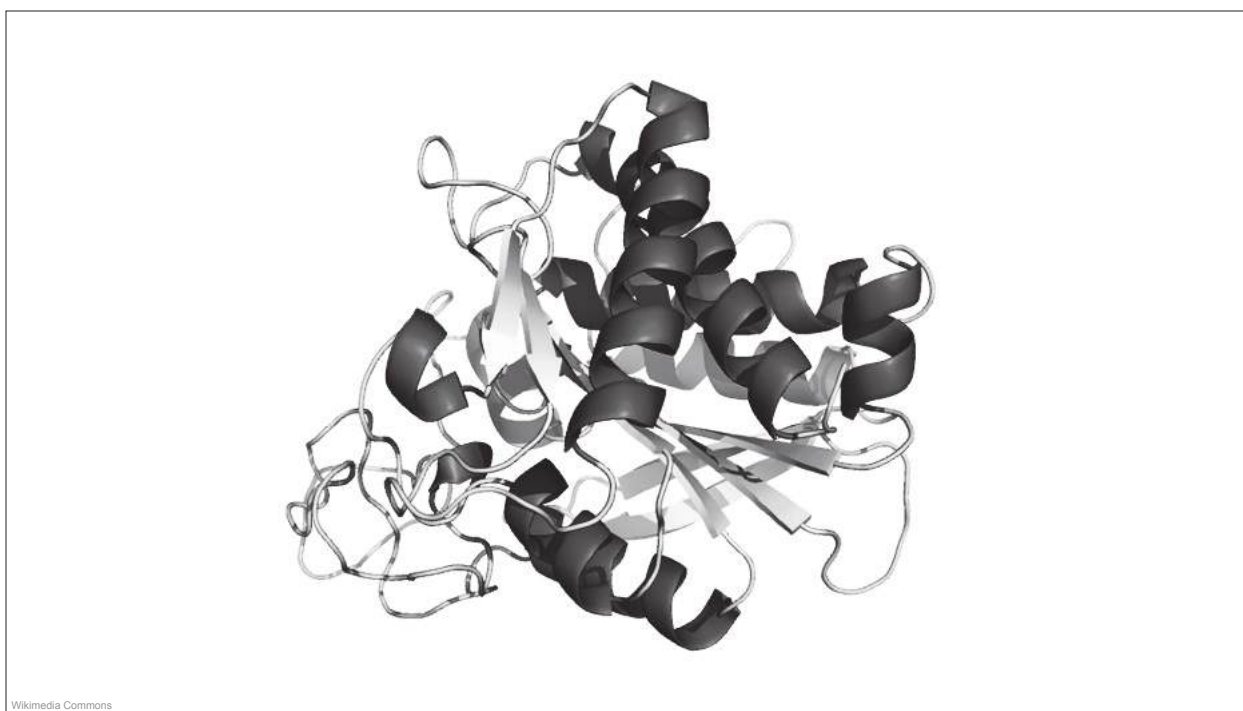
Enzyme Mechanisms



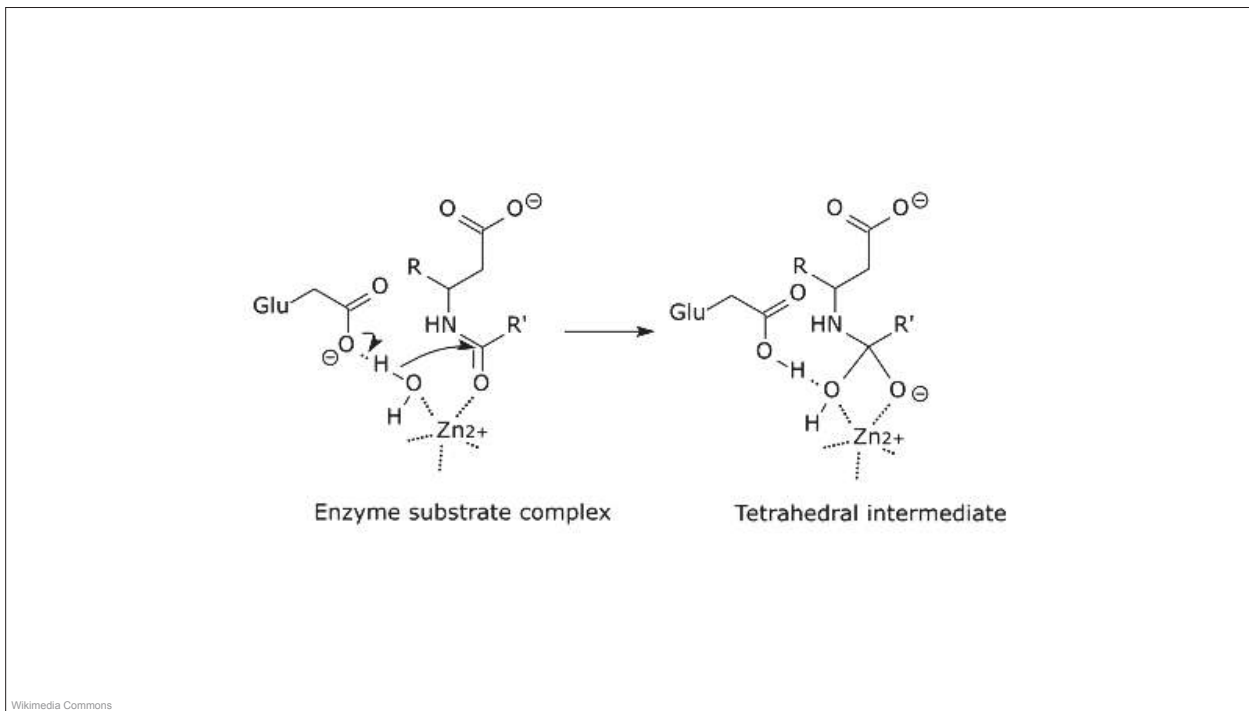
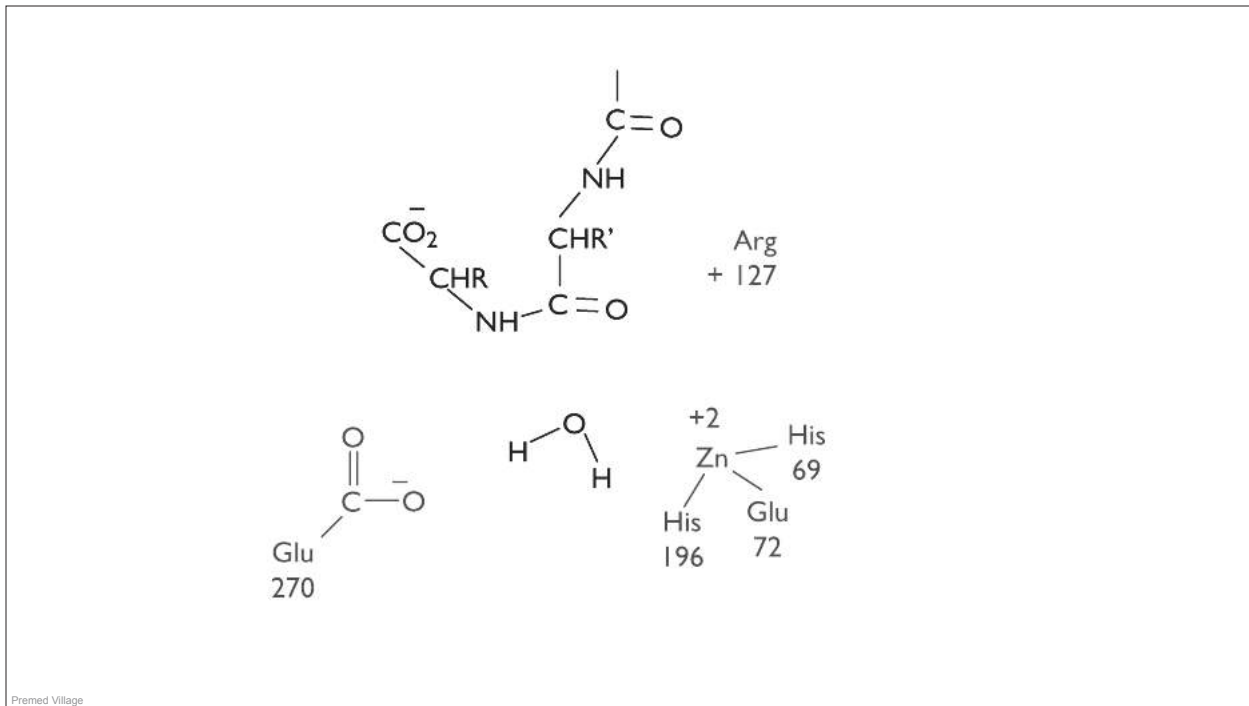
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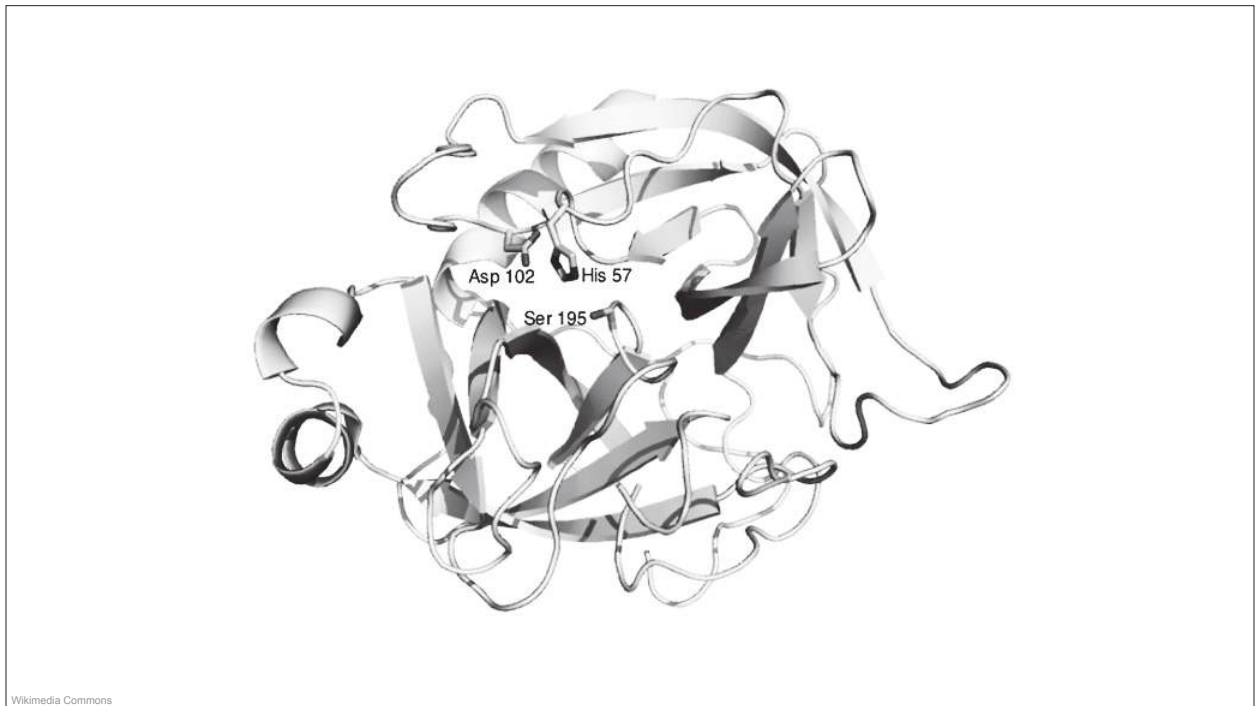


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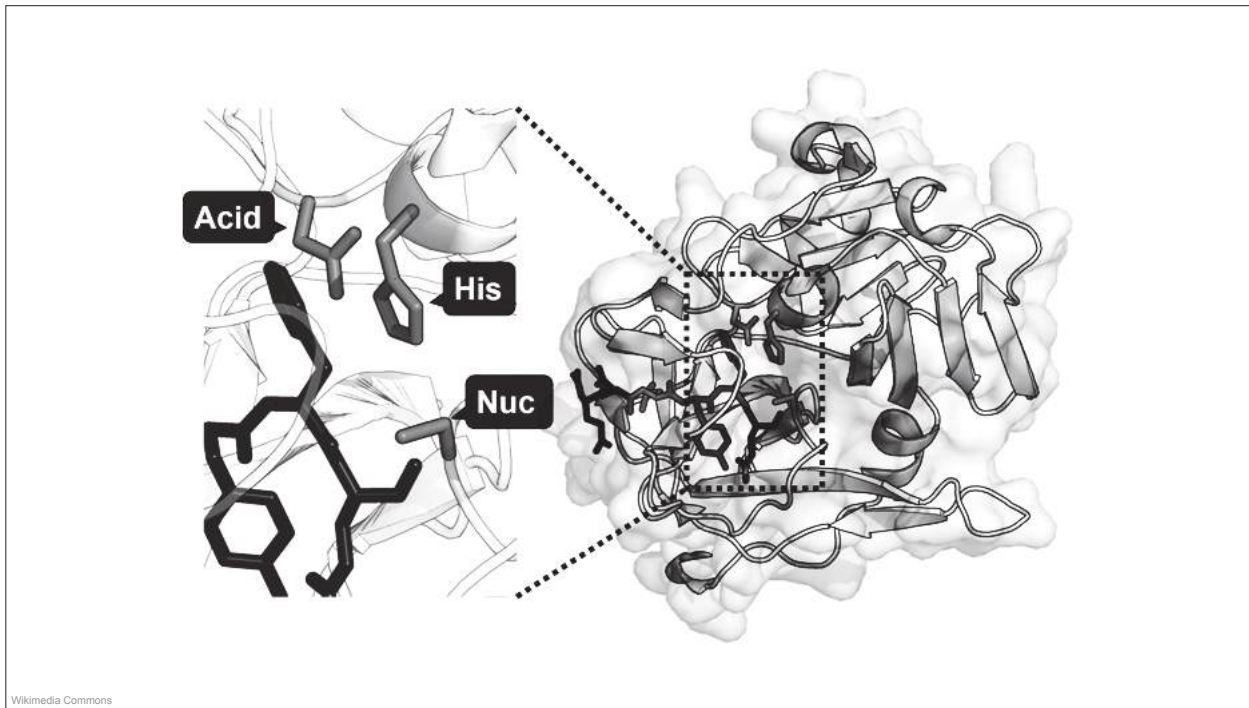
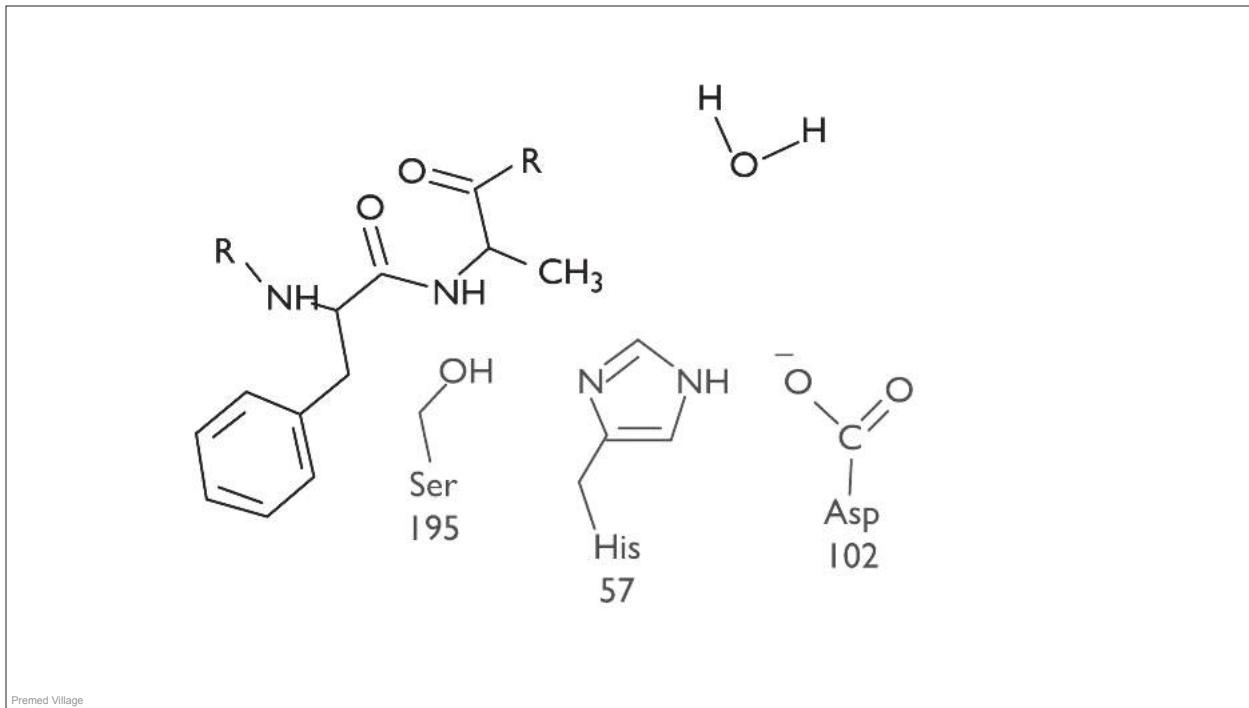
Enzyme Mechanisms

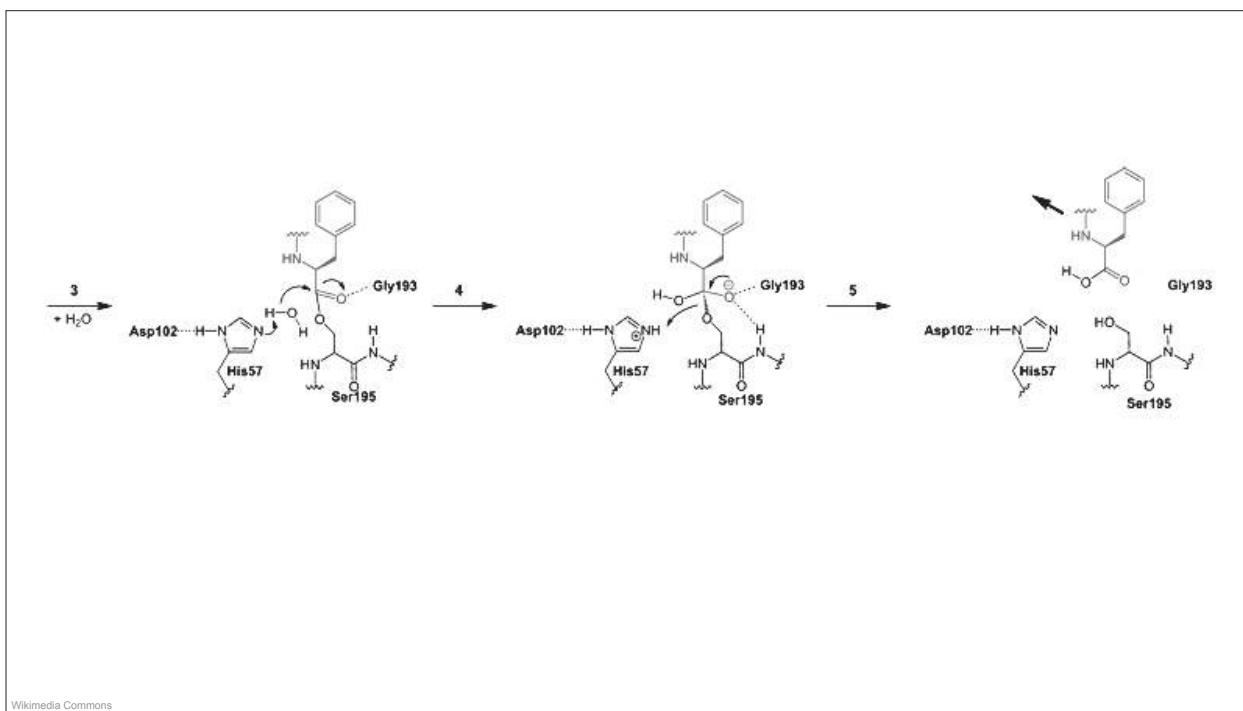
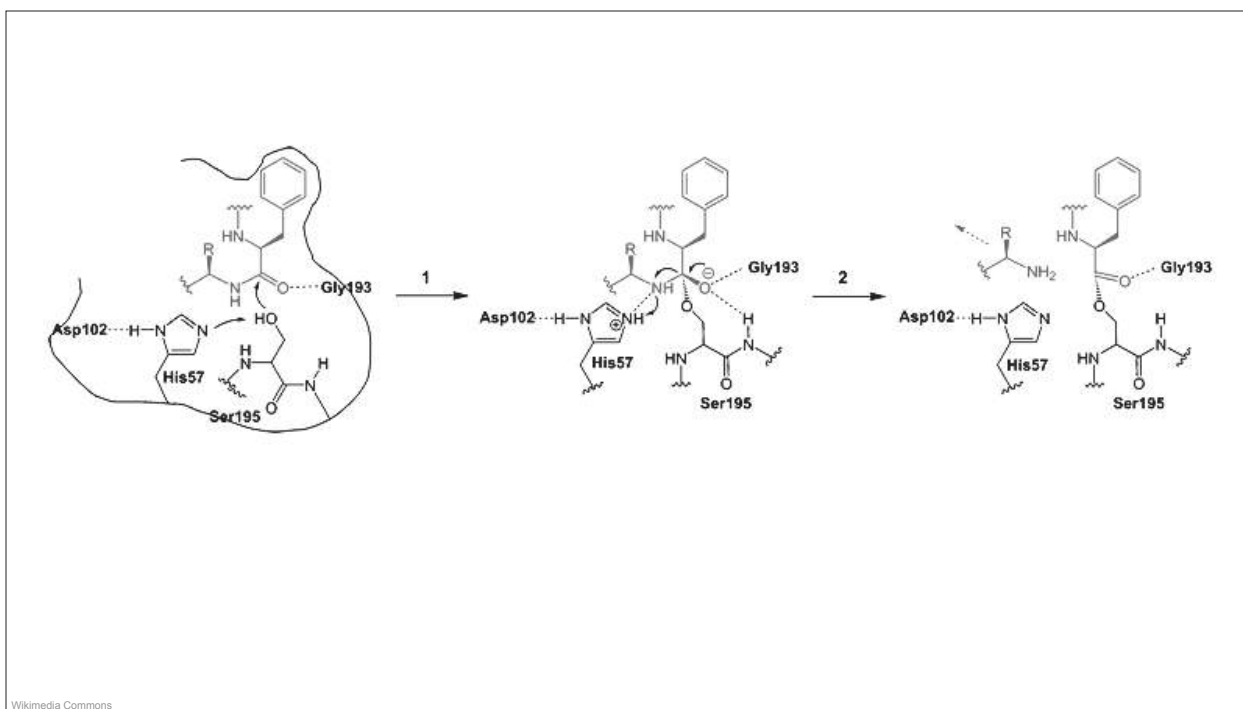




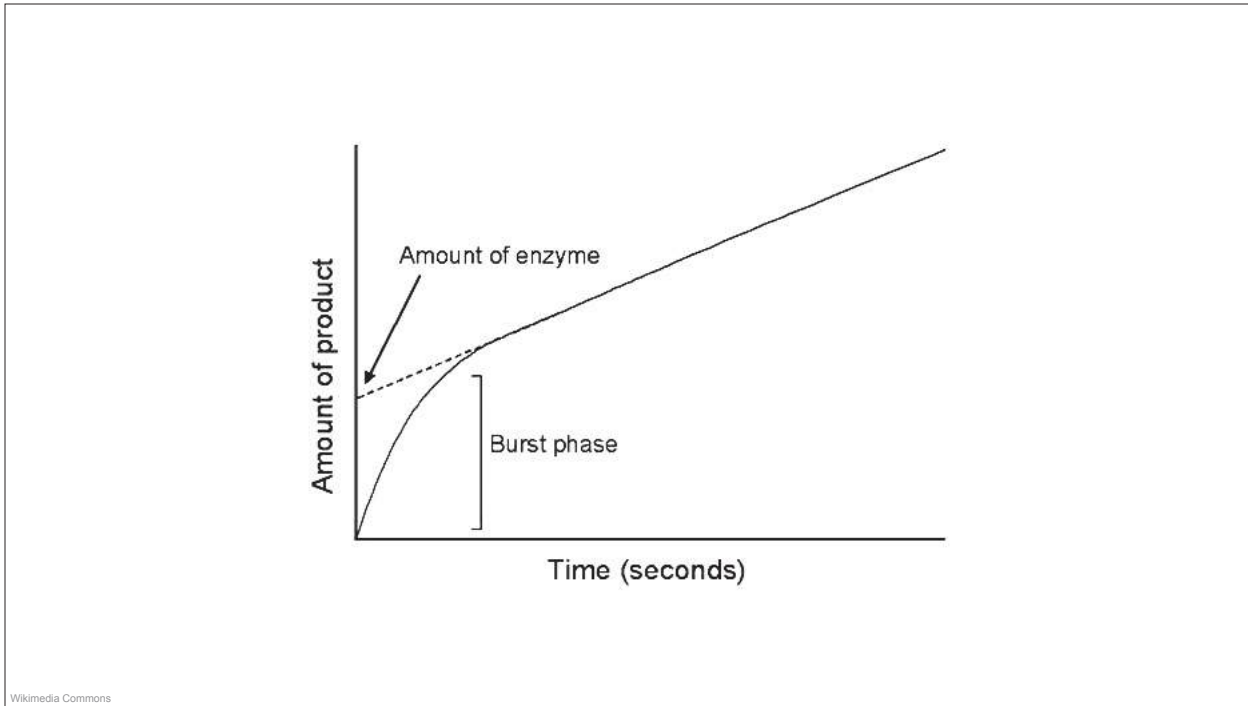
Chymotrypsin <i>aromatic, bulky residue</i>	Trypsin <i>lysine or arginine</i>	Elastase <i>smaller, uncharged residue</i>
---	---	--

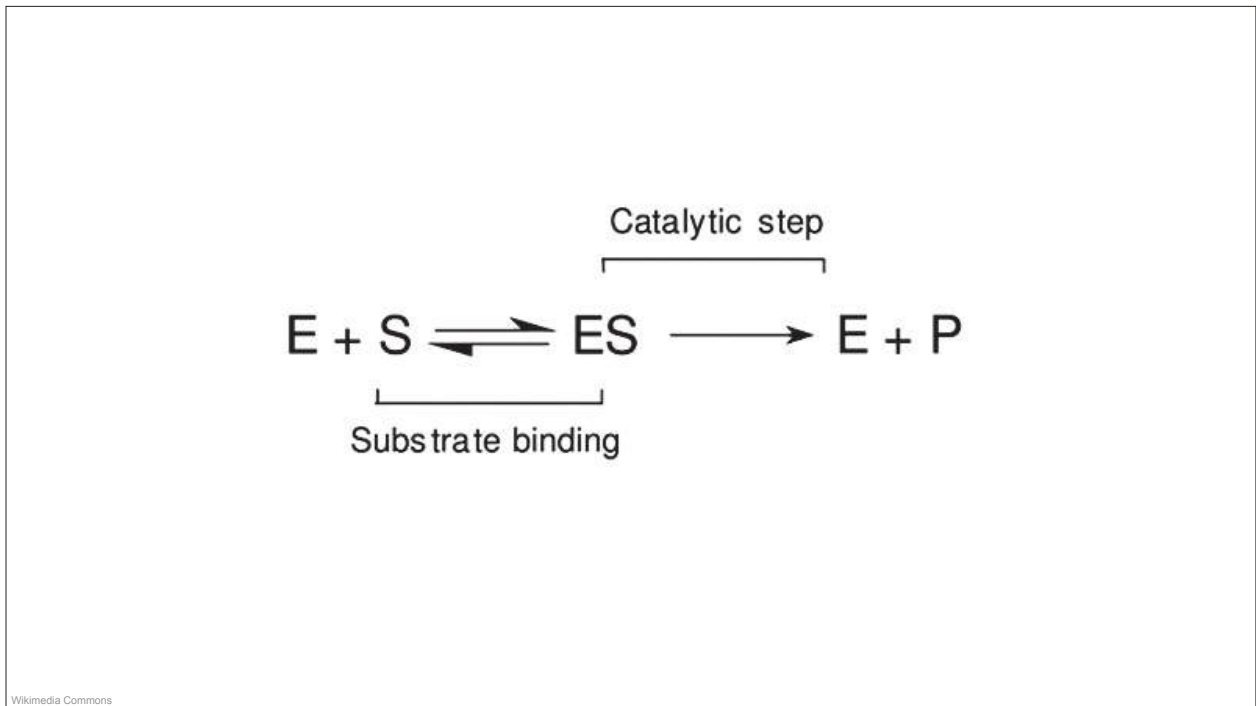
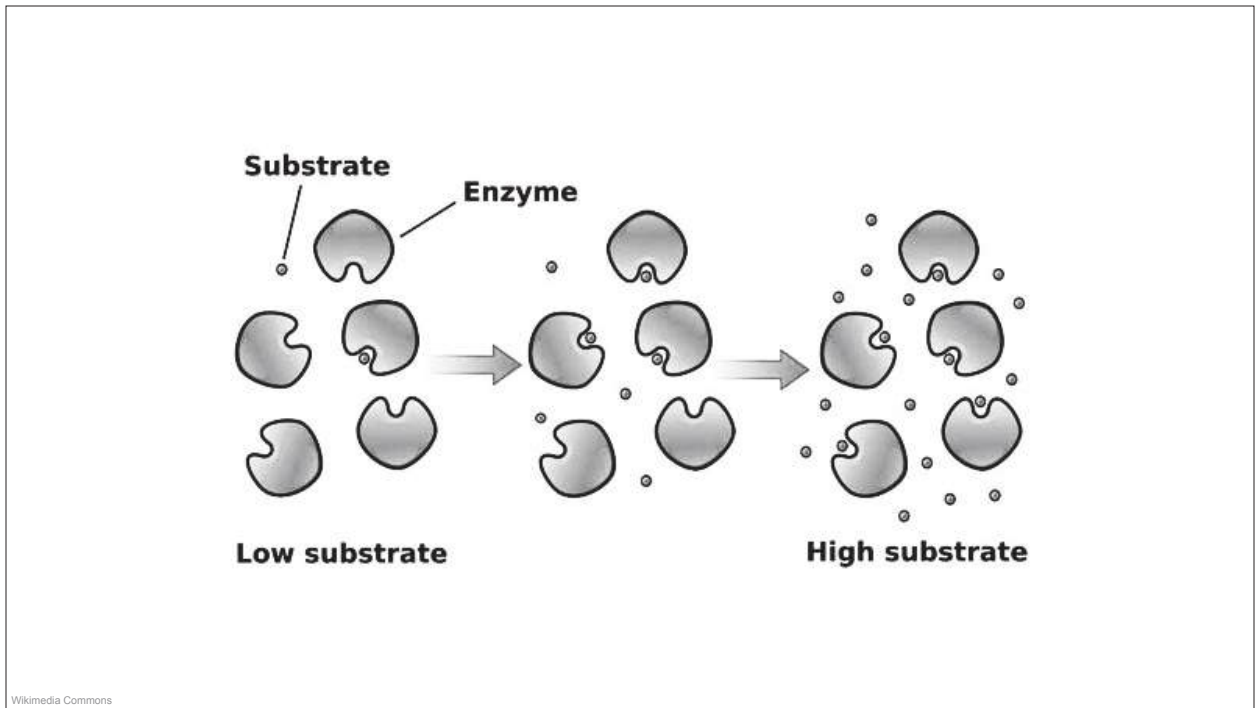
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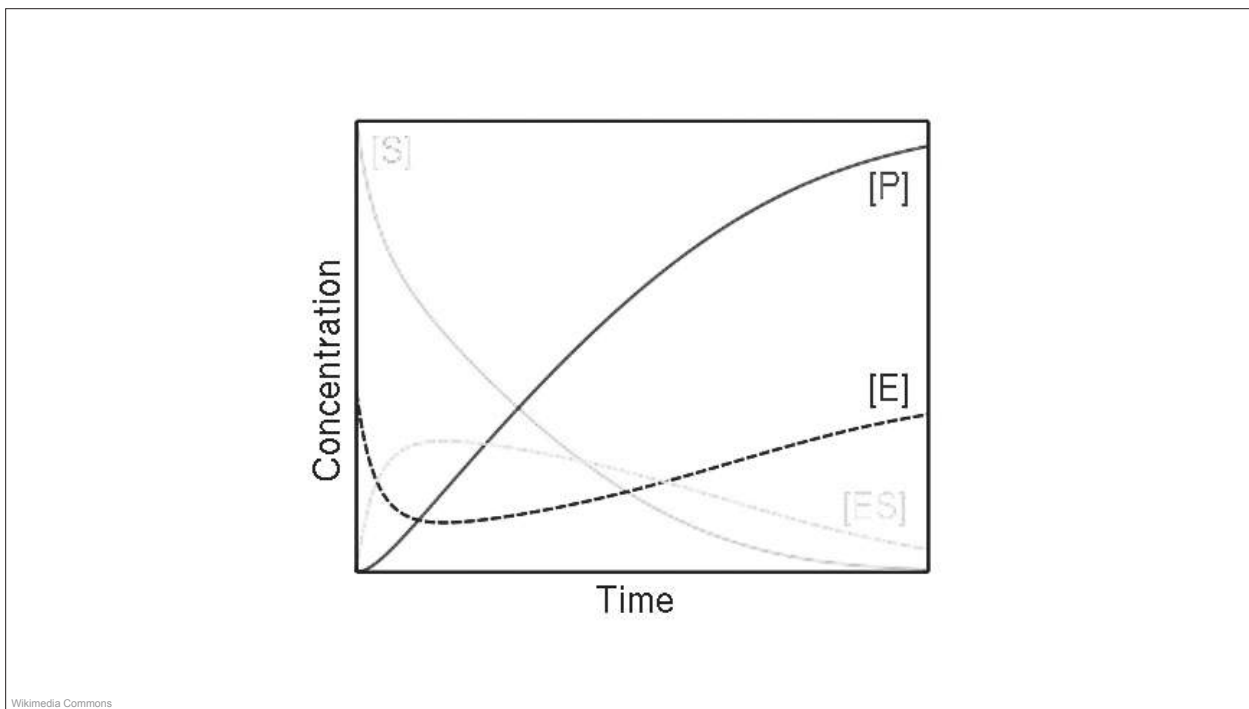
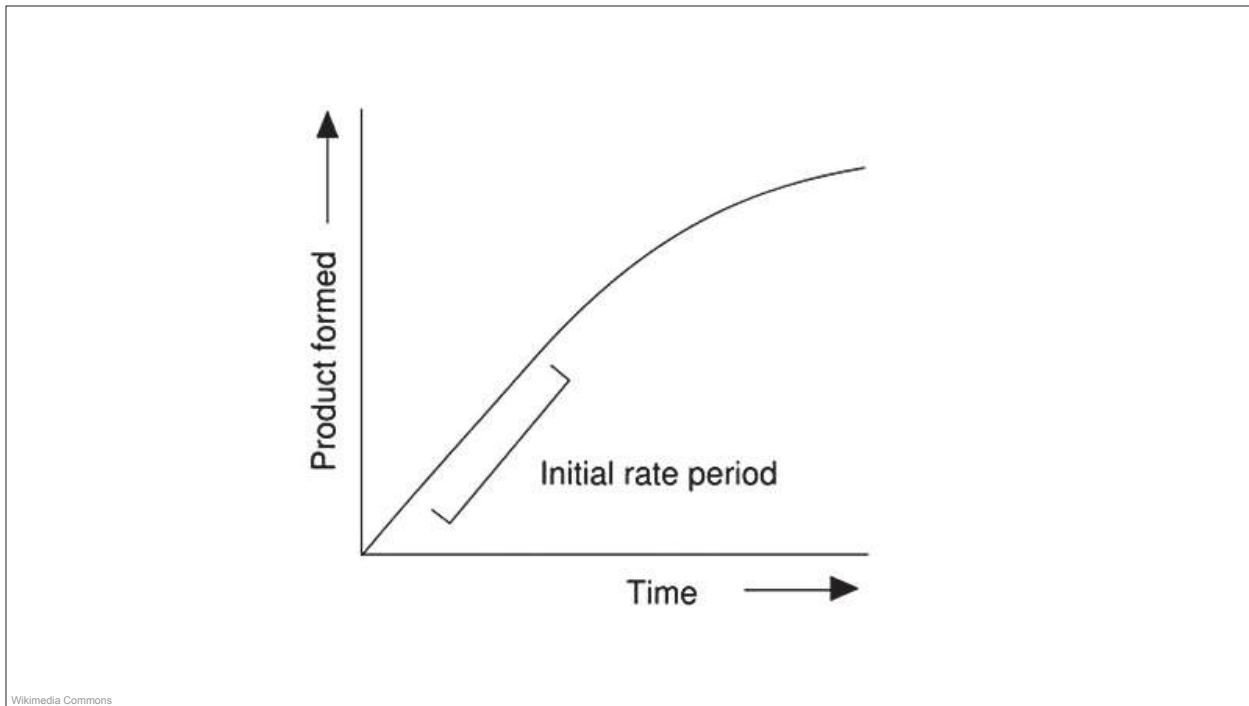


Enzyme Mechanisms



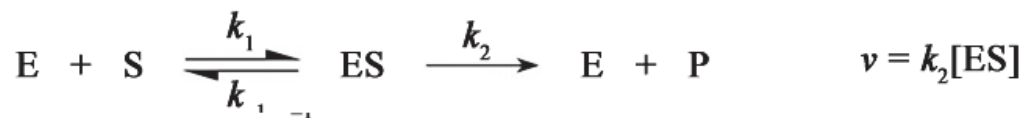


Enzyme Kinetics





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1) Assuming a steady state where $[ES]$ is constant:

$$k_1[E][S] = (k_{-1} + k_2)[ES]$$

$$[ES] = \frac{[E][S]}{(k_{-1} + k_2)/k_1}$$

$$K_M = \frac{k_{-1} + k_2}{k_1}$$

$$[ES] = \frac{[E][S]}{K_M}$$

2) Assuming total enzyme doesn't change:

$$[E] = [E_T] - [ES]$$

$$[ES] = \frac{([E_T] - [ES])[S]}{K_M}$$

$$[ES] = [E_T] \frac{[S]}{[S] + K_M}$$

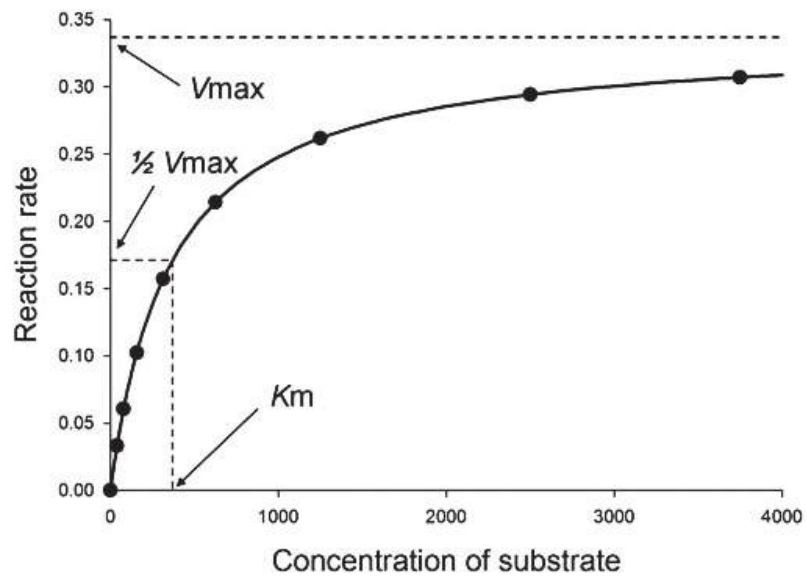
$$v = k_2[E_T] \frac{[S]}{[S] + K_M}$$

$$v = V_{\max} \frac{[S]}{[S] + K_M}$$

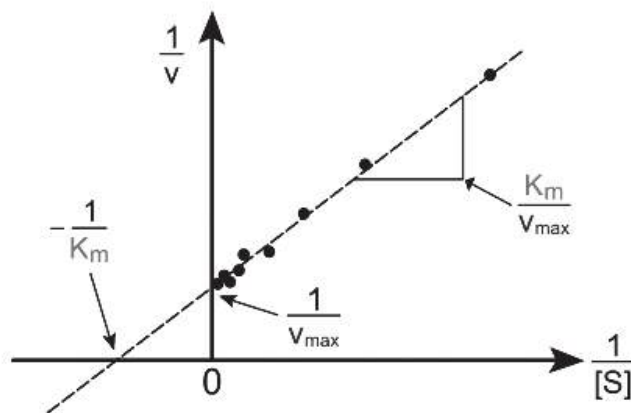
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Enzyme Kinetics

$$v = V_{\max} \frac{[S]}{[S] + K_M}$$



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$$\frac{1}{v} = \frac{1}{V_{\max}} + \left(\frac{K_M}{V_{\max}} \right) \left(\frac{1}{[S]} \right)$$

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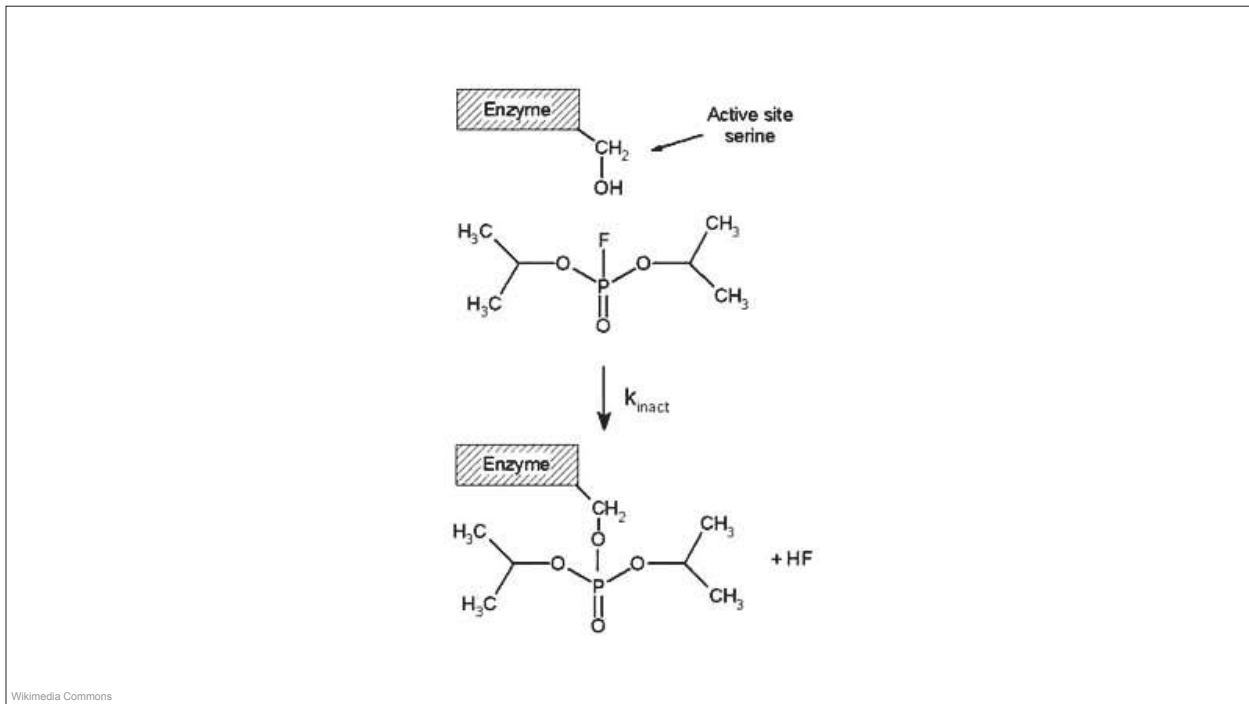
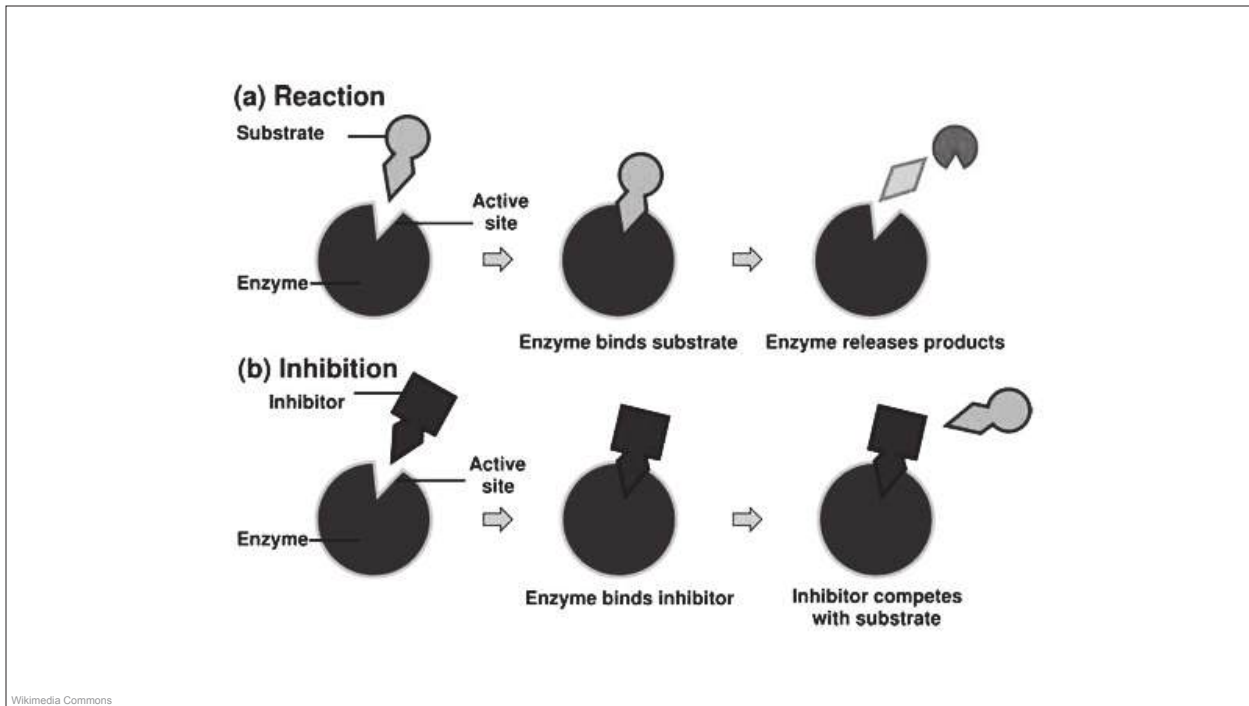


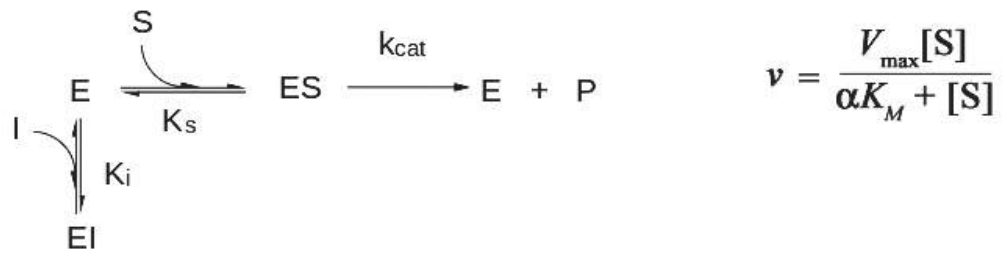
Enzyme	K_m (M)	k_{cat} (1/s)	k_{cat}/K_m (1/M*s)
Chymotrypsin	1.5×10^{-2}	0.14	9.3
Pepsin	3.0×10^{-4}	0.50	1.7×10^3
Tyrosyl-tRNA synthetase	9.0×10^{-4}	7.6	8.4×10^3
Ribonuclease	7.9×10^{-3}	7.9×10^2	1.0×10^5
Carbonic anhydrase	2.6×10^{-2}	4.0×10^5	1.5×10^7
Fumarase	5.0×10^{-6}	8.0×10^2	1.6×10^8

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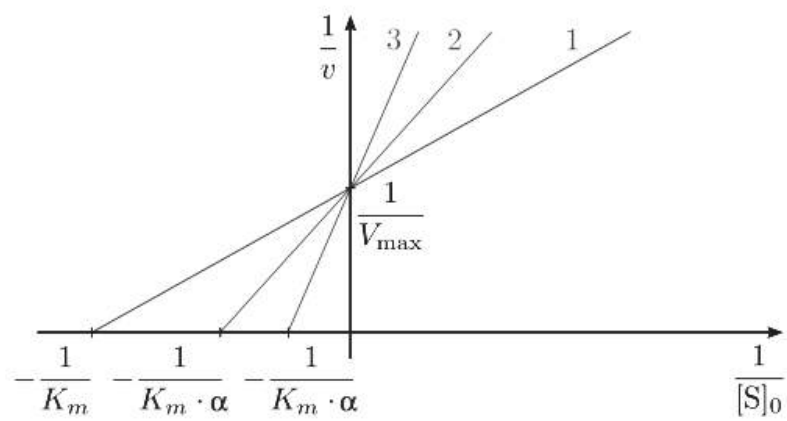
Hexokinase catalyzes the phosphorylation of both glucose and fructose. K_m for hexokinase with glucose is 0.15mM. K_m for fructose is 1.5mM. Assuming that V_{max} is the same for both enzymes, calculate the normalized initial velocity (v_0 / V_{max}) when the initial substrate concentration is 0.15mM.

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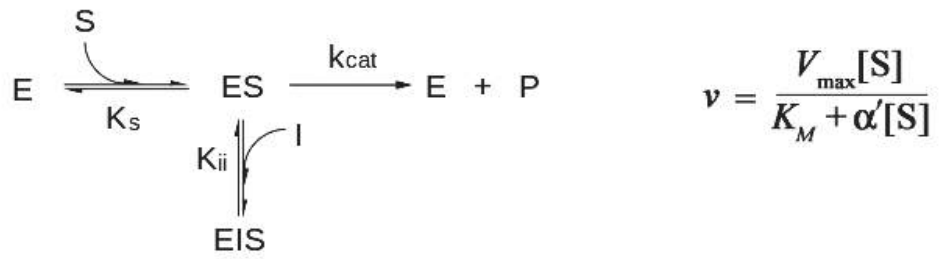




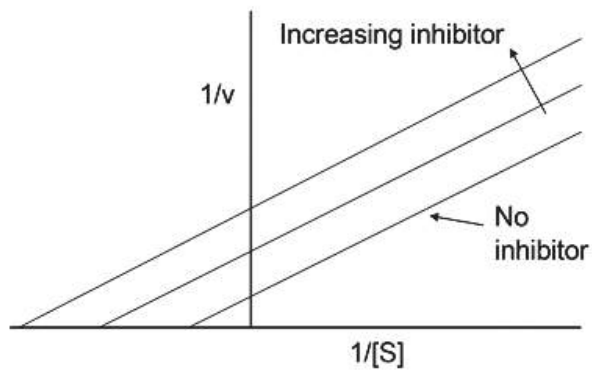
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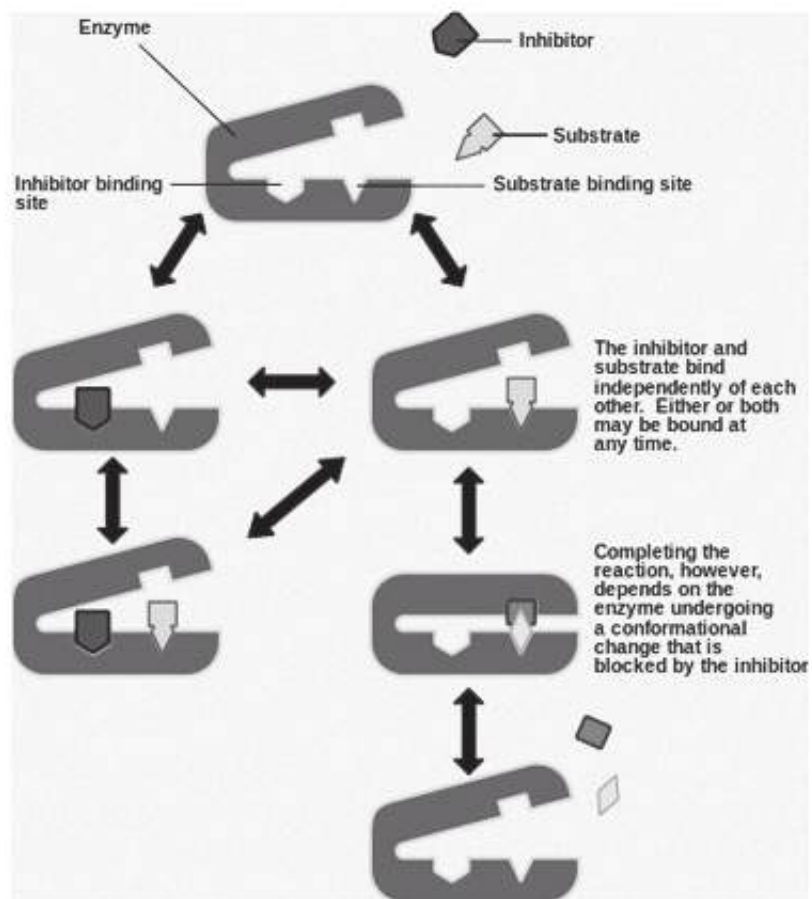
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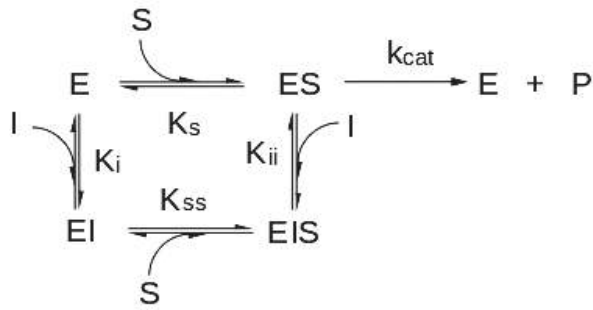
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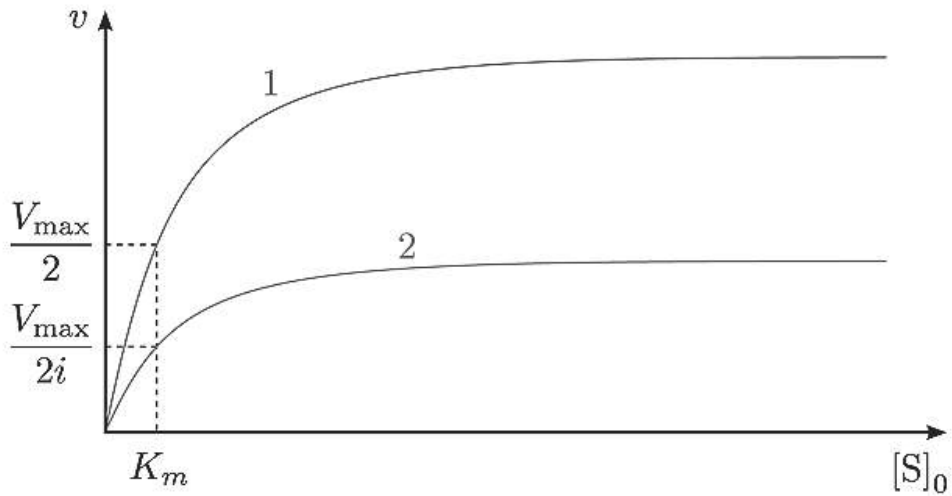


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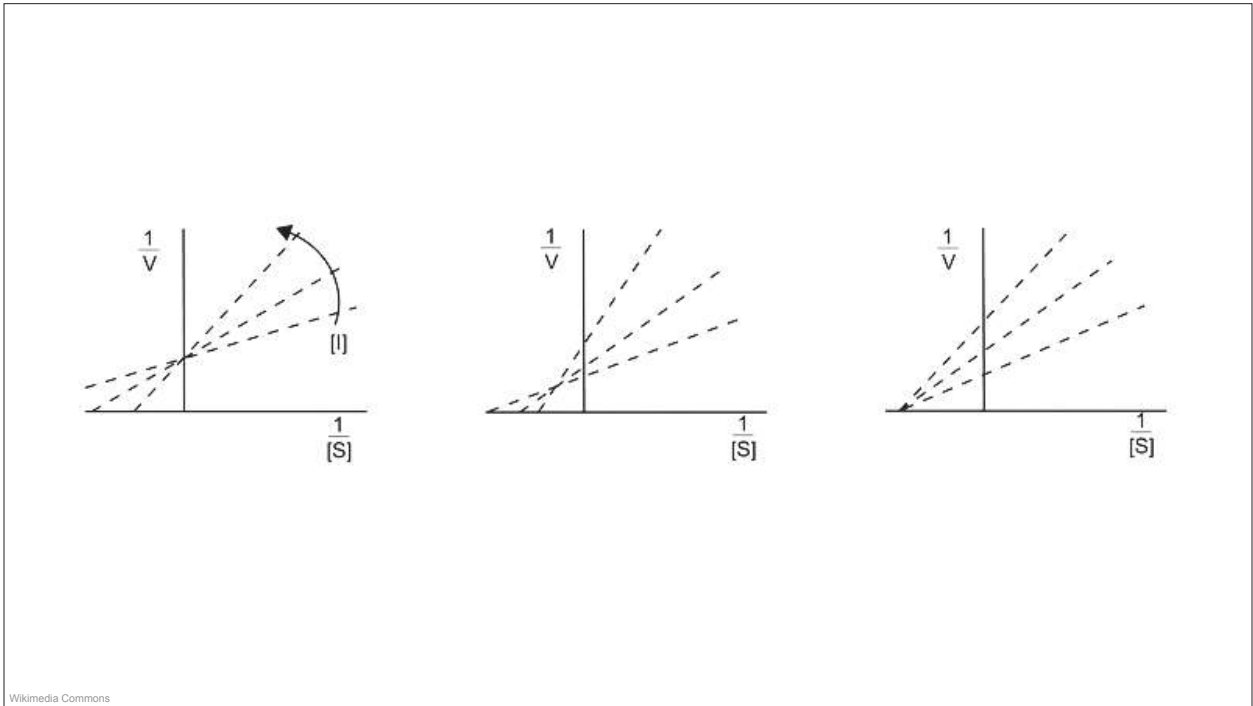


$$v = \frac{V_{\max} [S]}{\alpha K_M + \alpha' [S]}$$

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Type of inhibition	K_m apparent	V_{max} apparent
competitive	$K_m \alpha$	V_{max}
uncompetitive	$\frac{K_m}{\alpha'}$	$\frac{V_{max}}{\alpha'}$
non-competitive	K_m	$\frac{V_{max}}{\alpha'}$
mixed	$\frac{K_m \alpha}{\alpha'}$	$\frac{V_{max}}{\alpha'}$

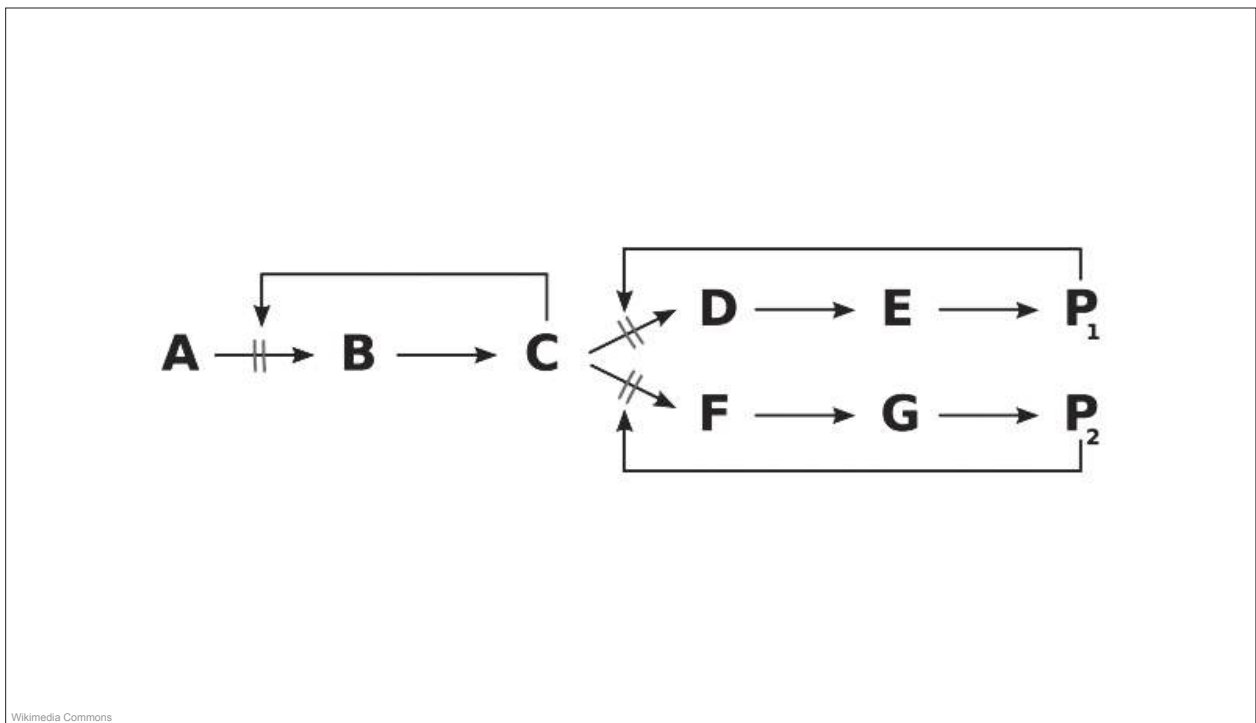
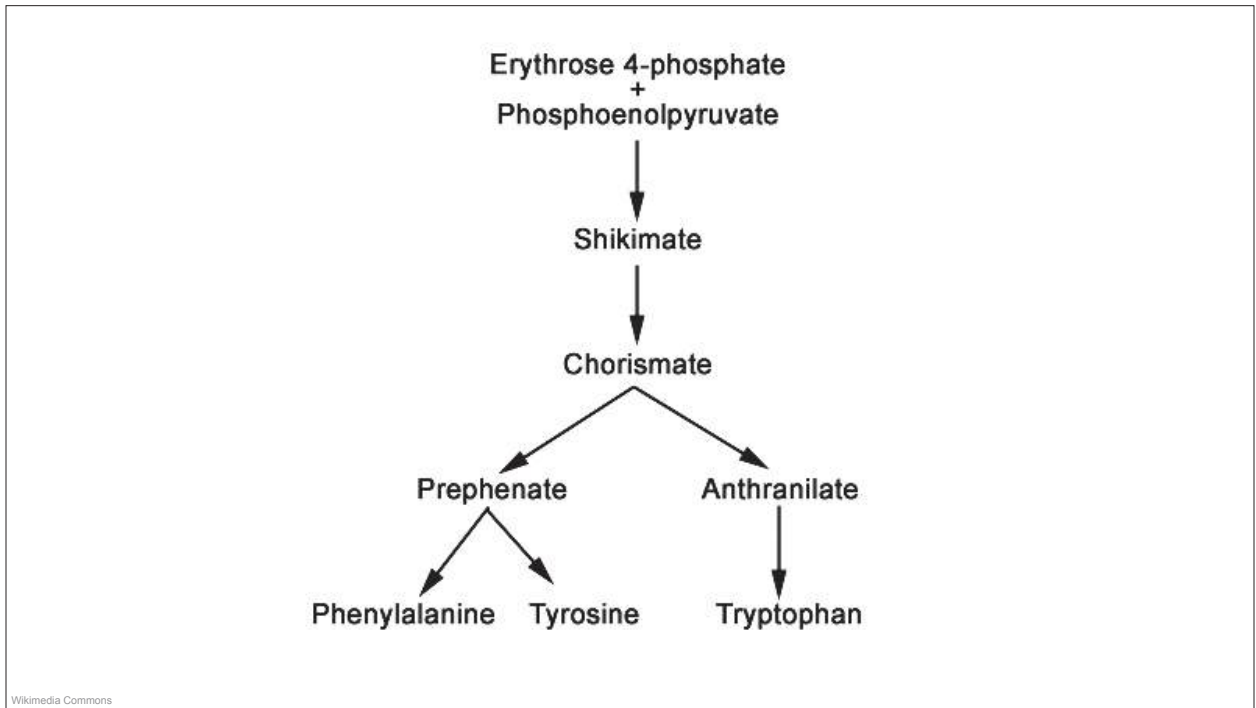
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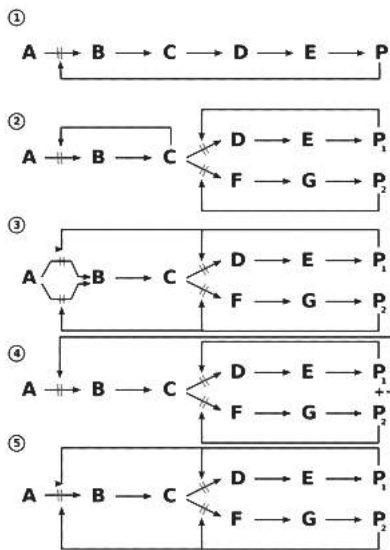


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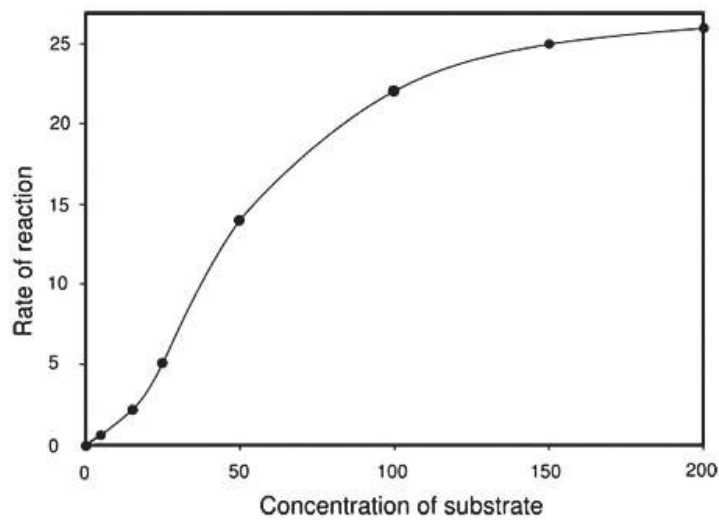
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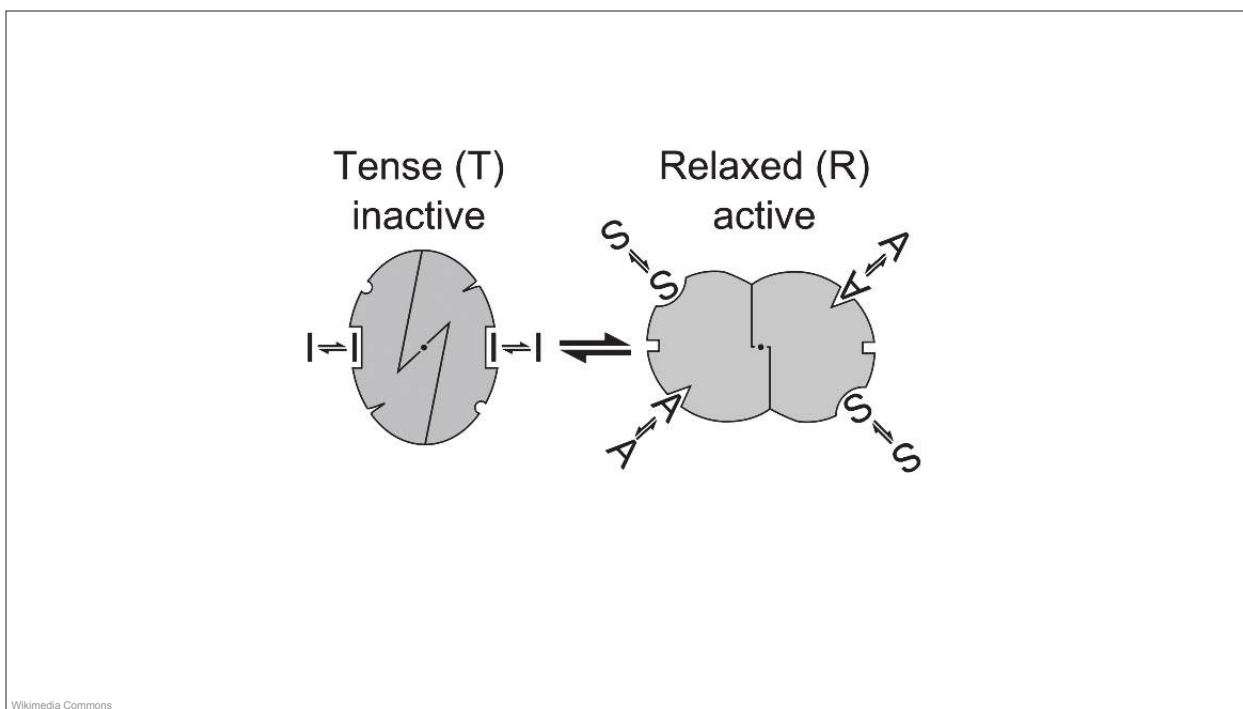


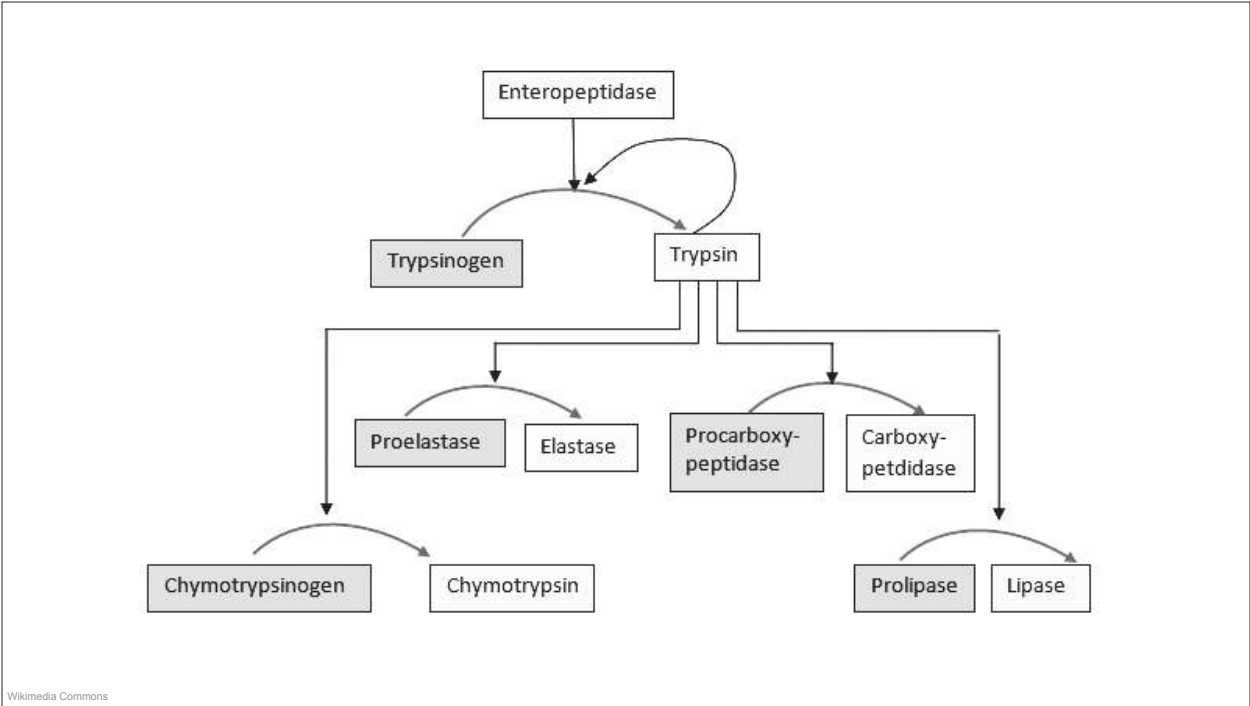
1. The basic feedback inhibition mechanism, where the product (P) inhibits the committed step (A-B).
2. *Sequential feedback inhibition.* The end products P₁ and P₂ inhibit the first committed step of their individual pathway (C-D or C-F). If both products are present in abundance, all pathways from C are blocked. This leads to a buildup of C, which in turn inhibits the first common committed step A-B.
3. *Enzyme multiplicity.* Each end product inhibits both the first individual committed step and one of the enzymes performing the first common committed step.
4. *Concerted feedback inhibition.* Each end product inhibits the first individual committed step. *Together,* they inhibit the first common committed step.
5. *Cumulative feedback inhibition.* Each end product inhibits the first individual committed step. Also, each end product *partially* inhibits the first common committed step.

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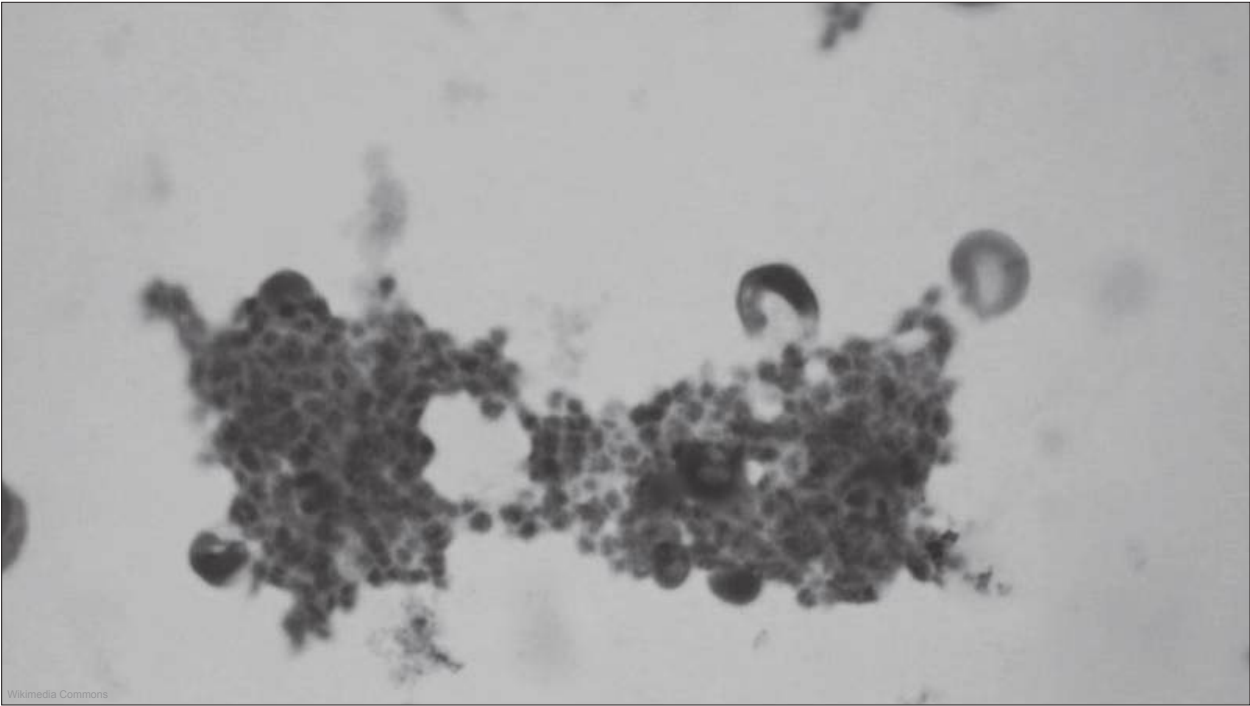


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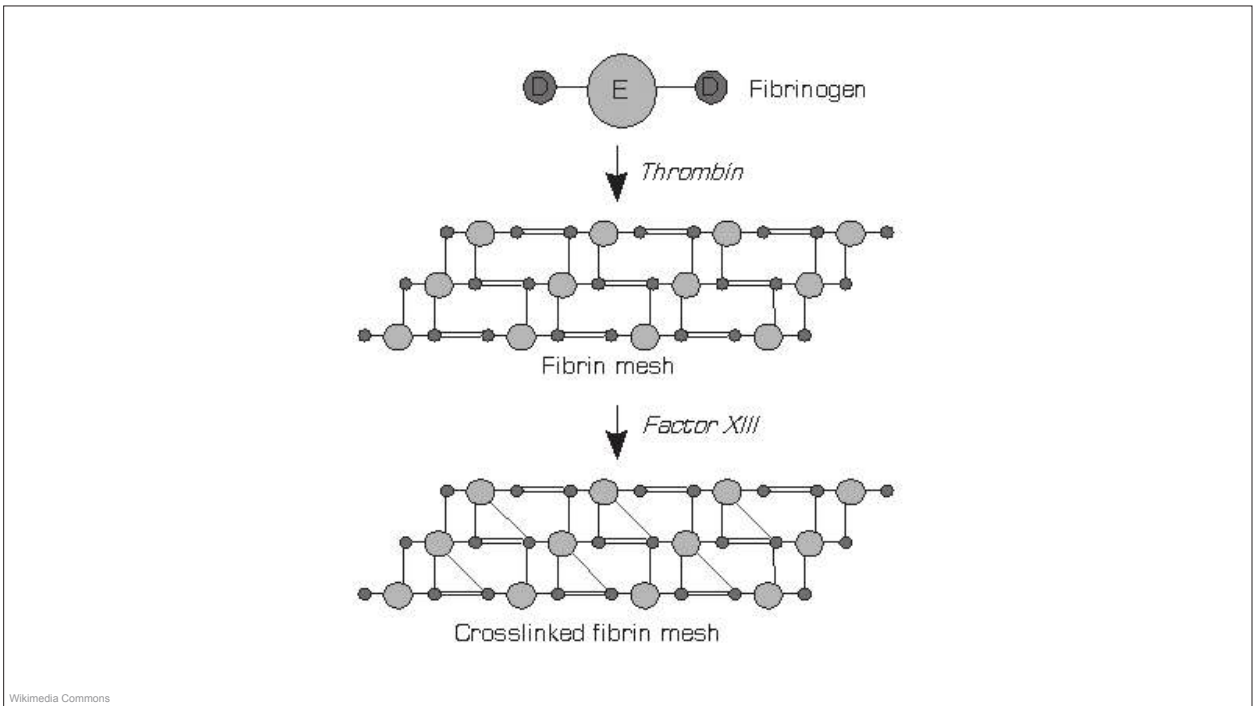
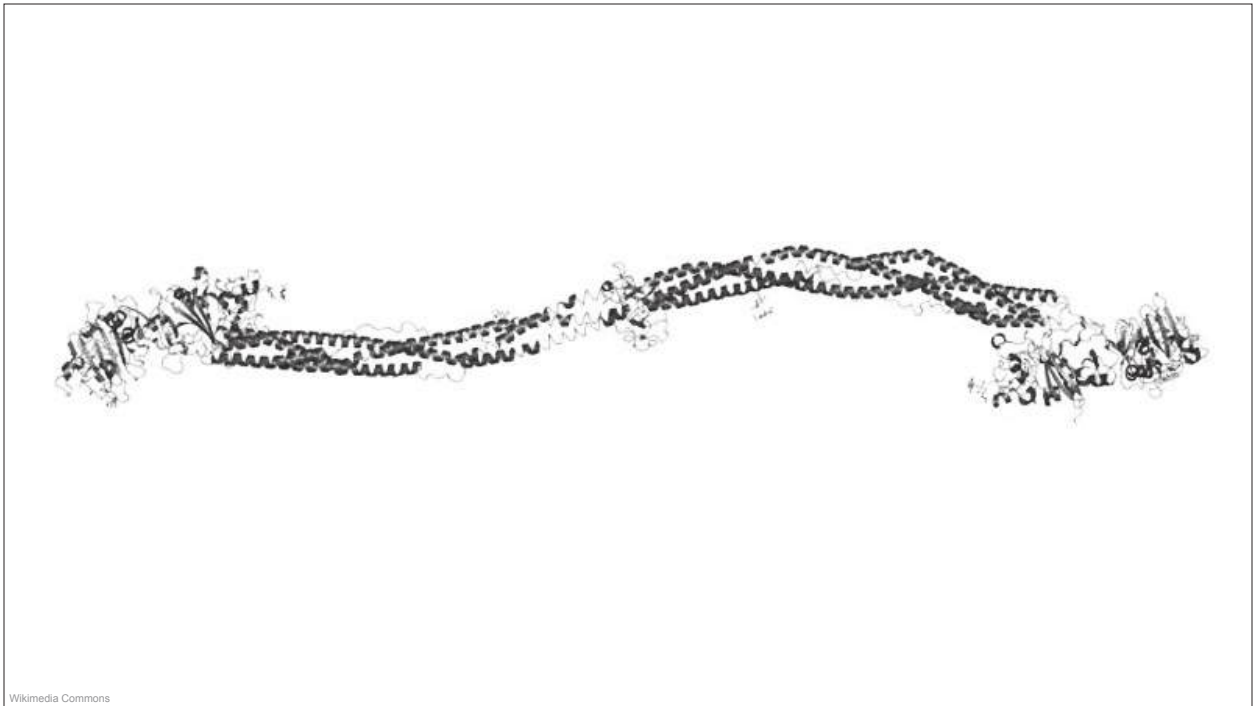




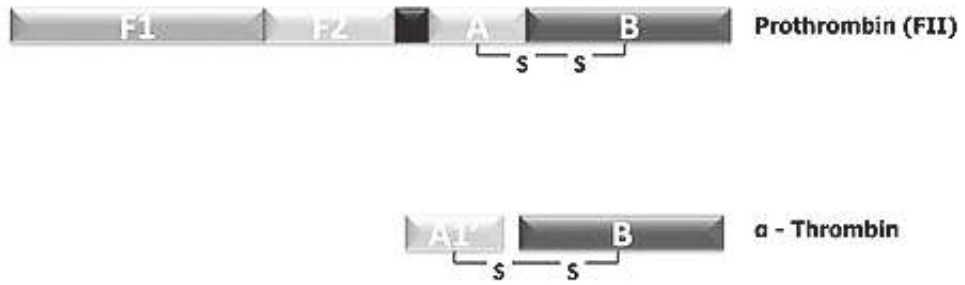
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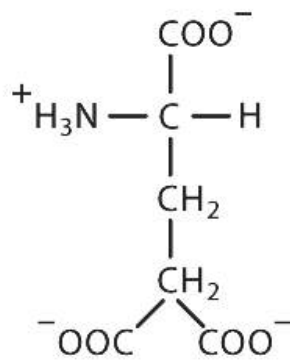
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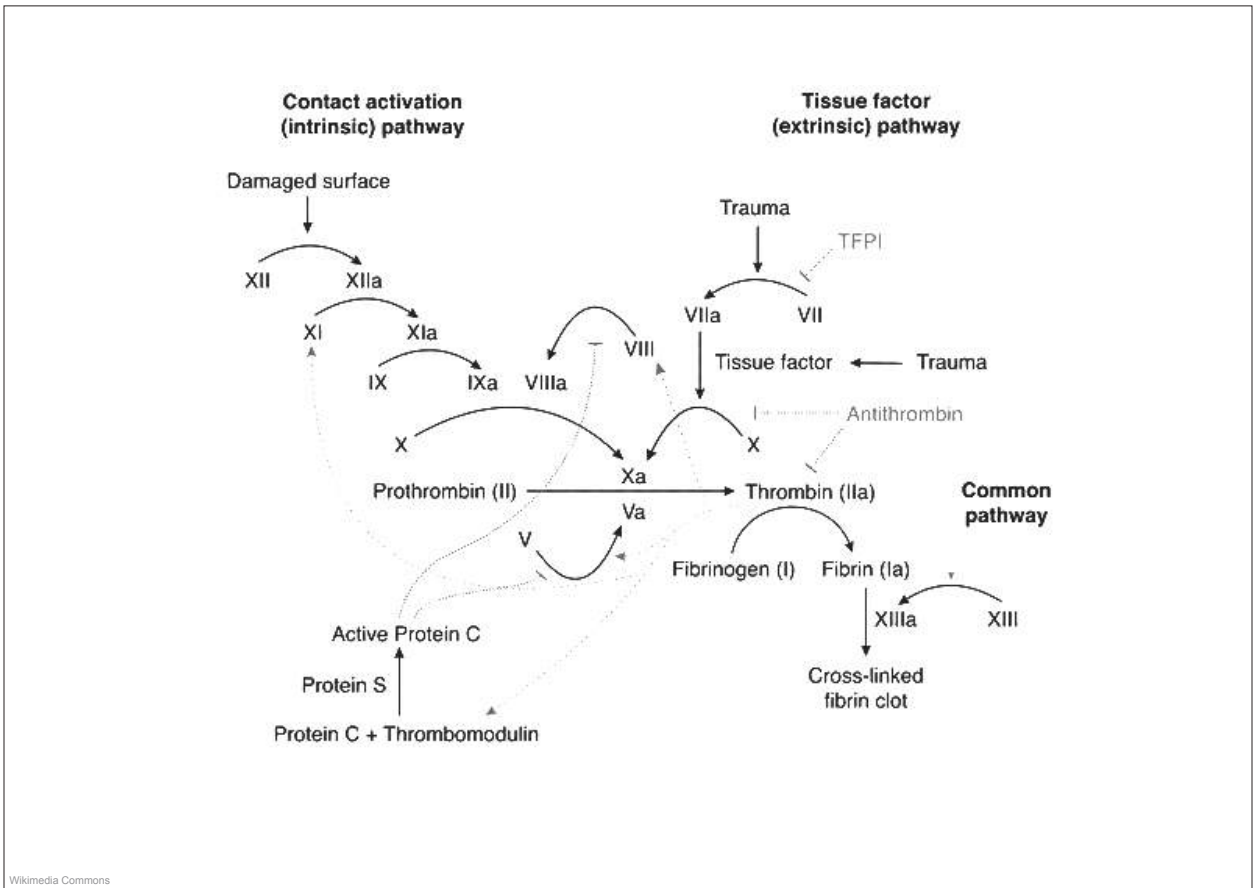
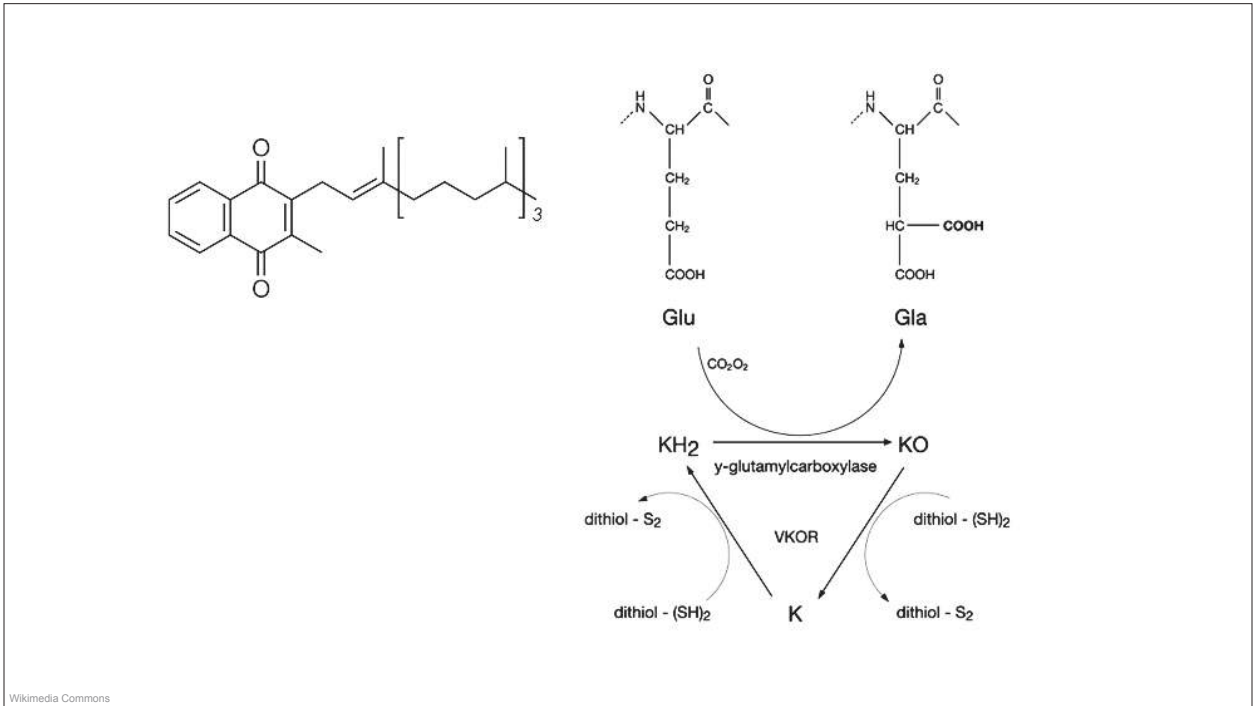
Blood Clotting & Connective Tissue Proteins



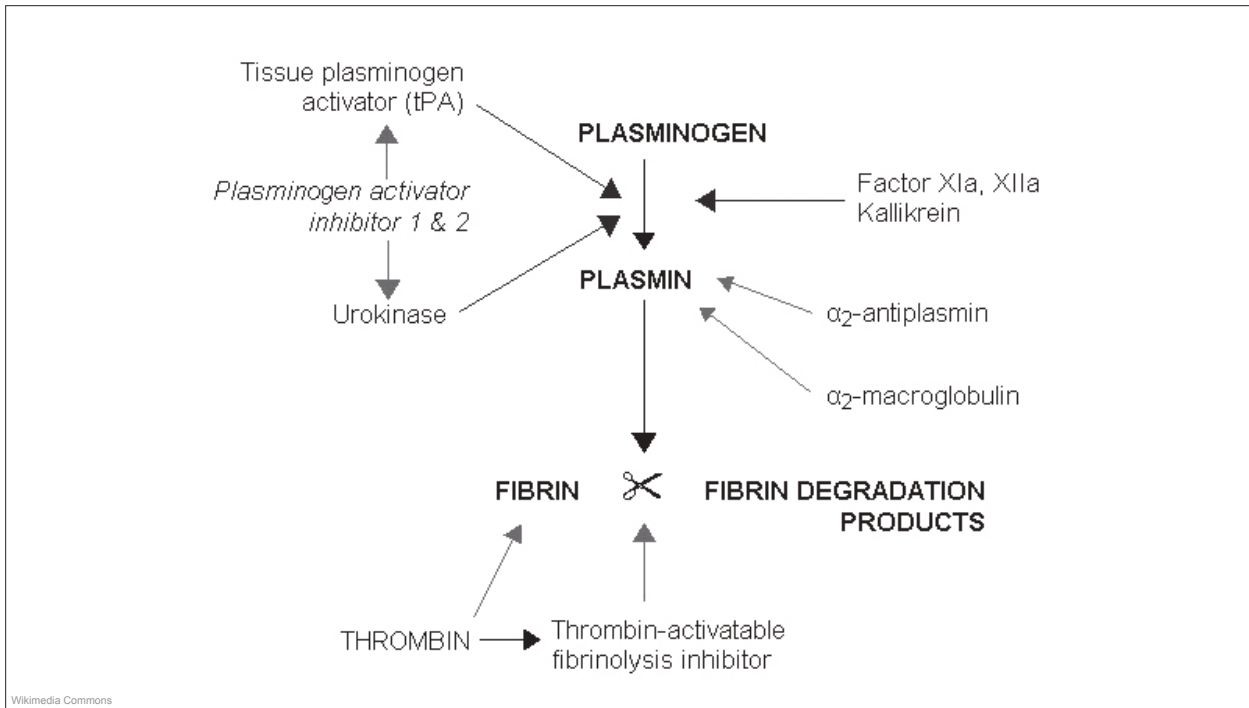
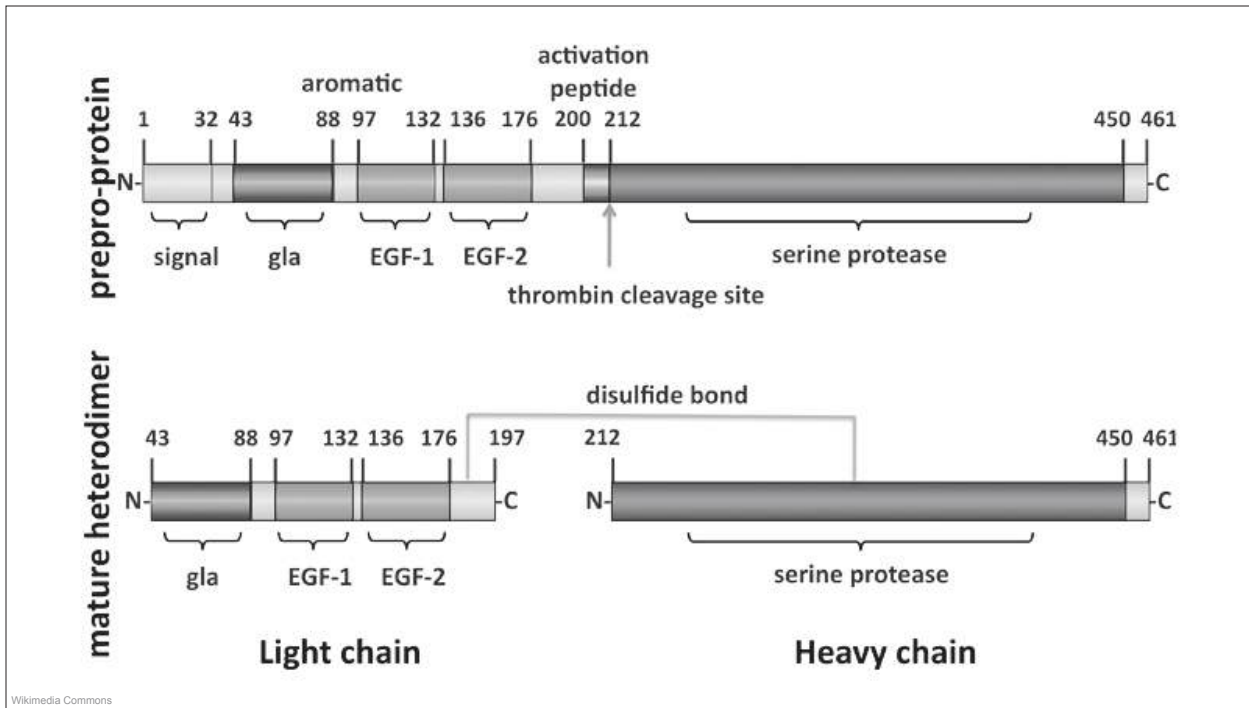
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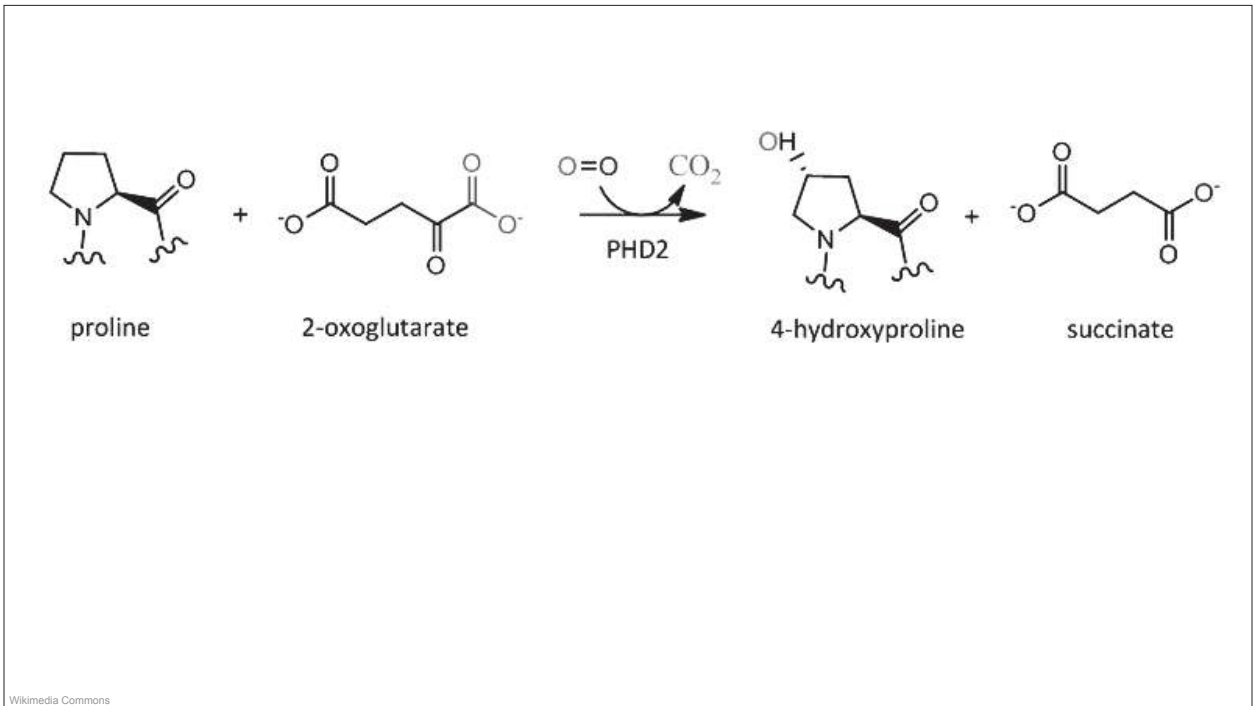
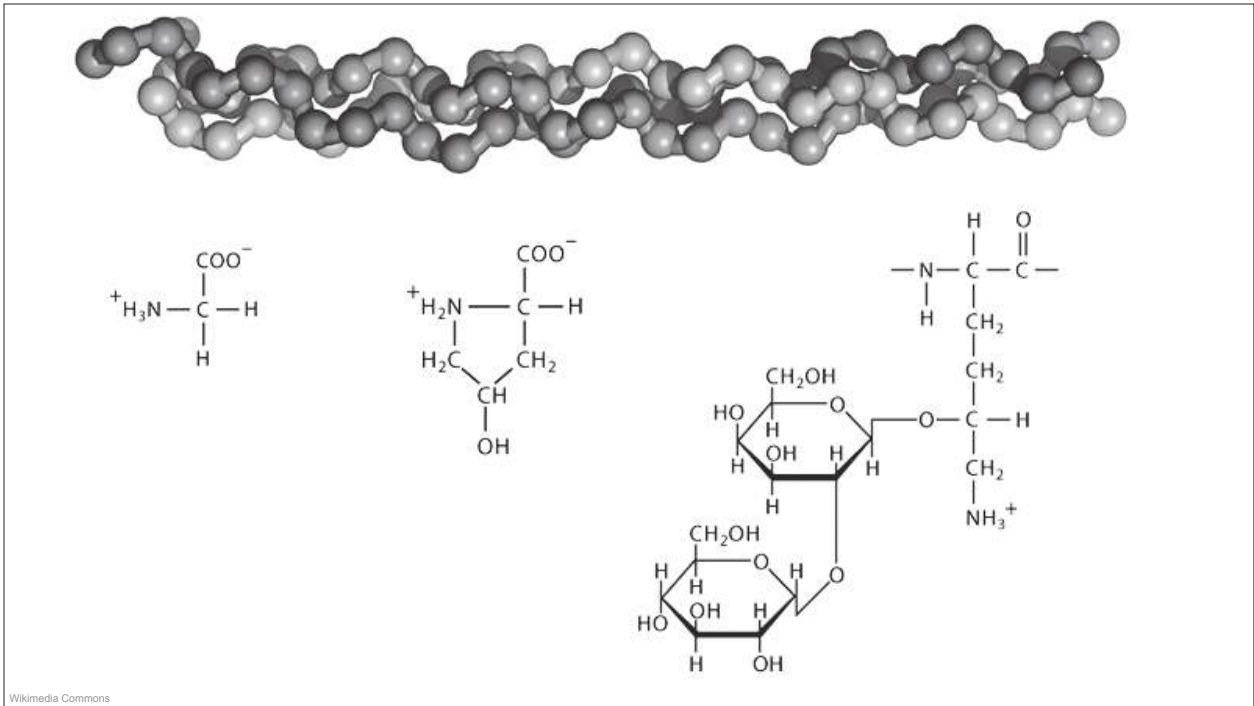


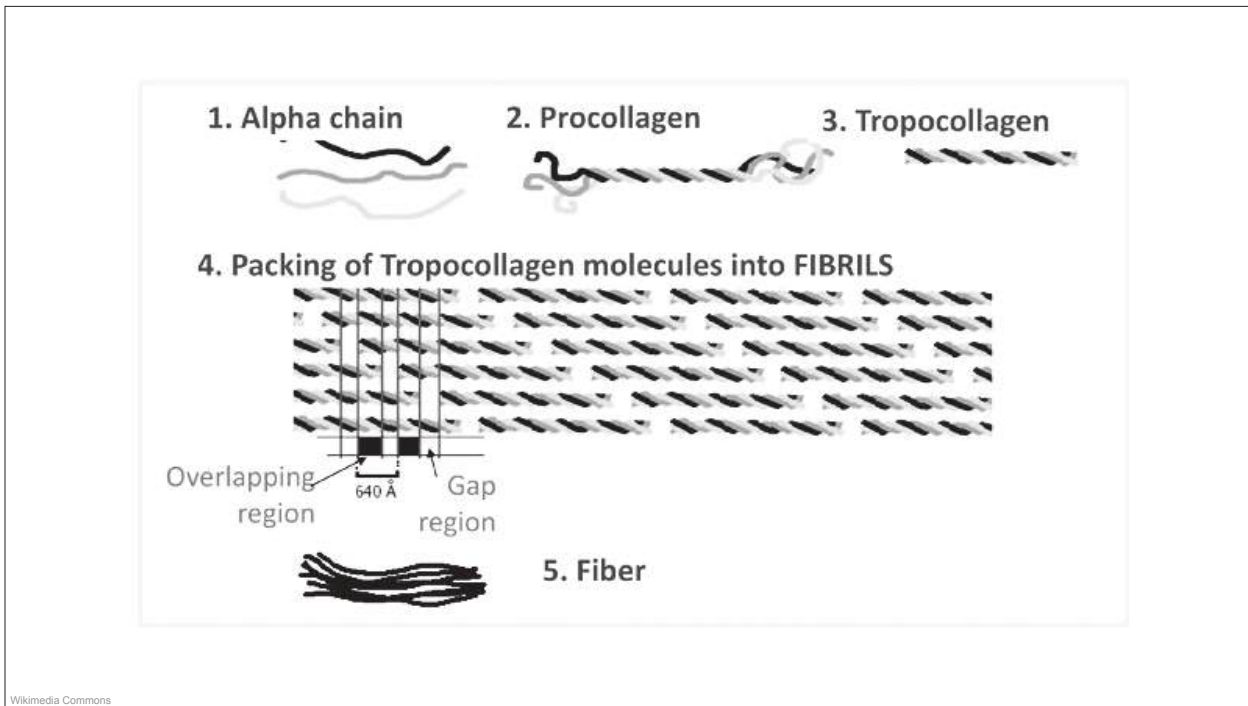
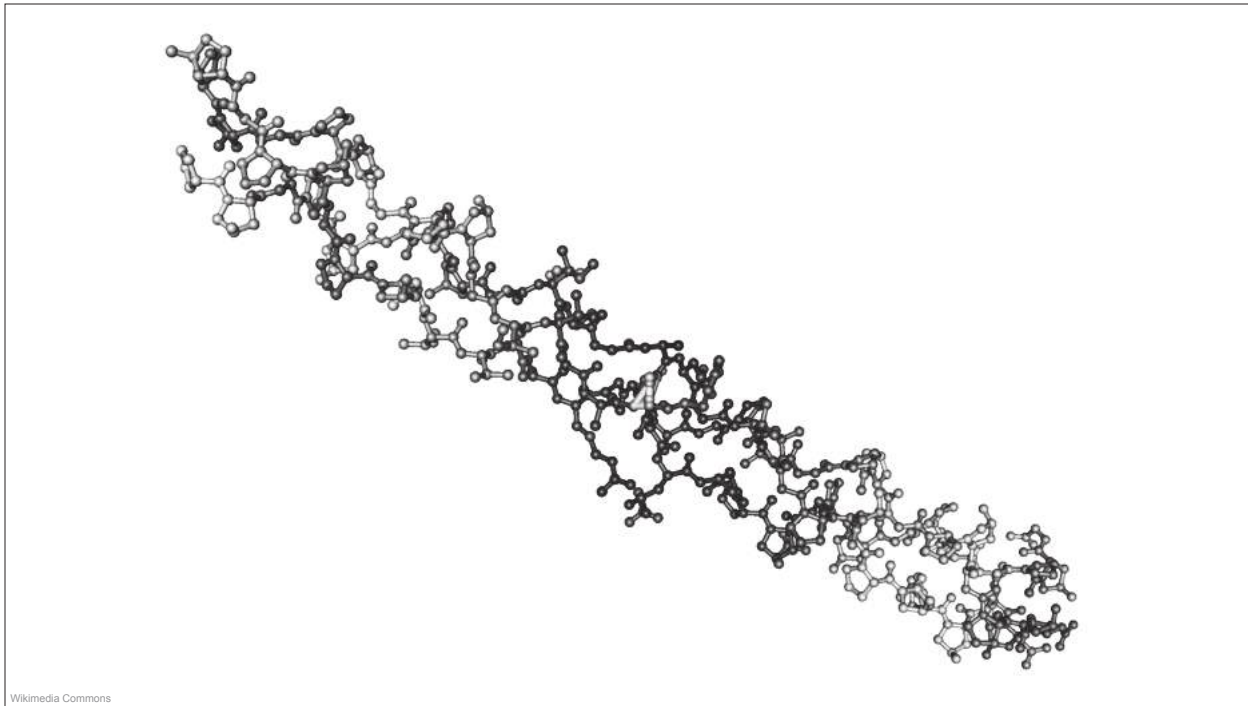
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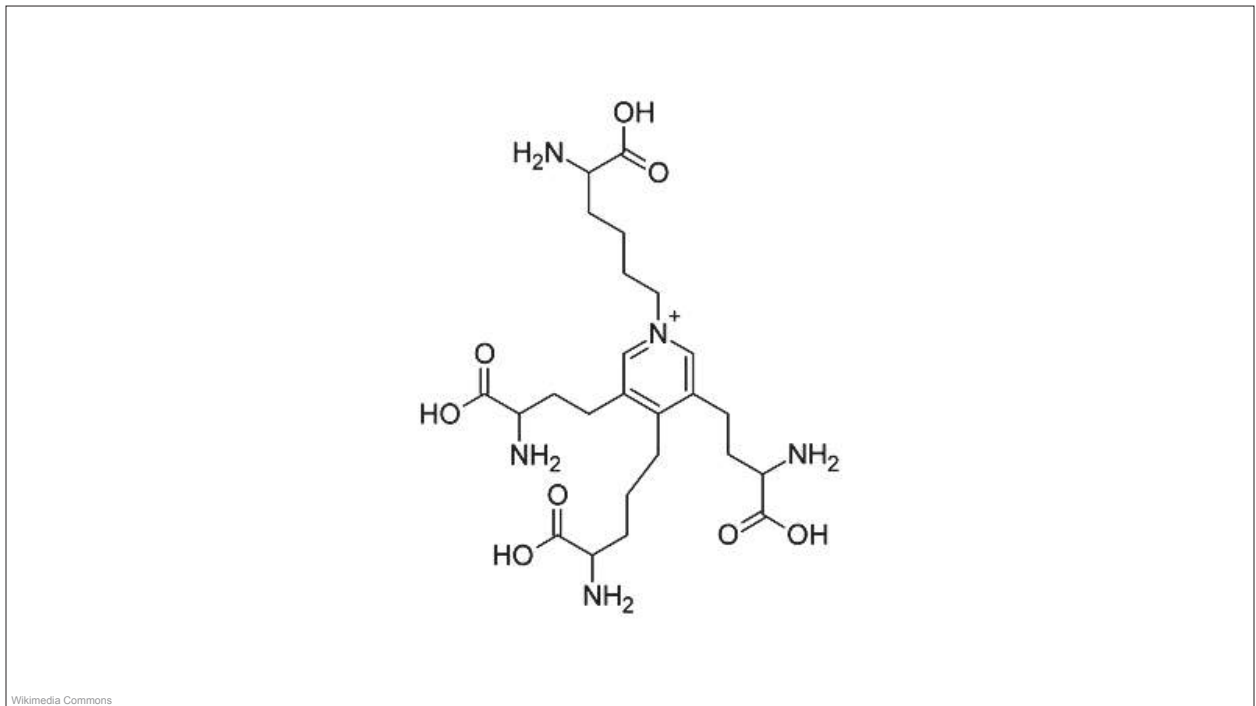
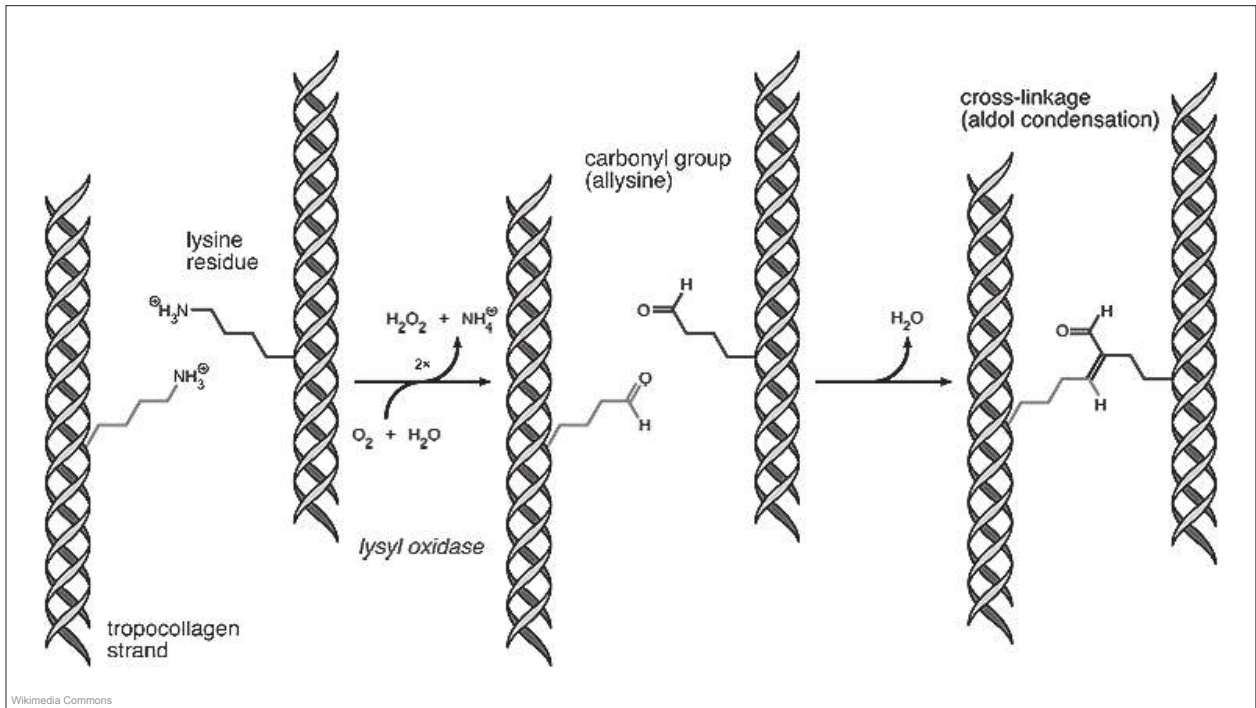


Blood Clotting & Connective Tissue Proteins

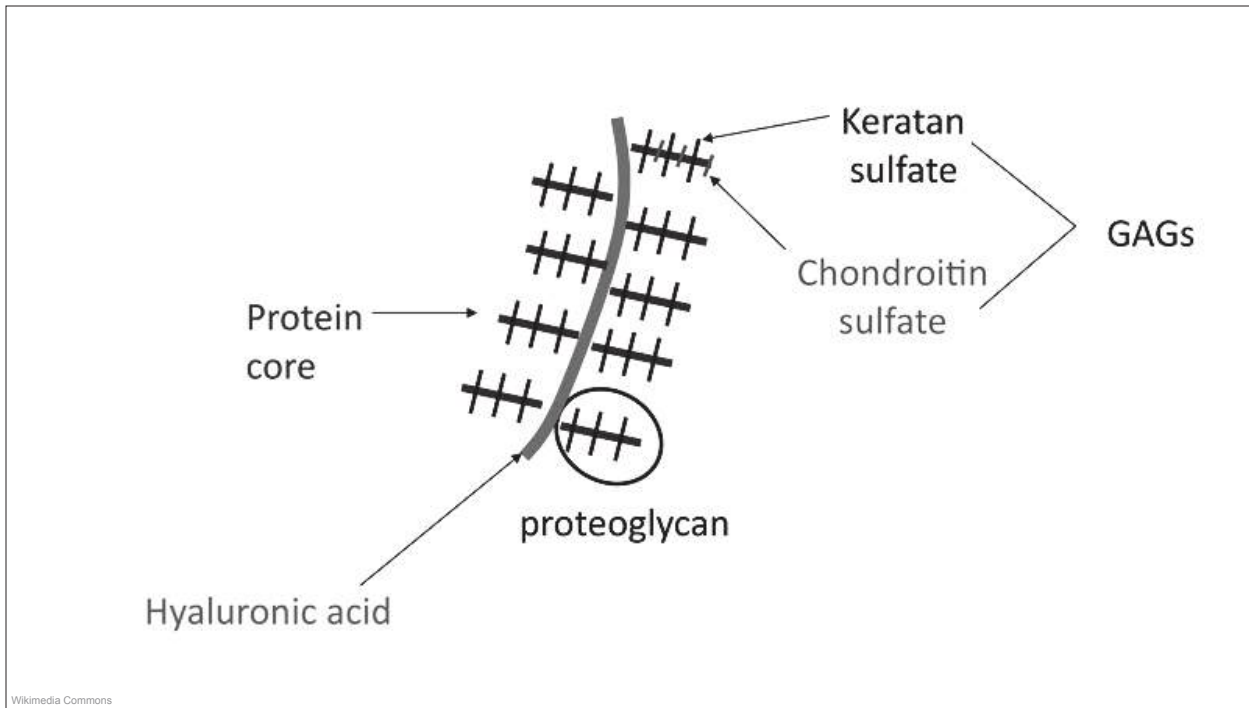




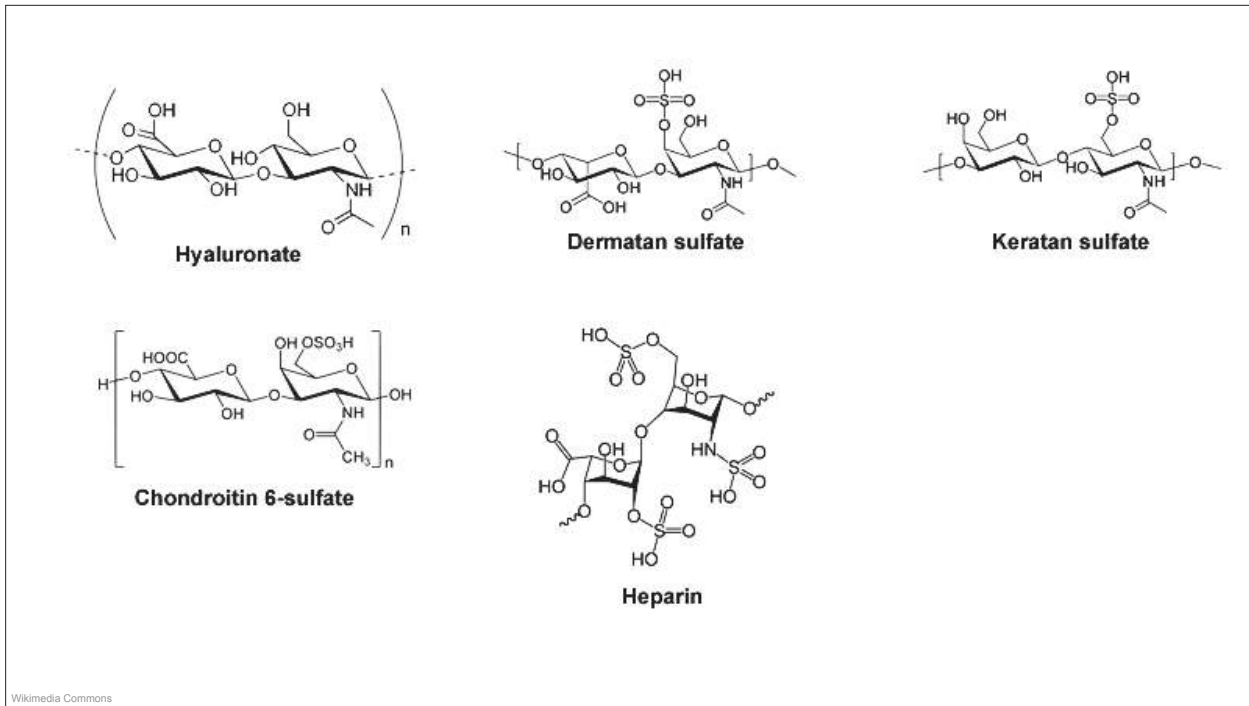




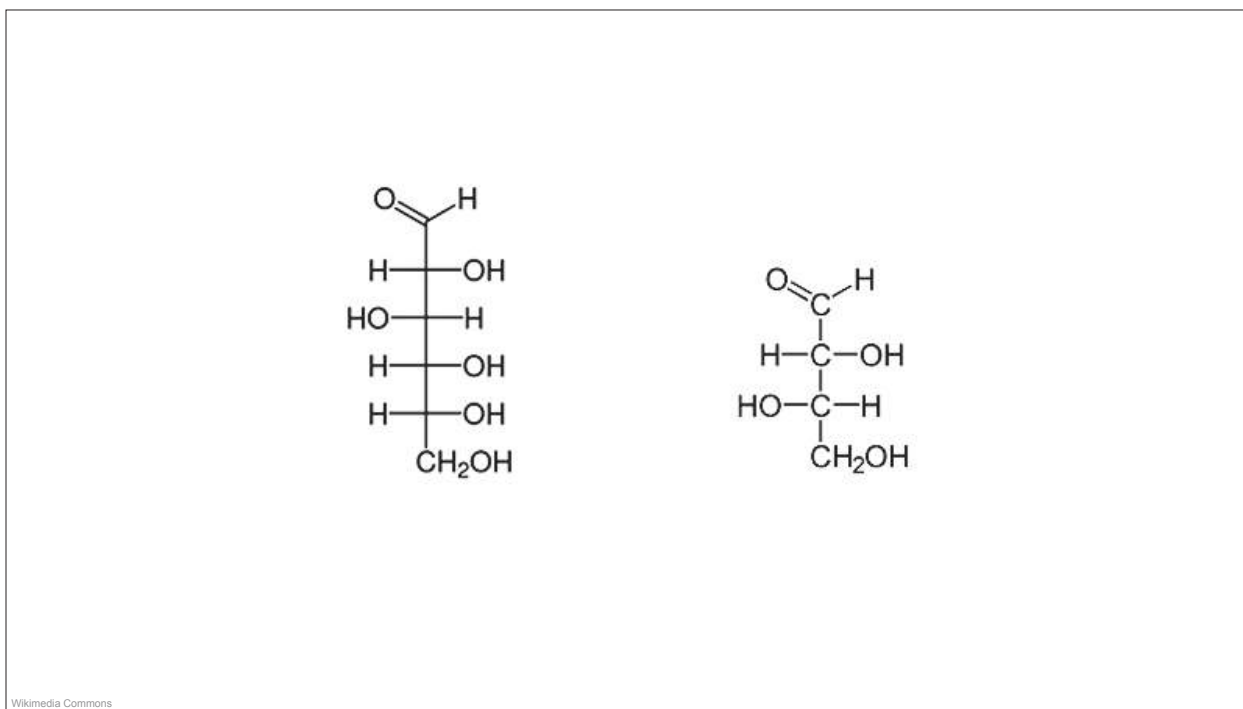
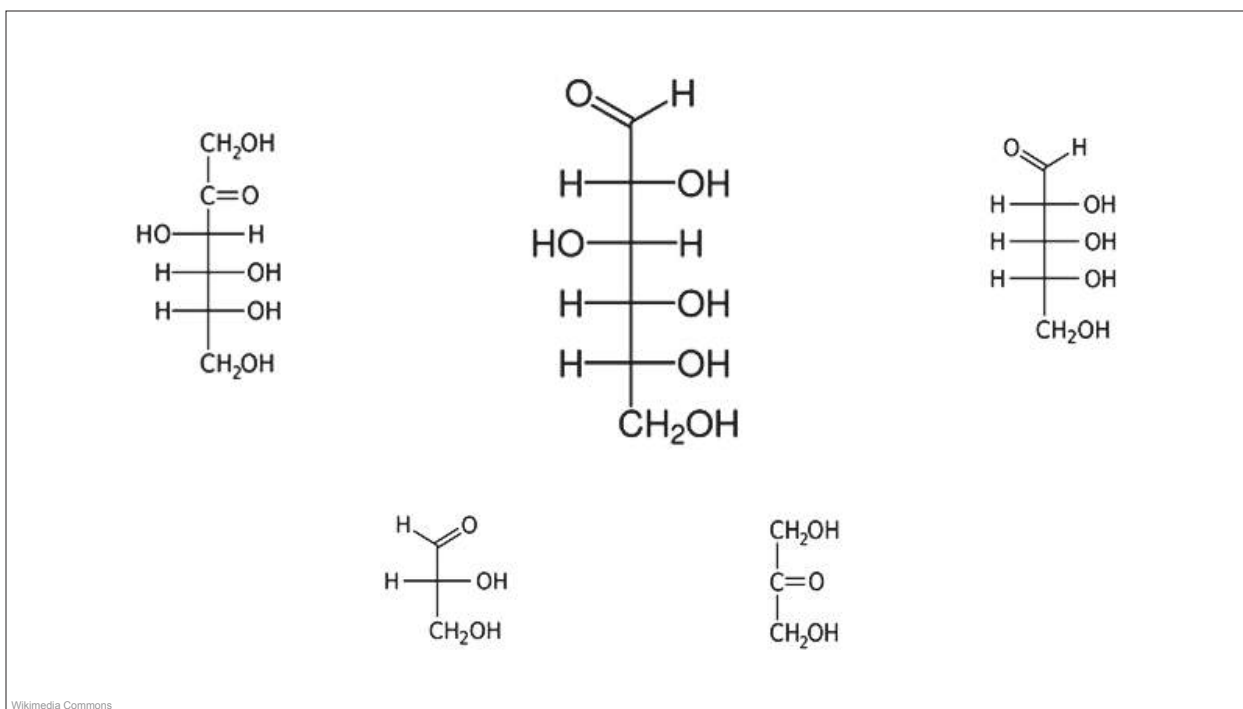
Blood Clotting & Connective Tissue Proteins



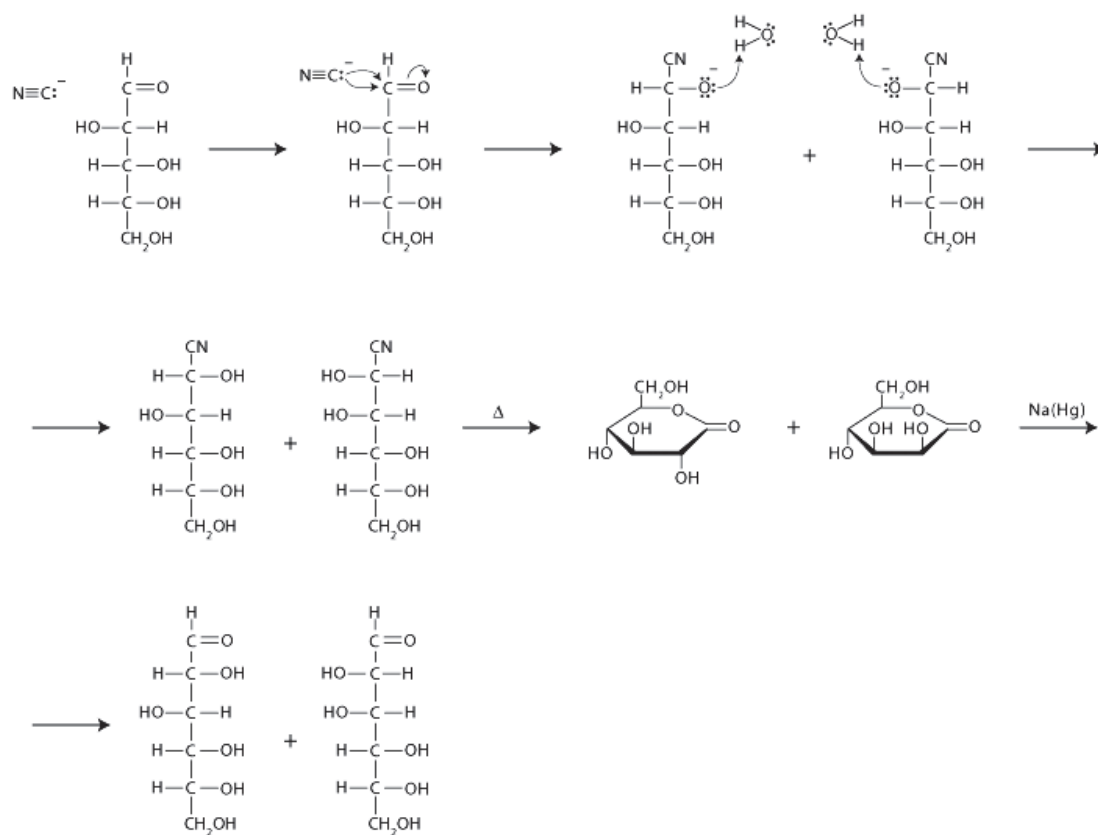
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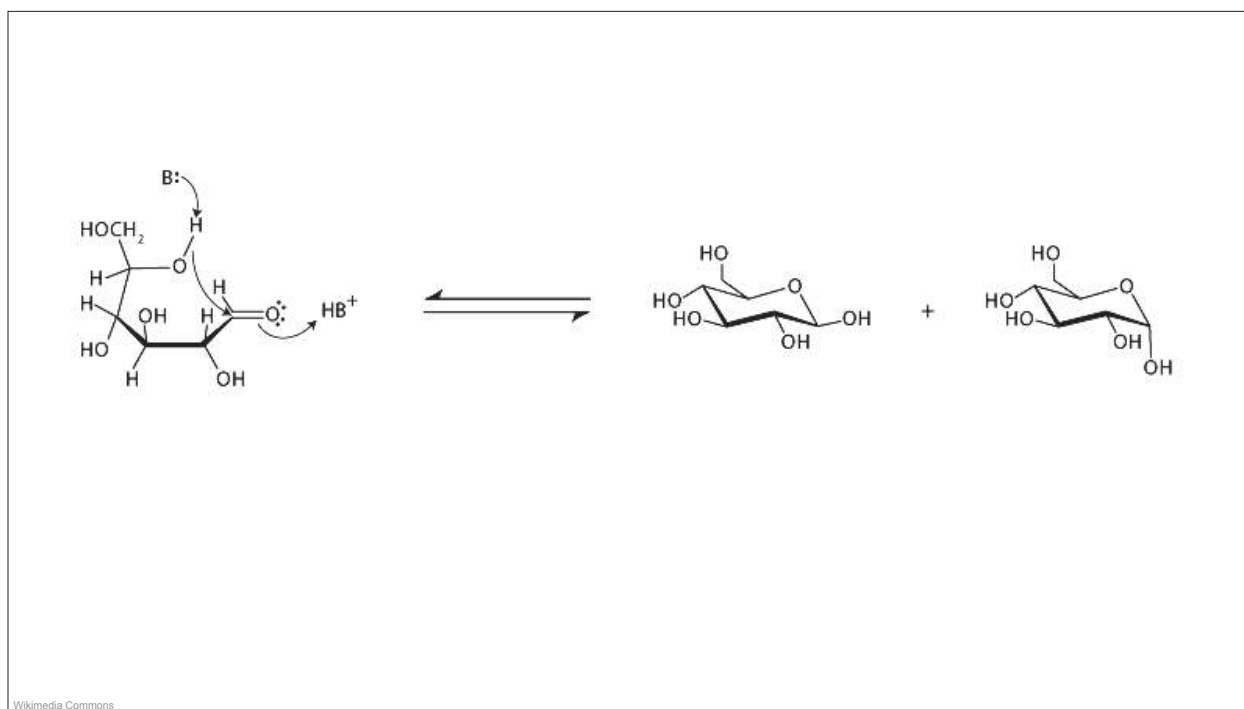
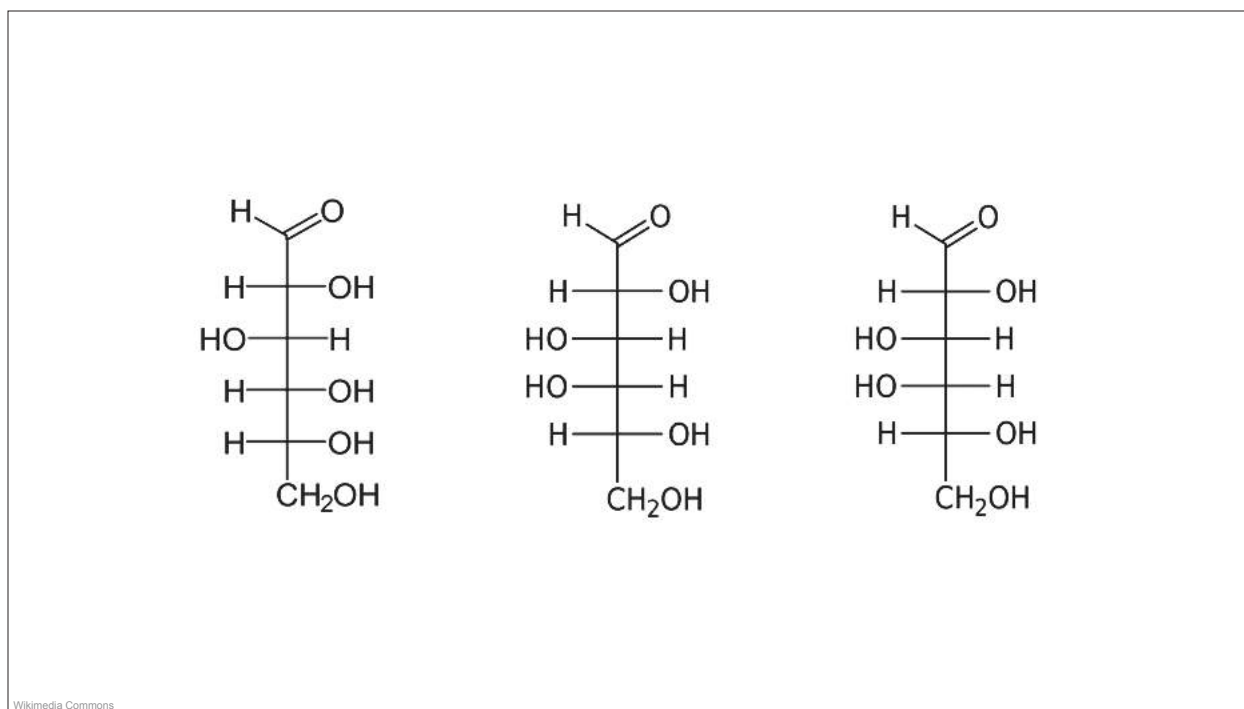


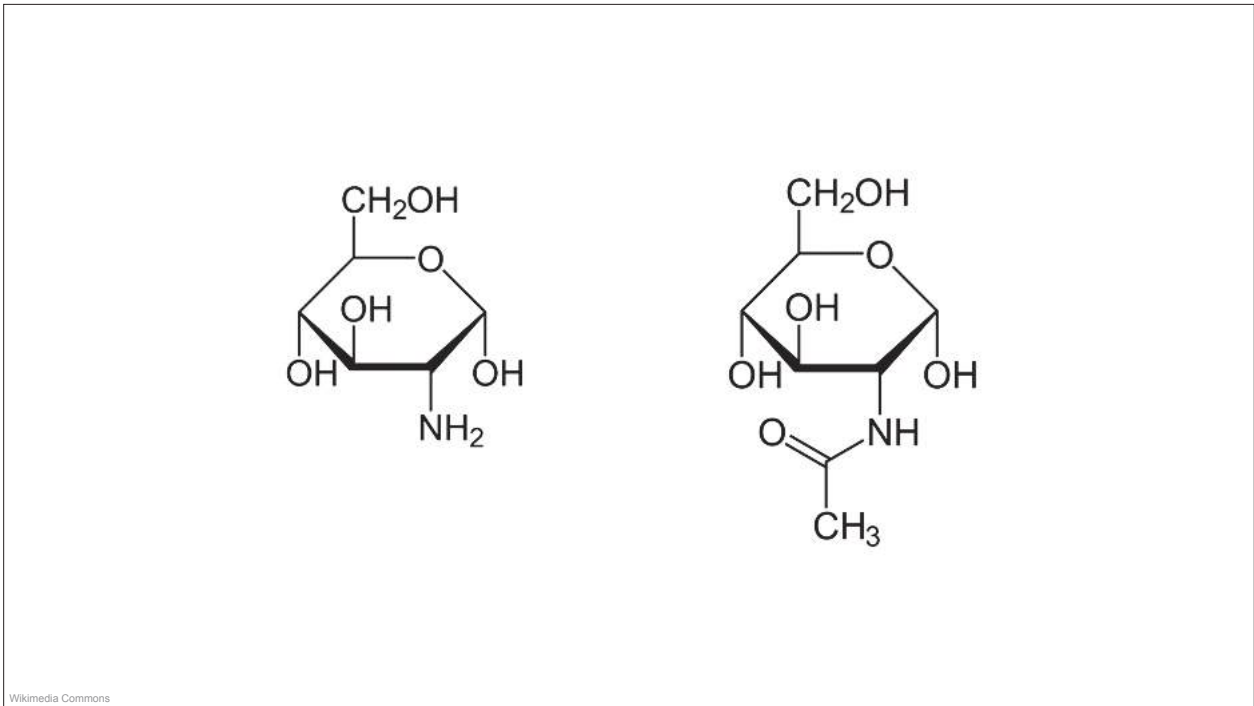
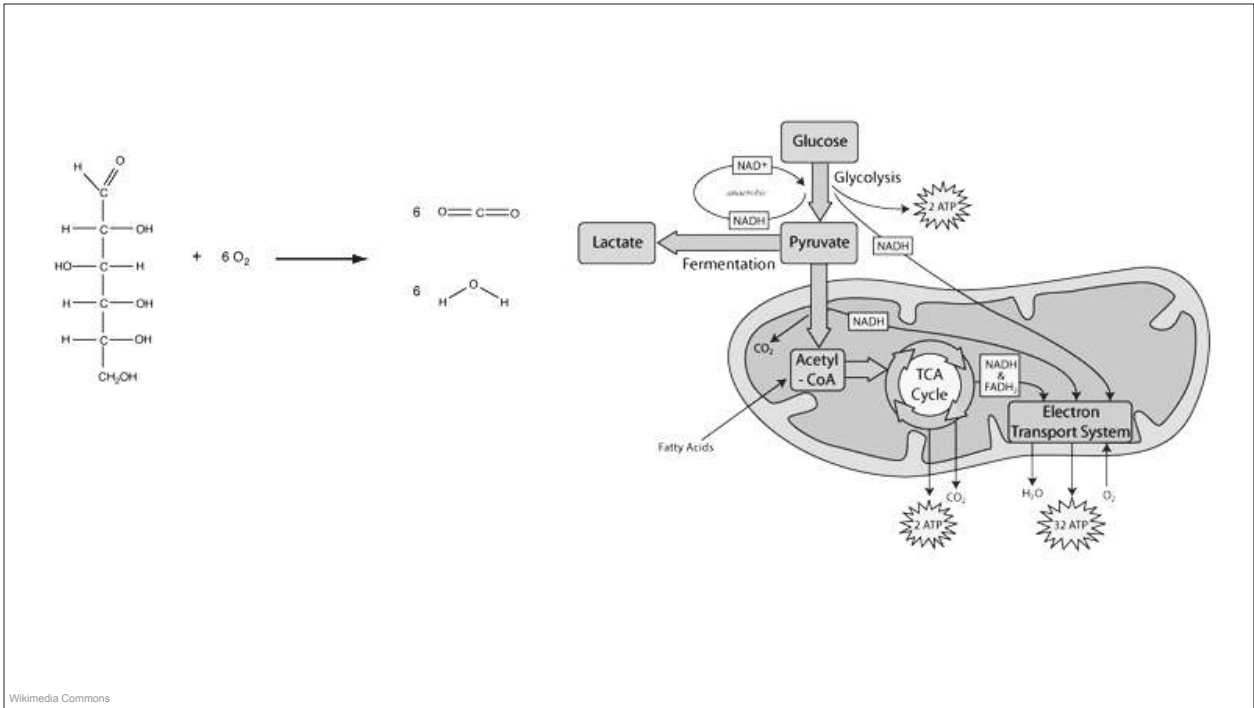
Carbohydrates



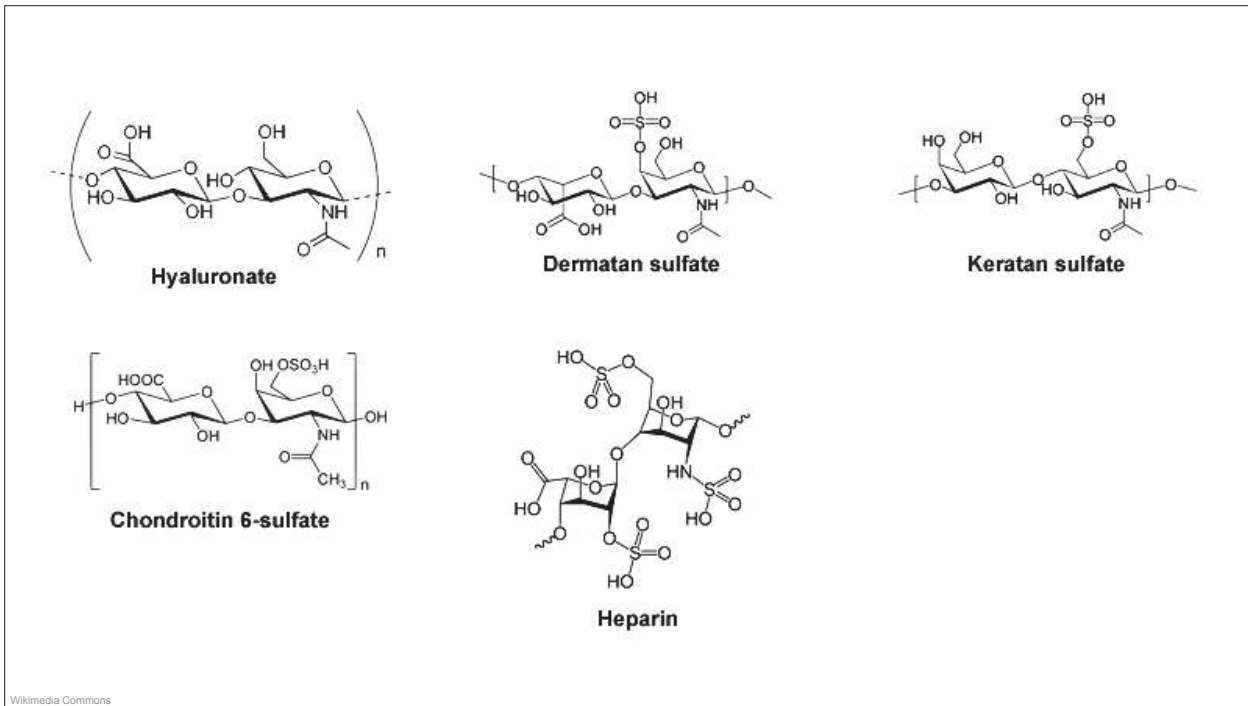
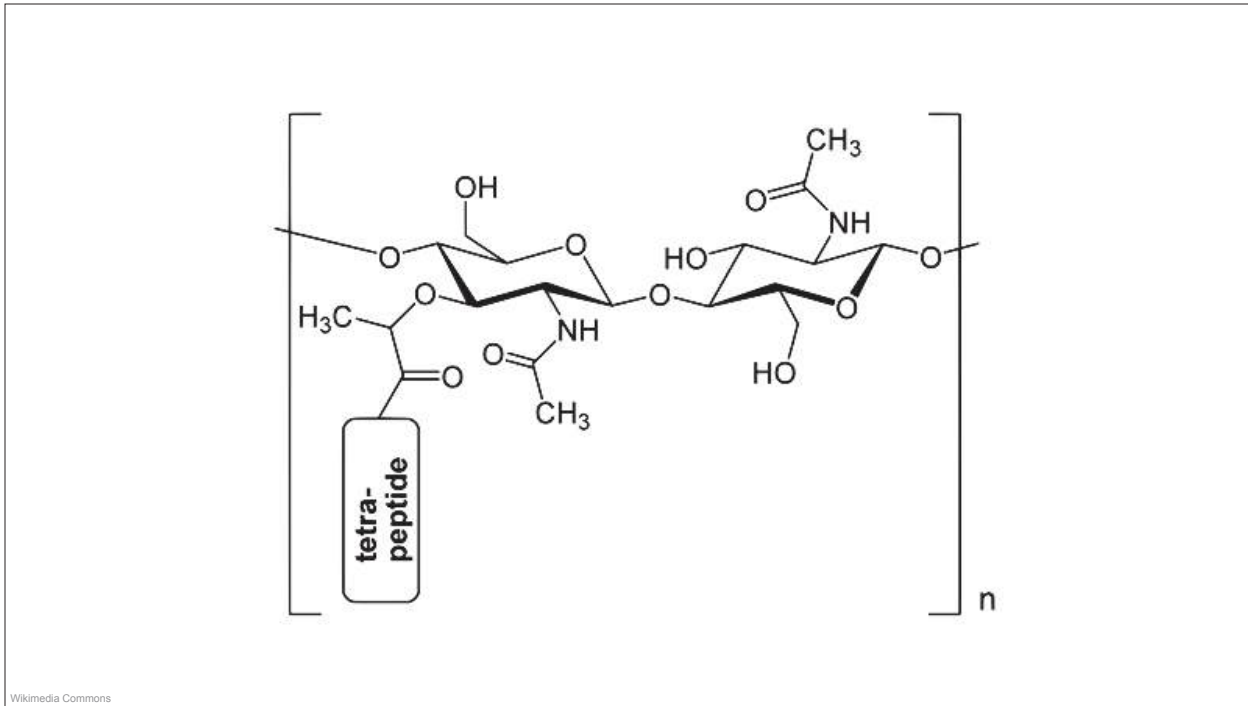
Steps of the Kiliani-Fischer synthesis of D-glucose and its C-2 epimer, D-mannose, from D-arabinose

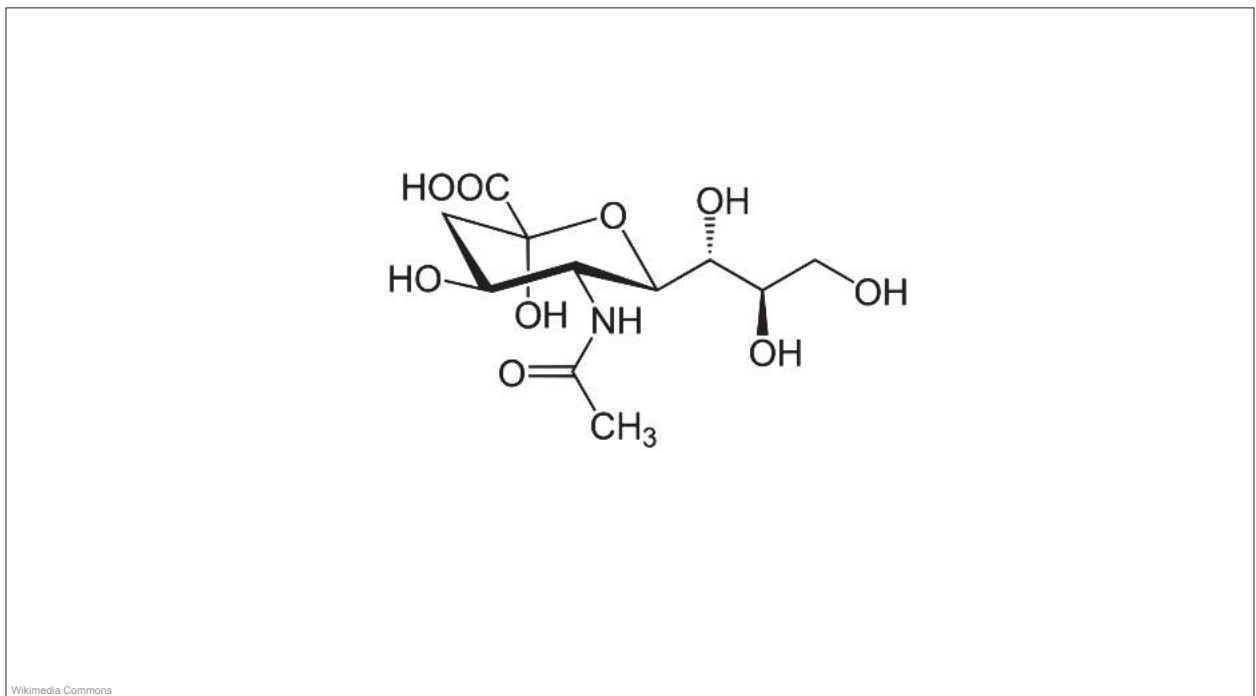
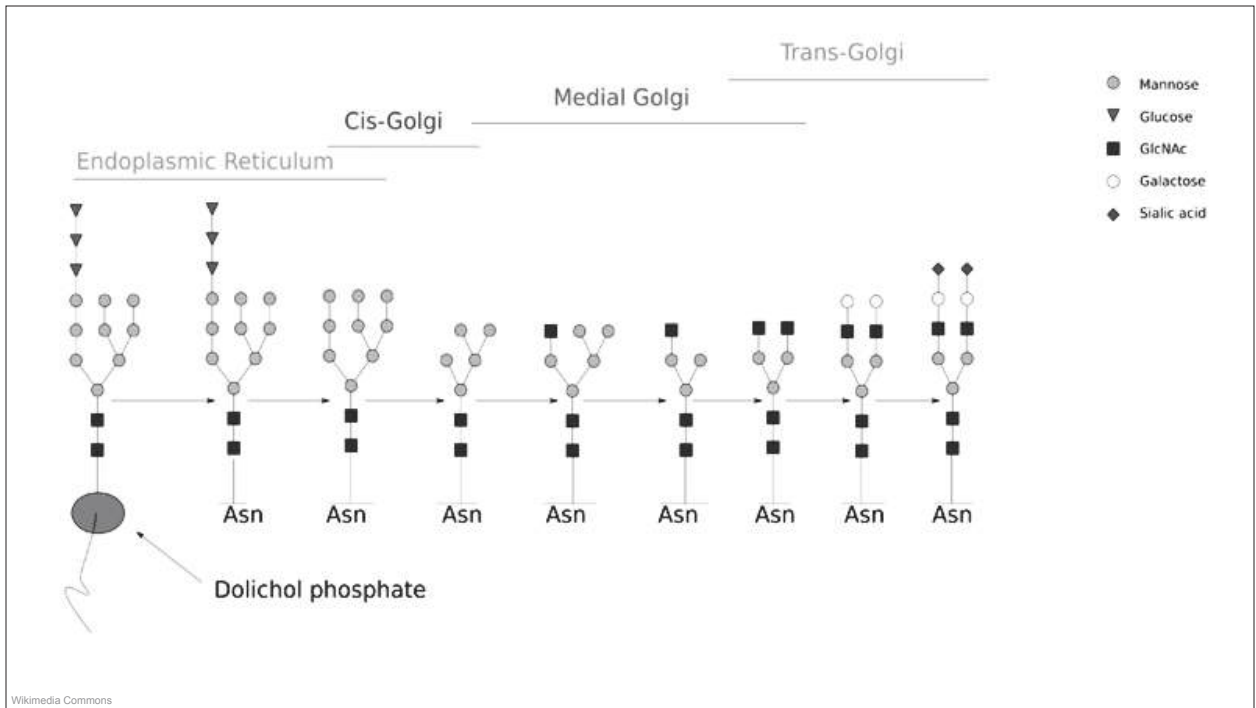
Carbohydrates



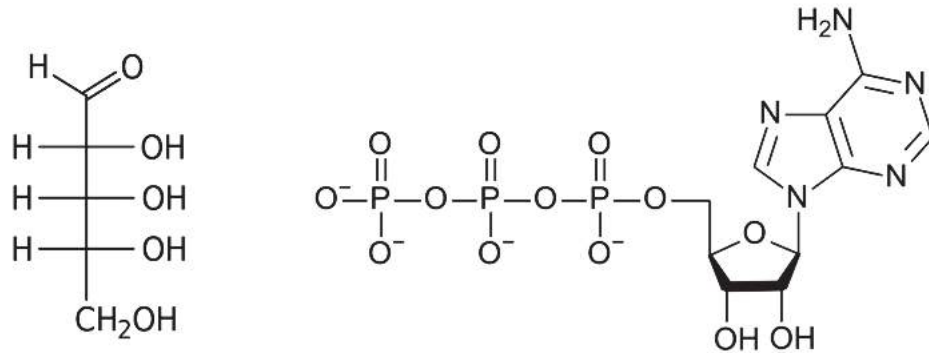


Carbohydrates

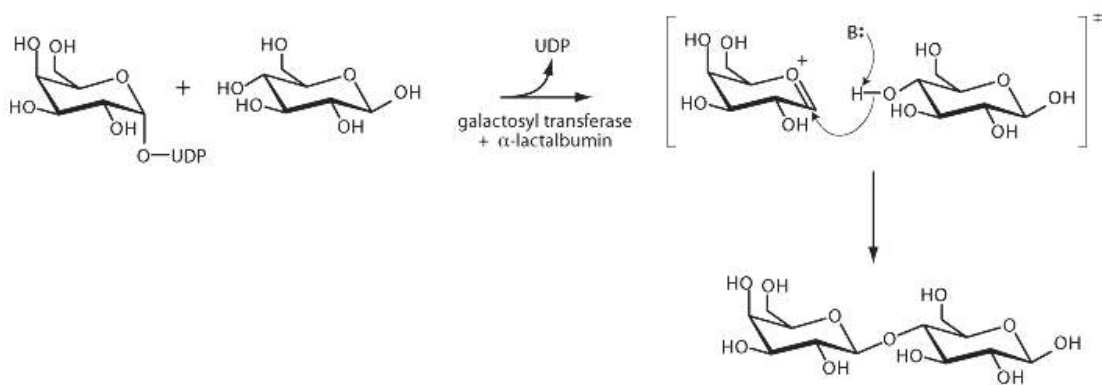




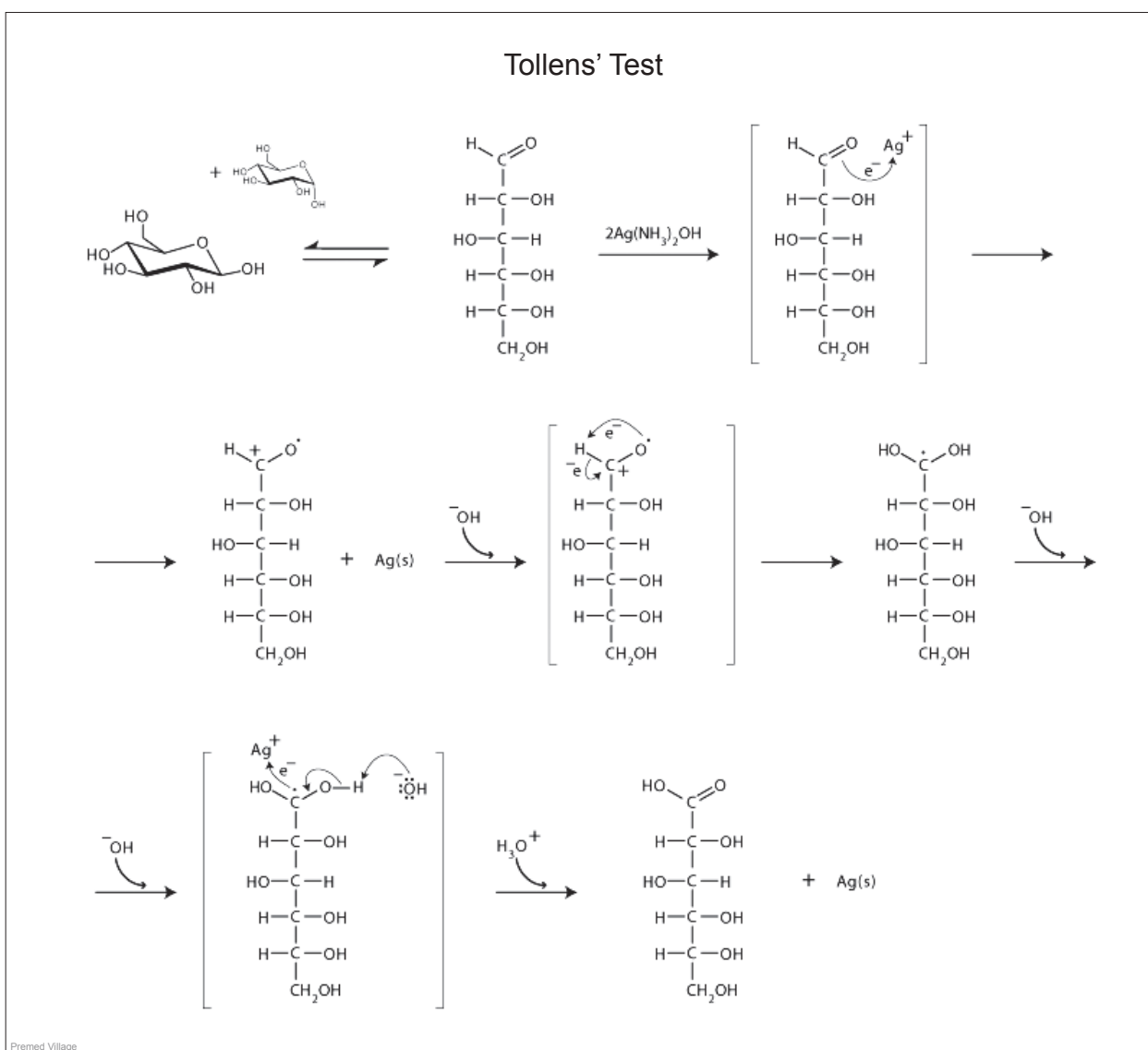
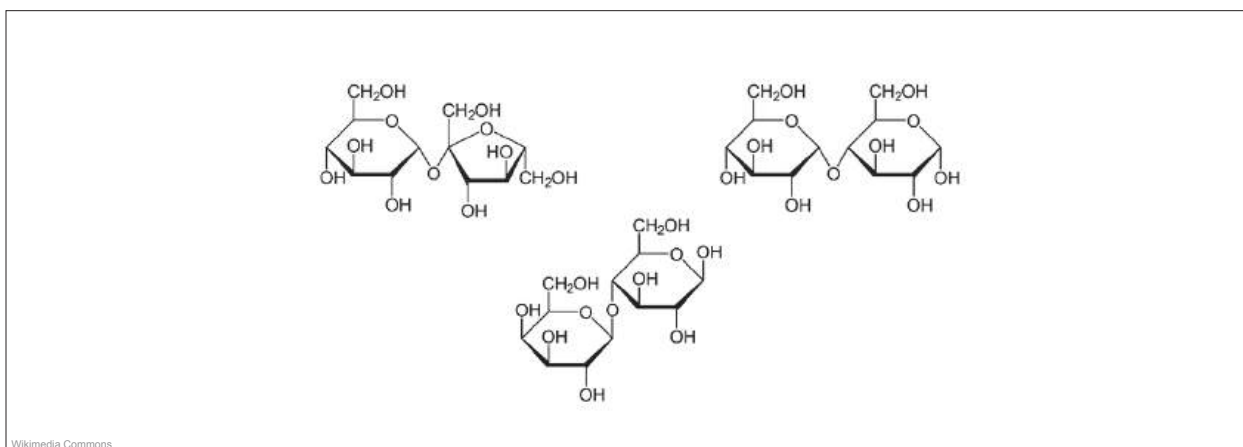
Carbohydrates



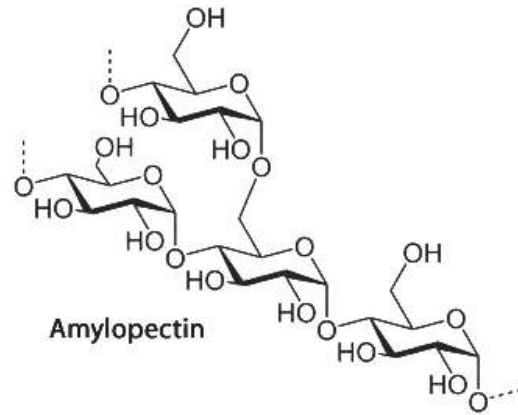
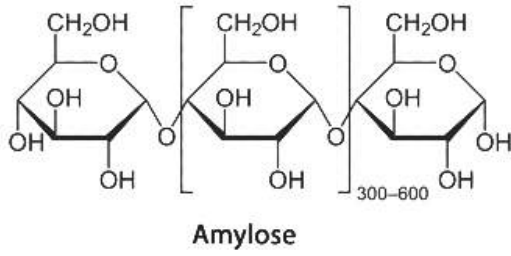
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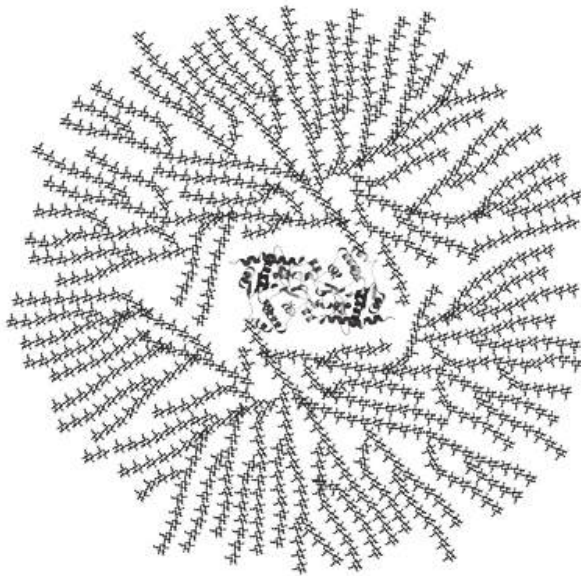
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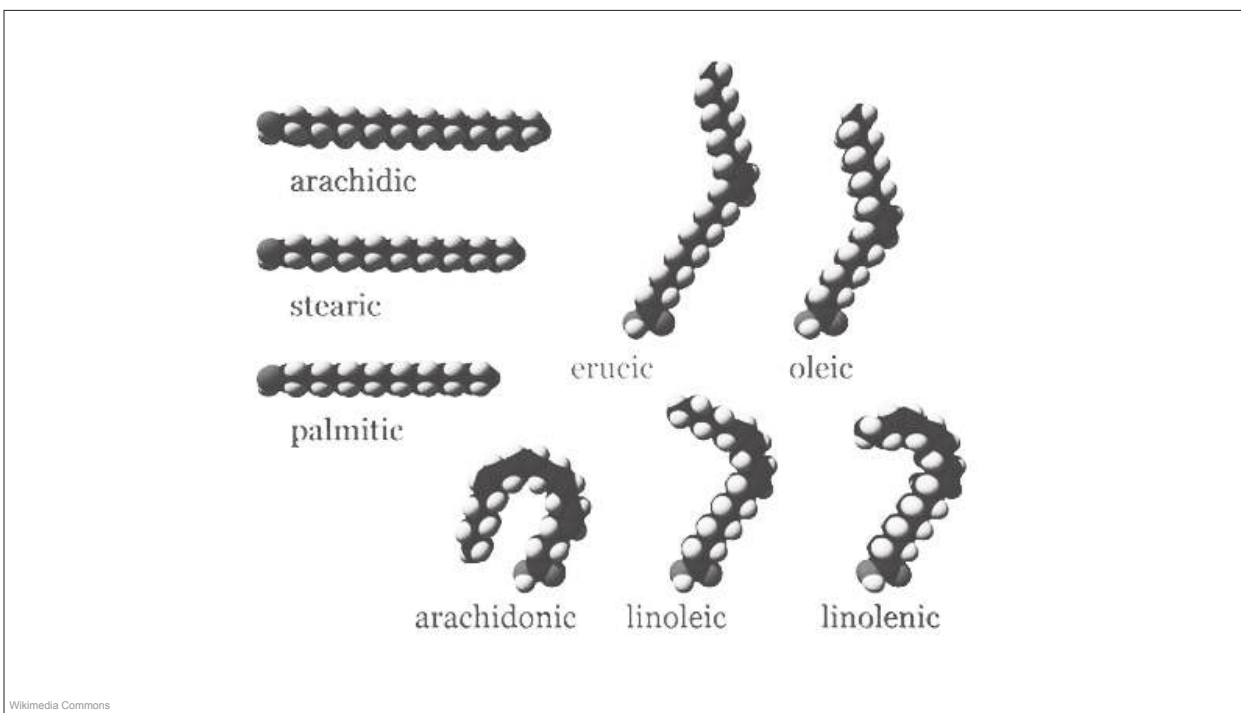
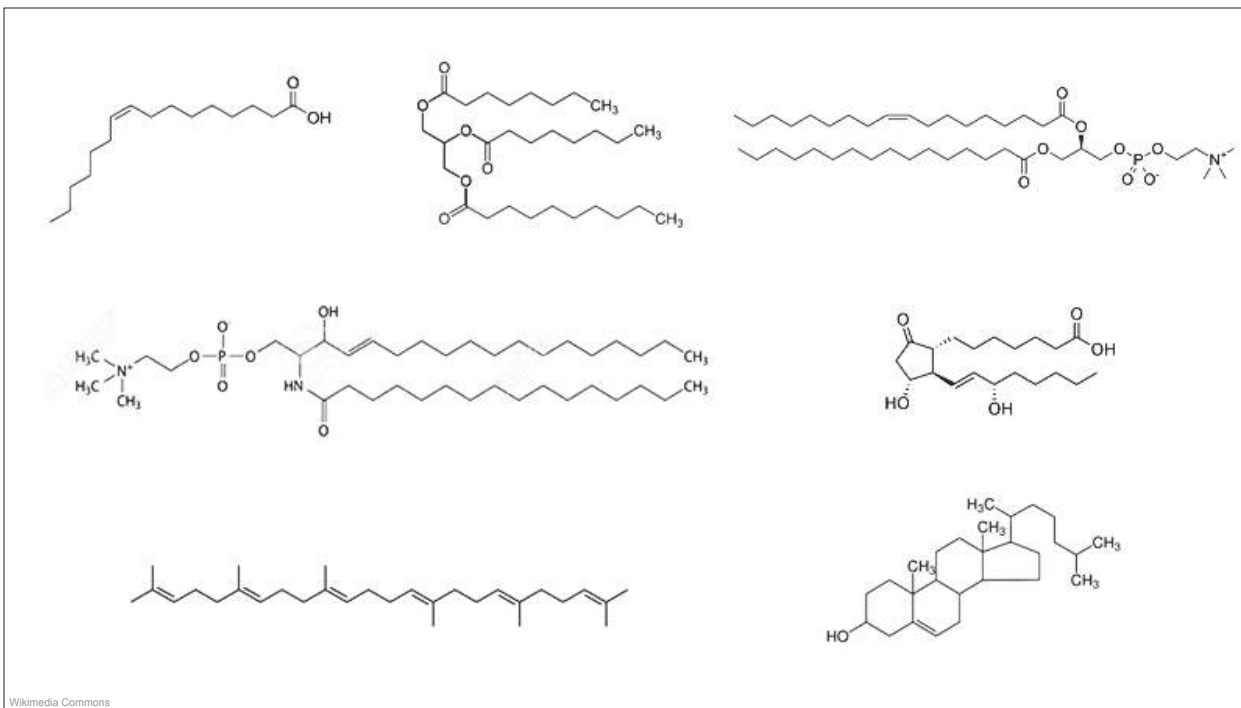
Carbohydrates



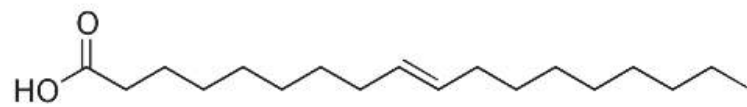
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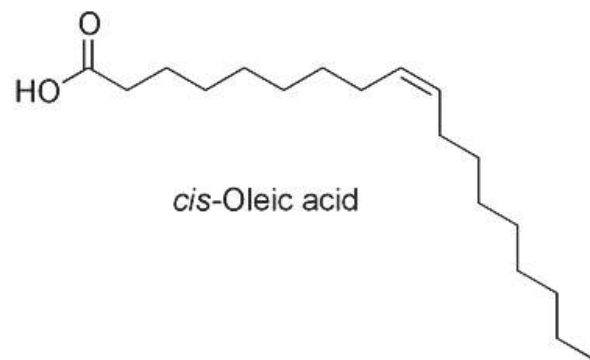
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Lipids

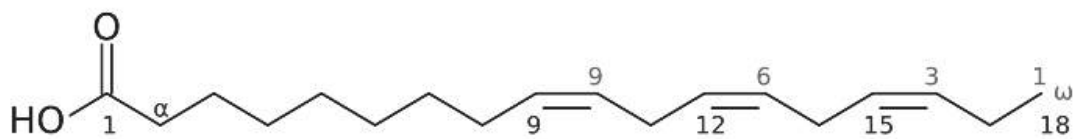


trans-Oleic acid

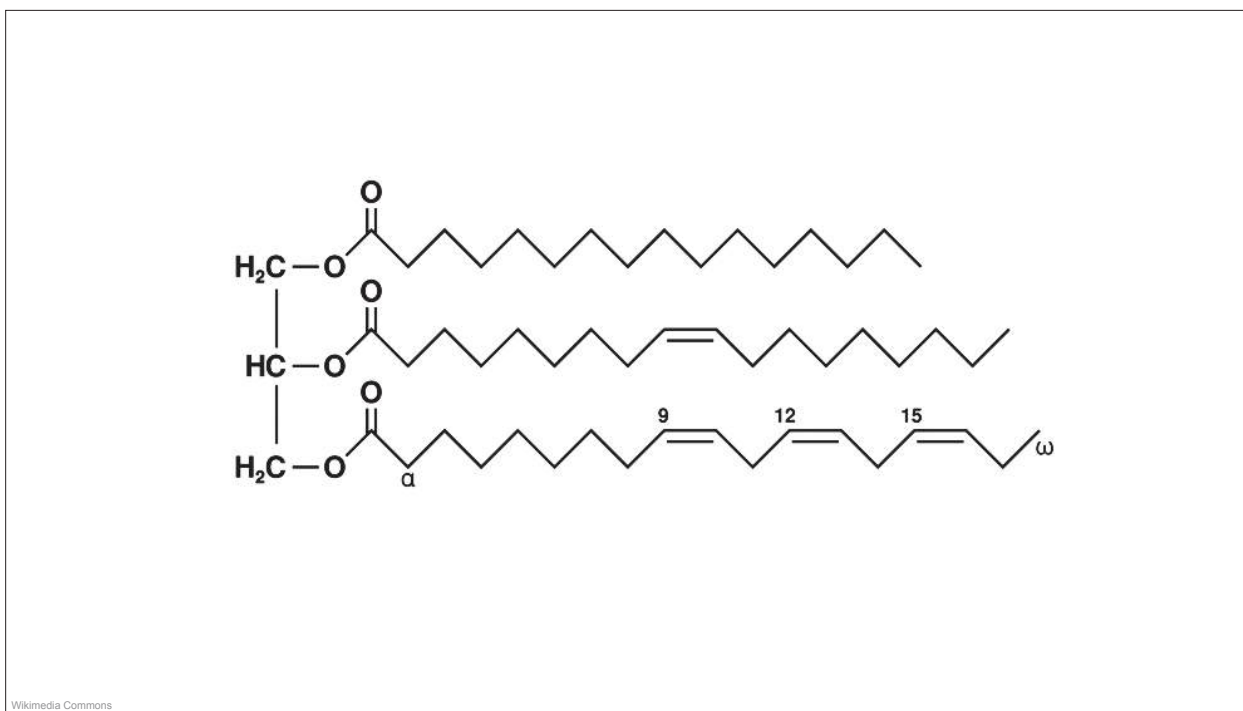
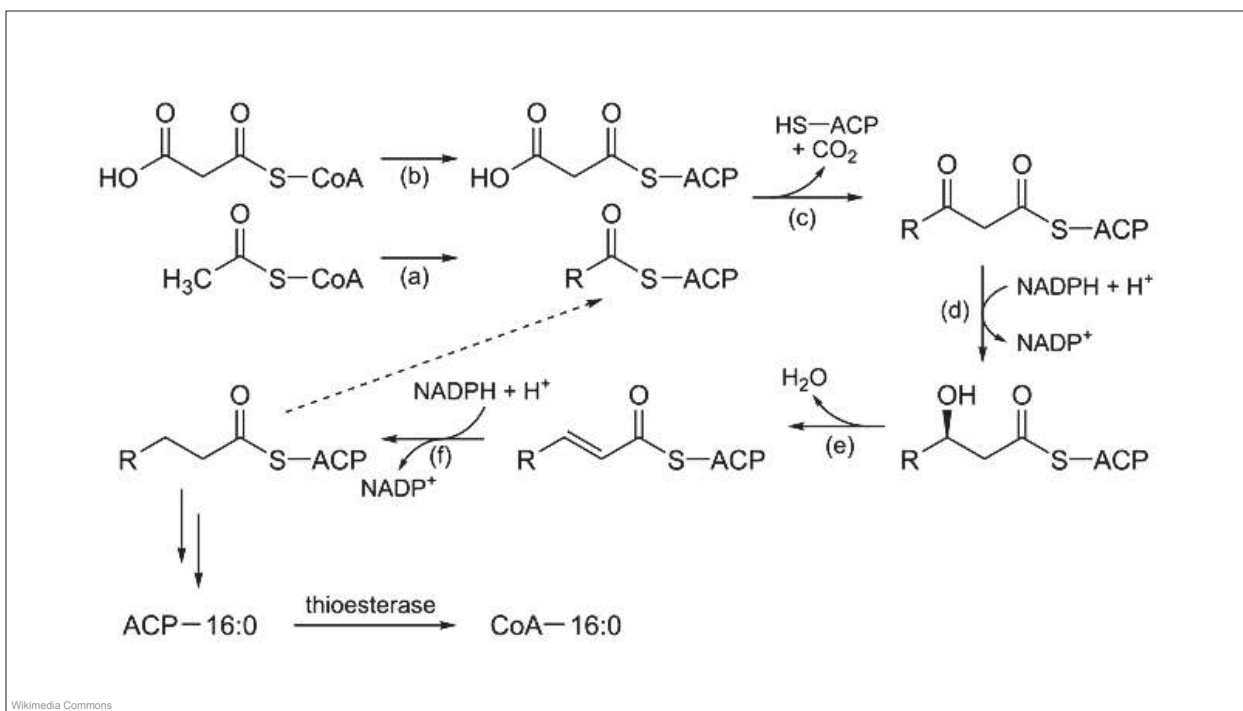


cis-Oleic acid

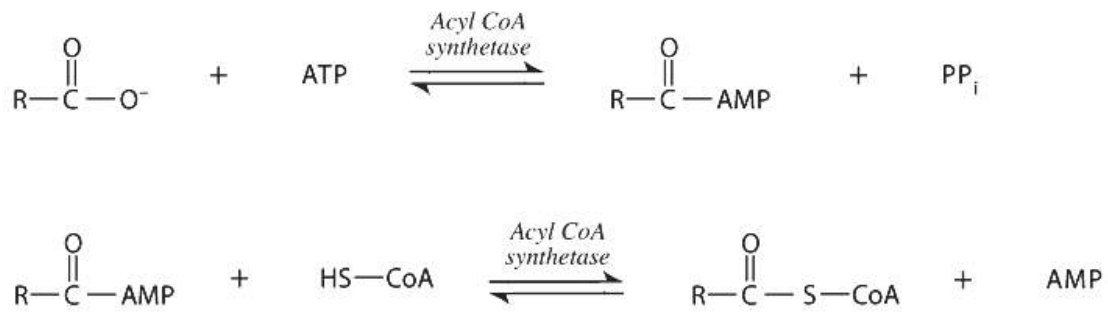
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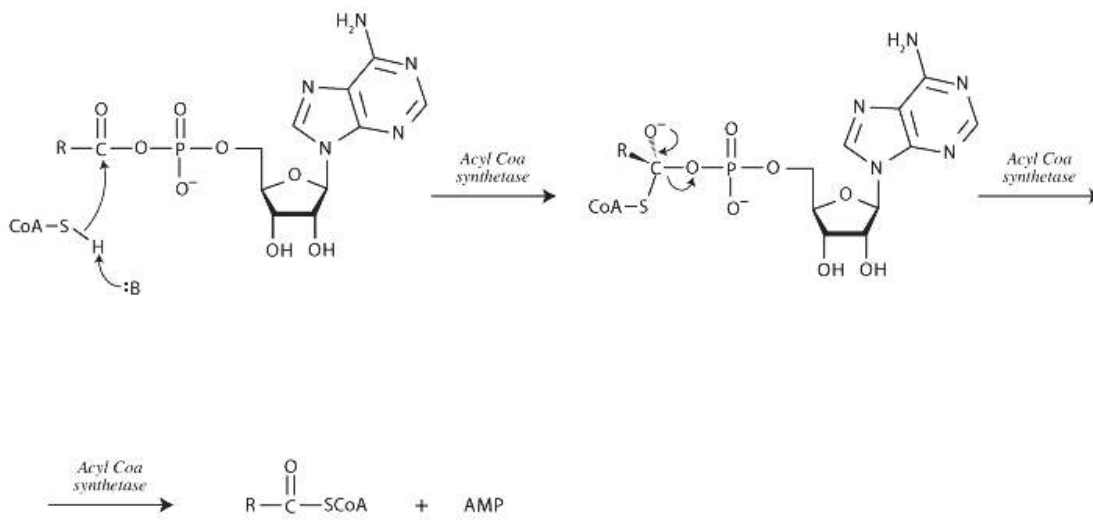
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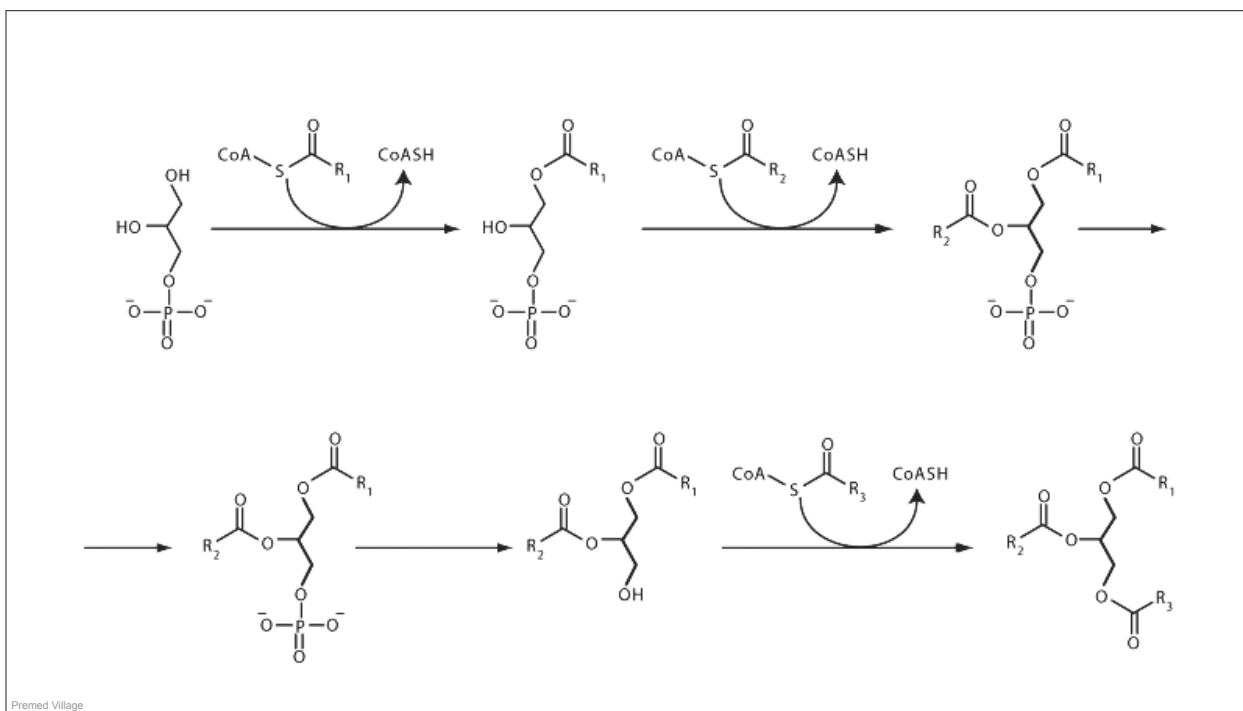
Lipids

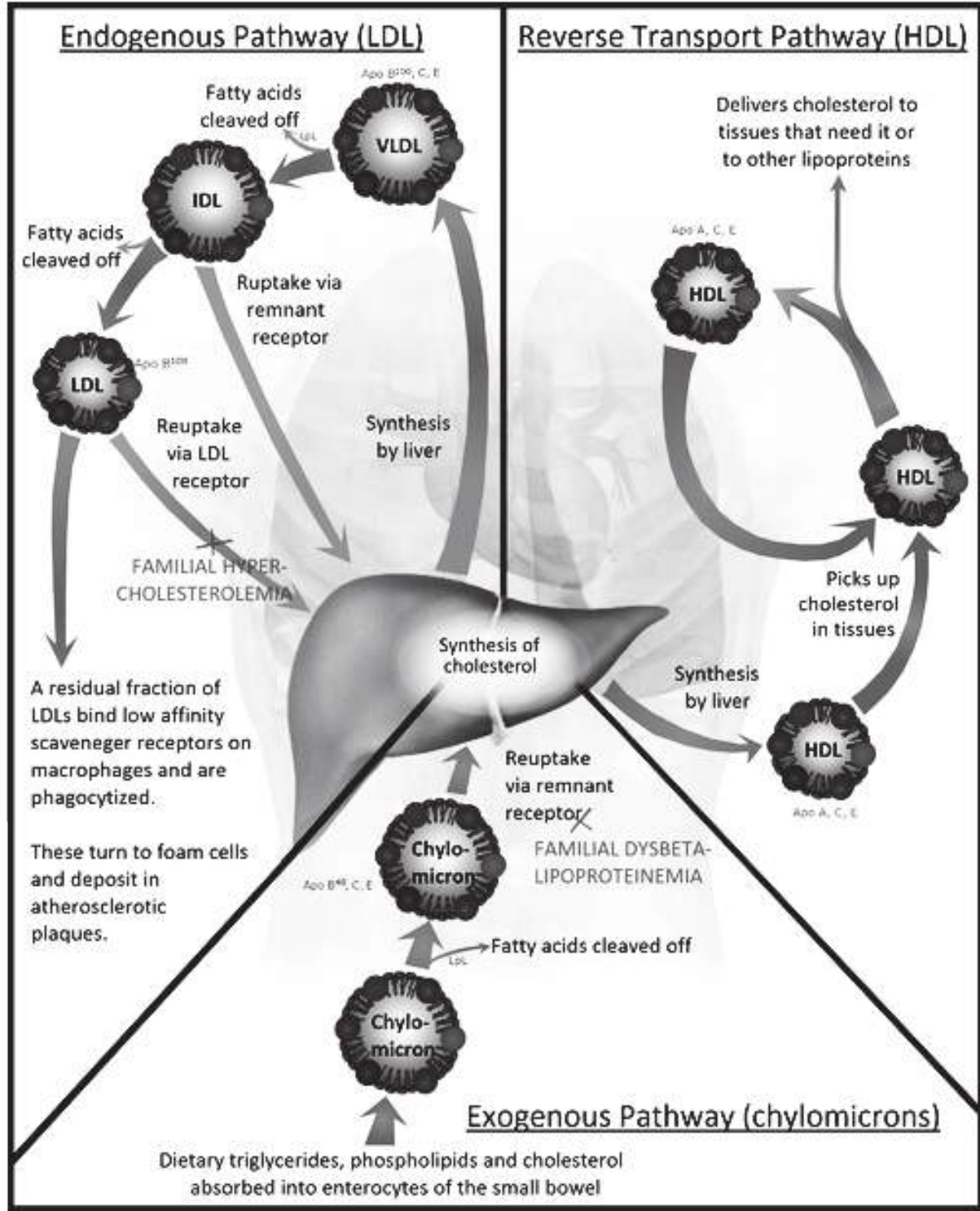


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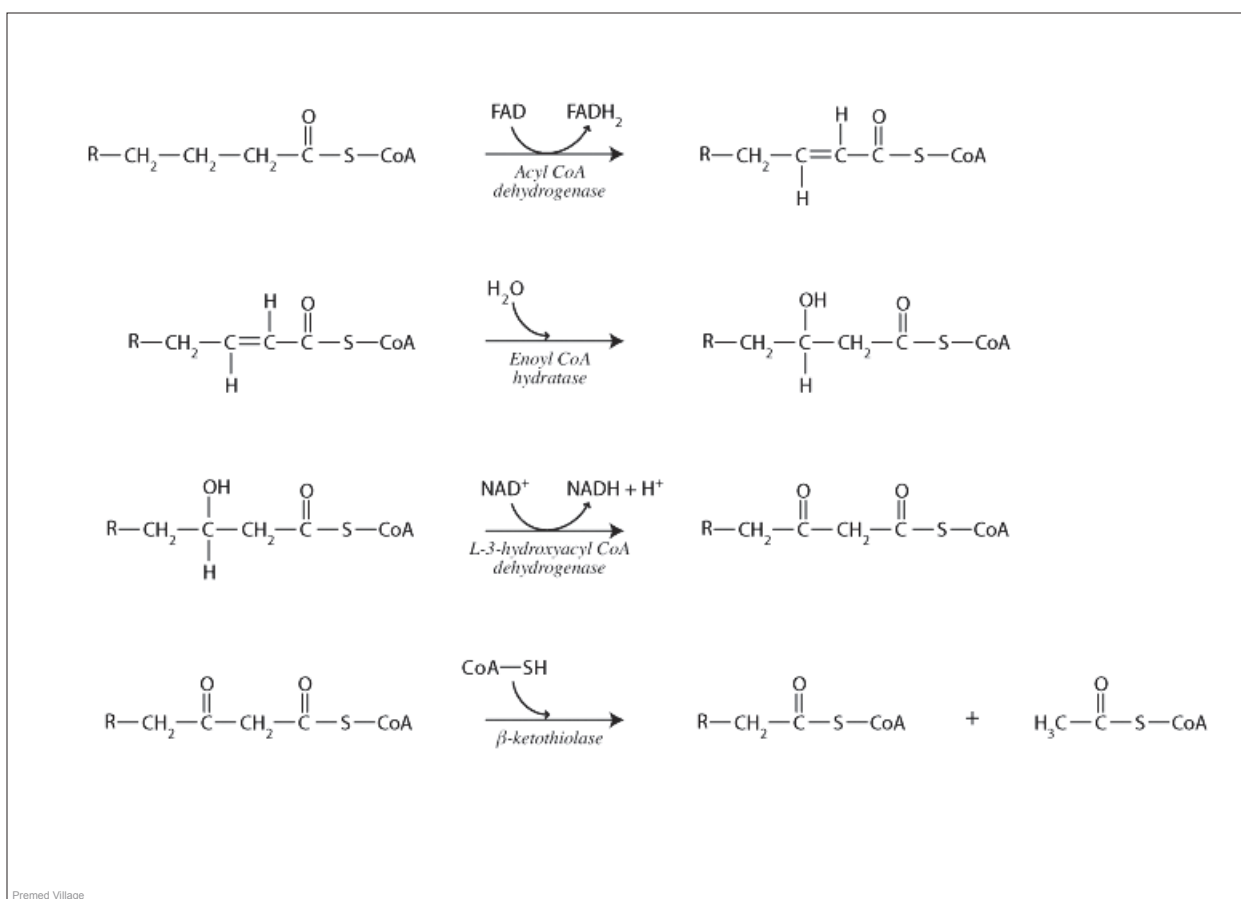


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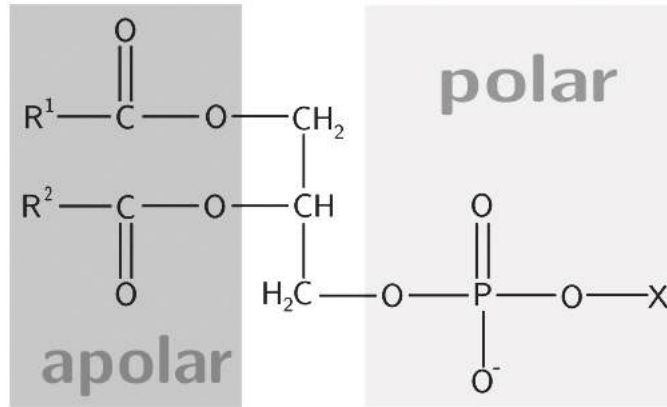




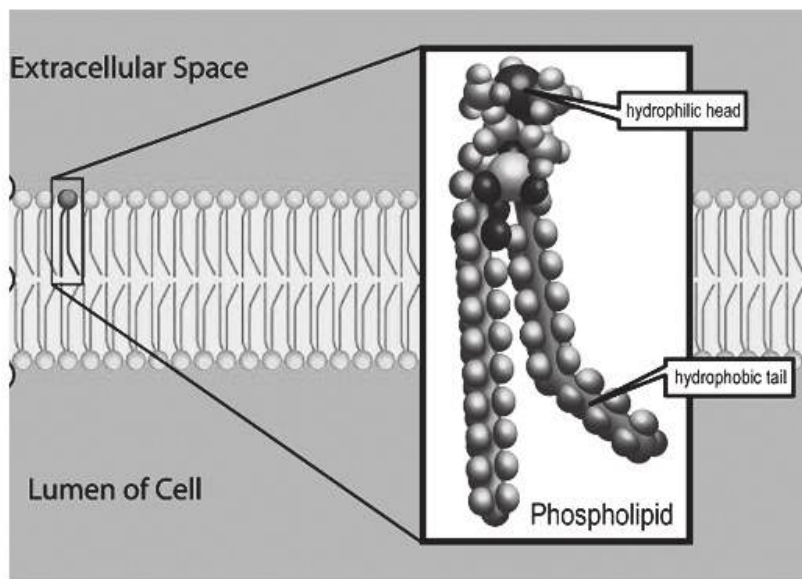
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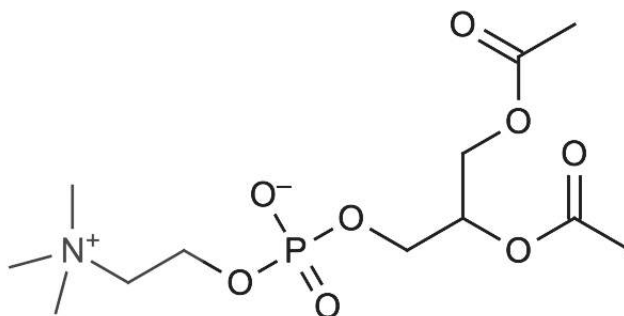
Lipids



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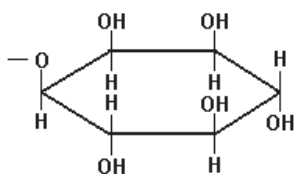
Glycerophospholipids

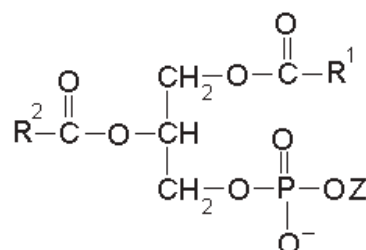
Z = -H Phosphatidic acid

Z = $-\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{COOH}$ Phosphatidylserine

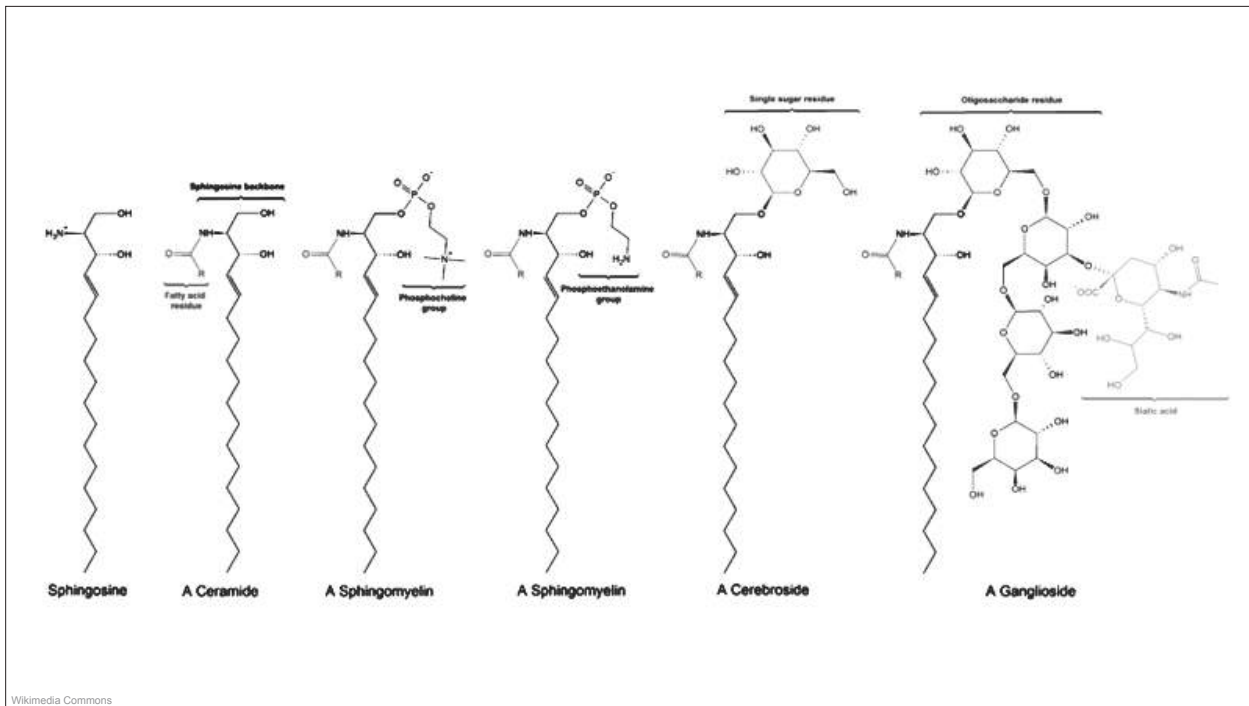
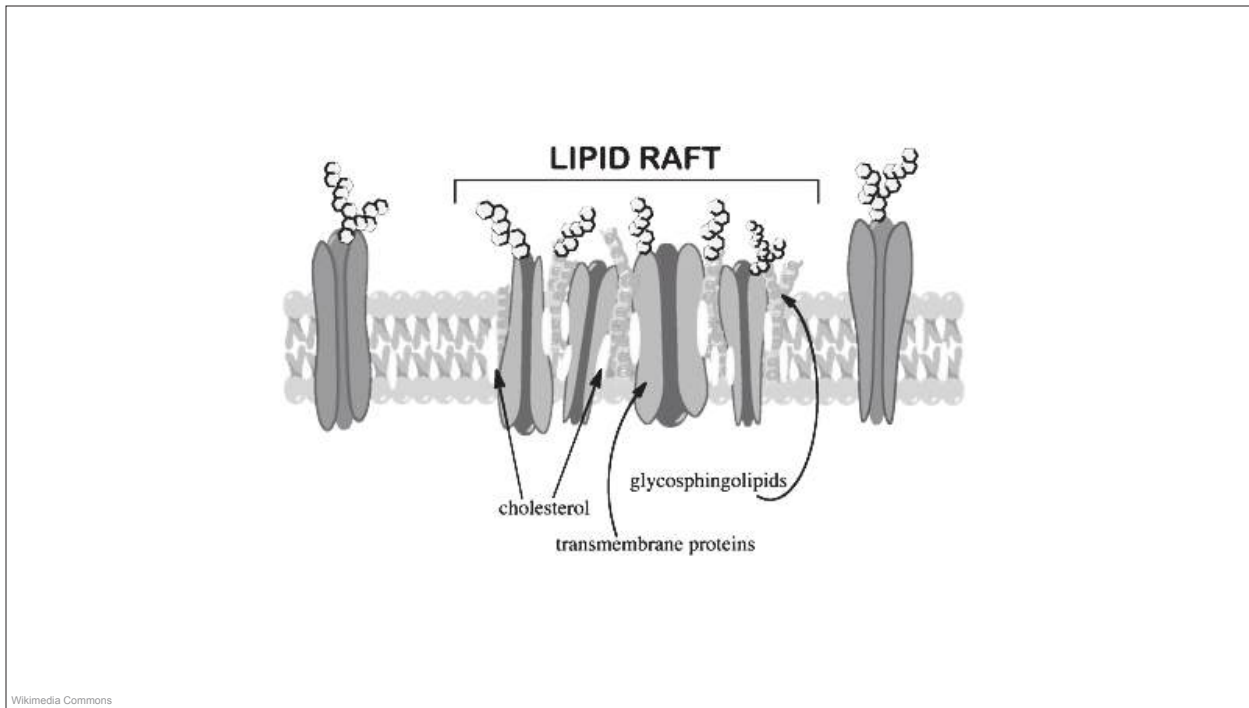
Z = $-\text{CH}_2-\text{CH}_2-\overset{+}{\text{NH}}_3$ Phosphatidylethanolamine

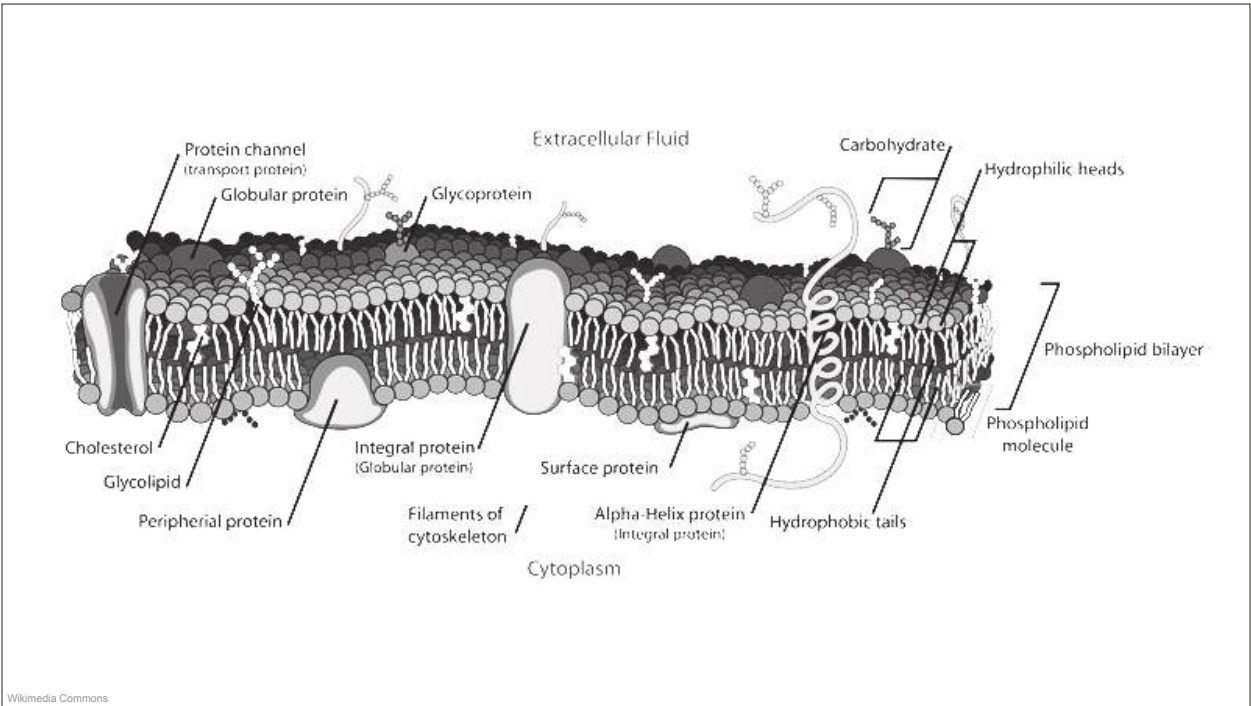
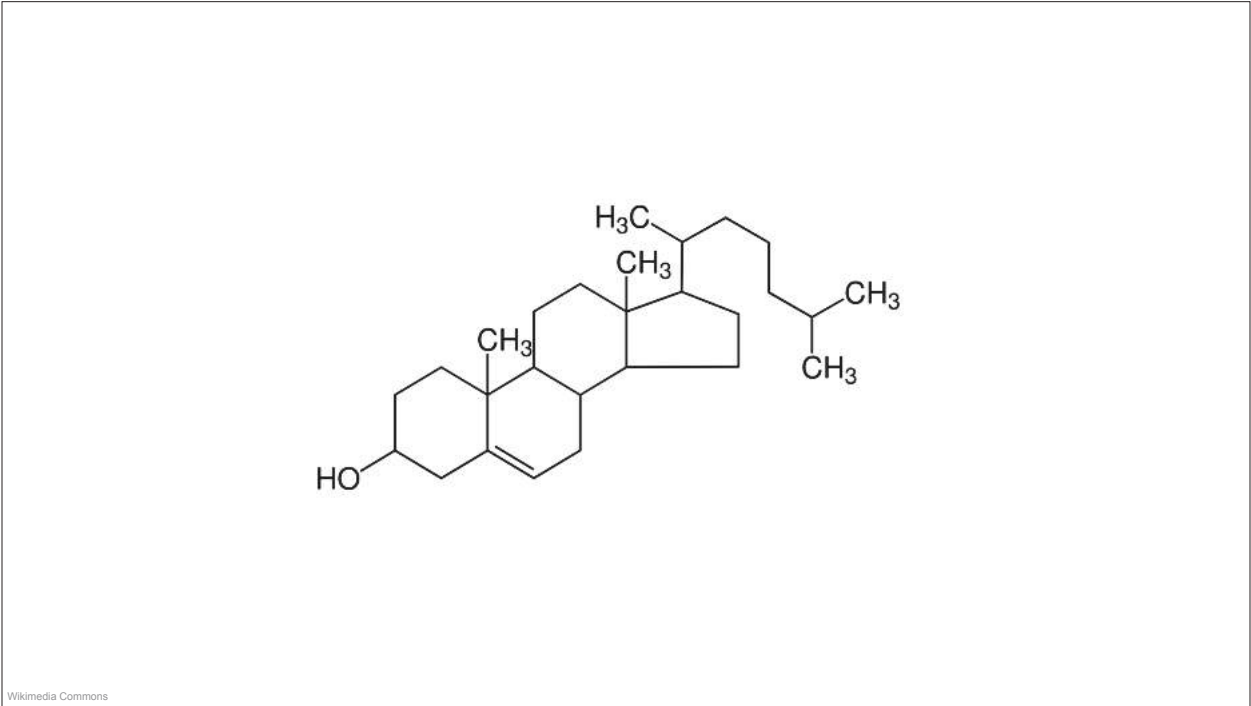
Z = $-\text{CH}_2-\text{CH}_2-\overset{+}{\text{N}}(\text{CH}_3)_3$ Phosphatidylcholine

Z =  Phosphatidylinositol

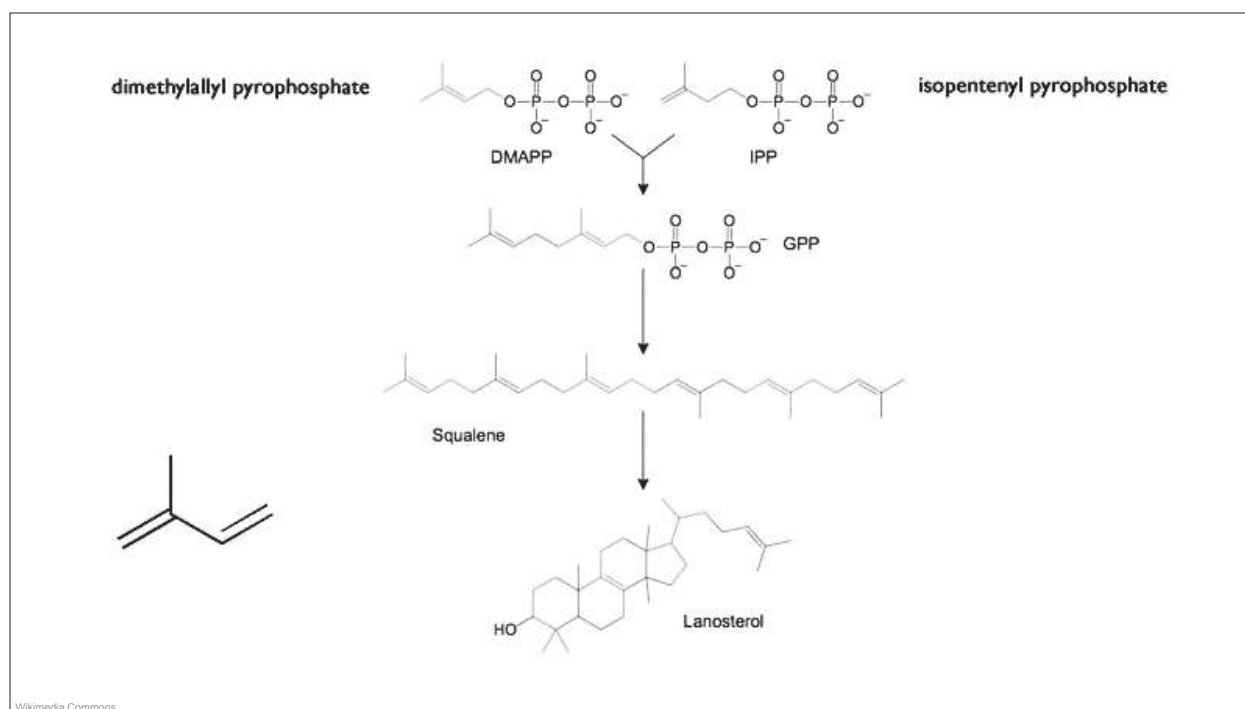


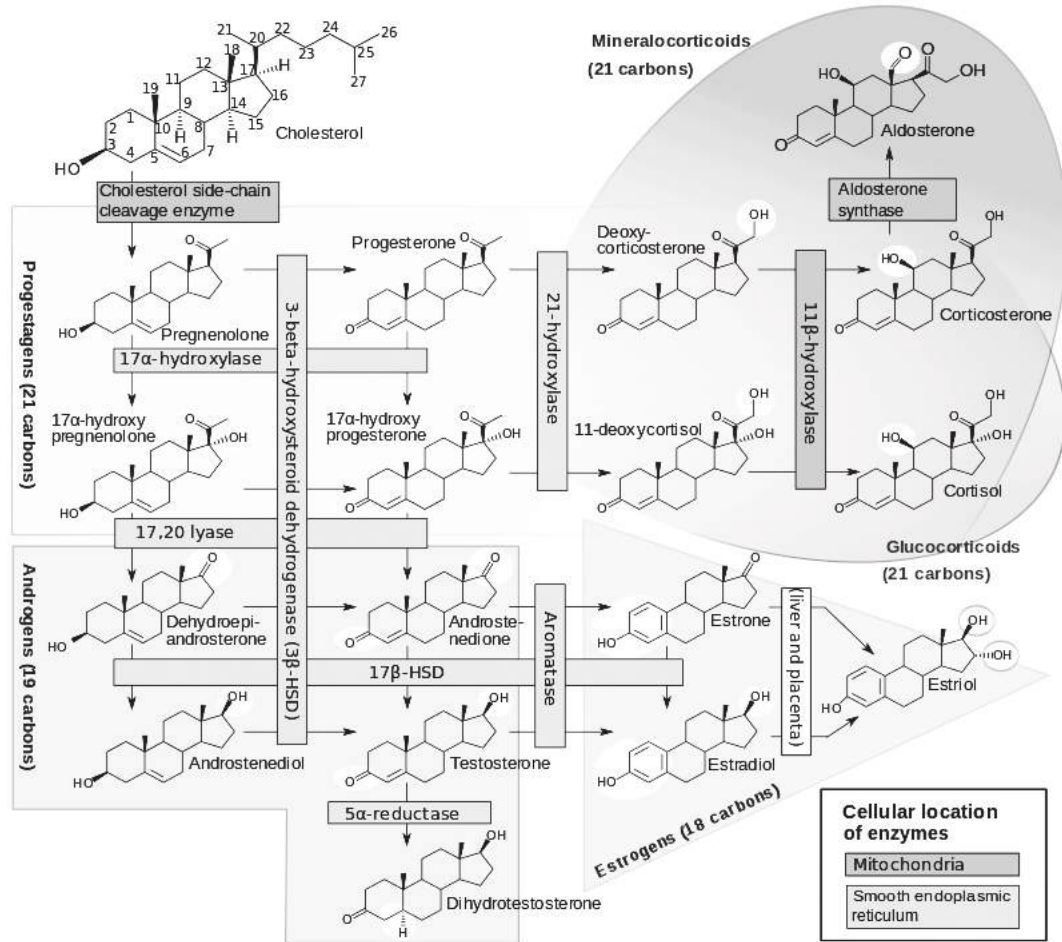
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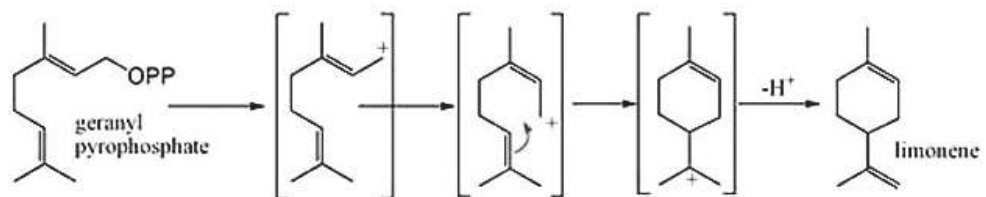


Lipids

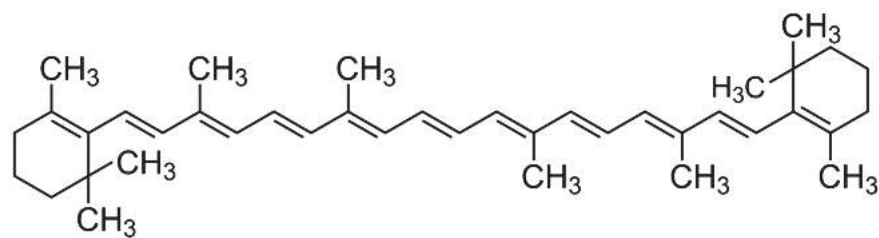




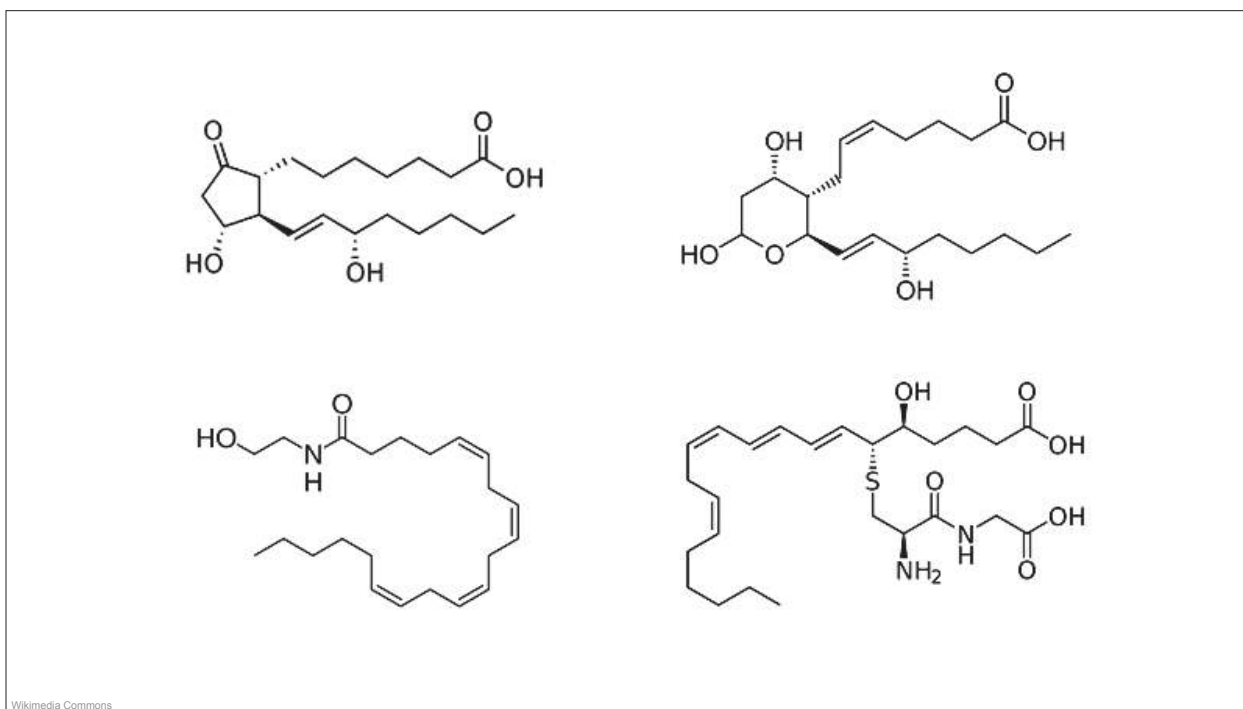
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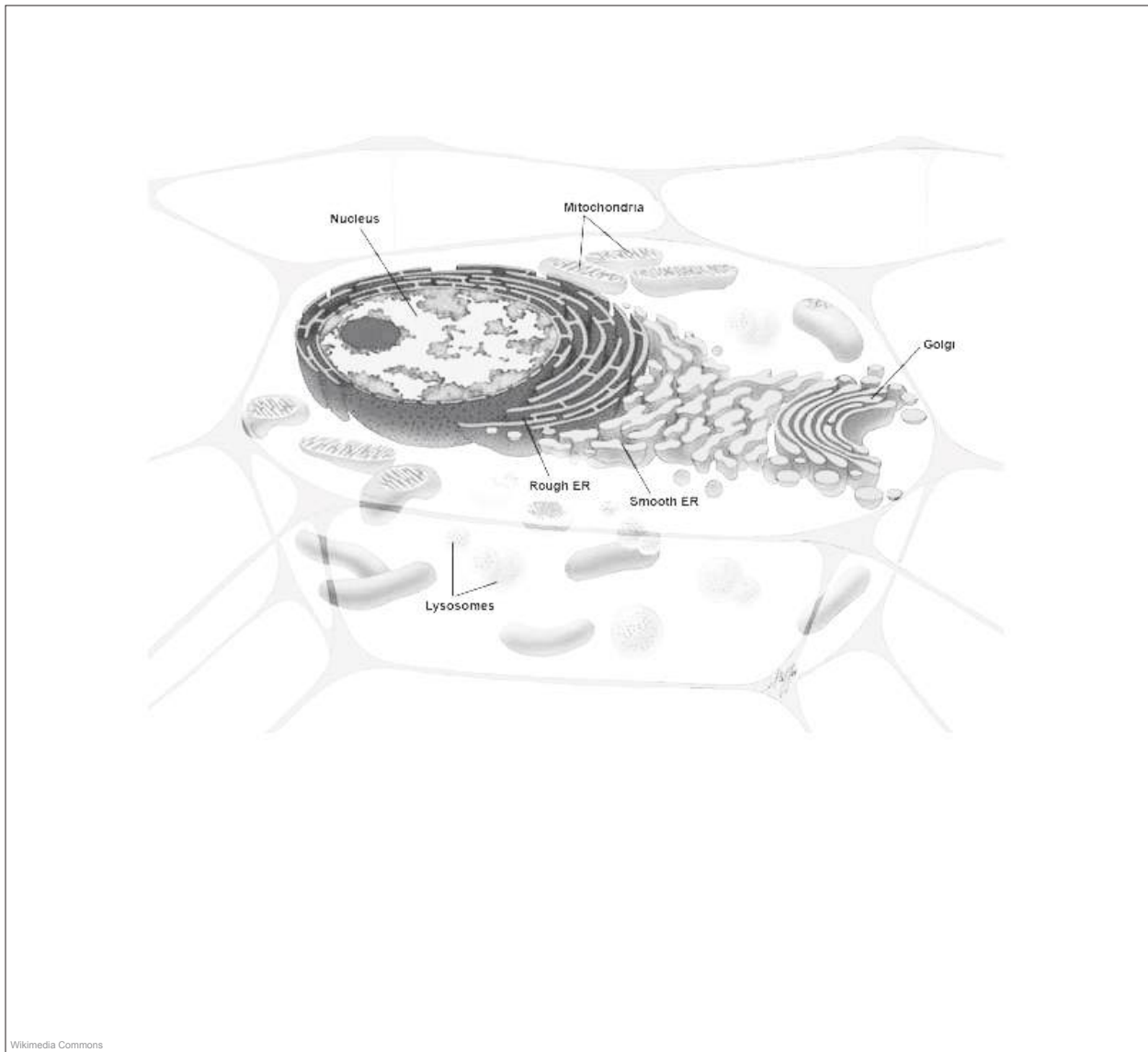


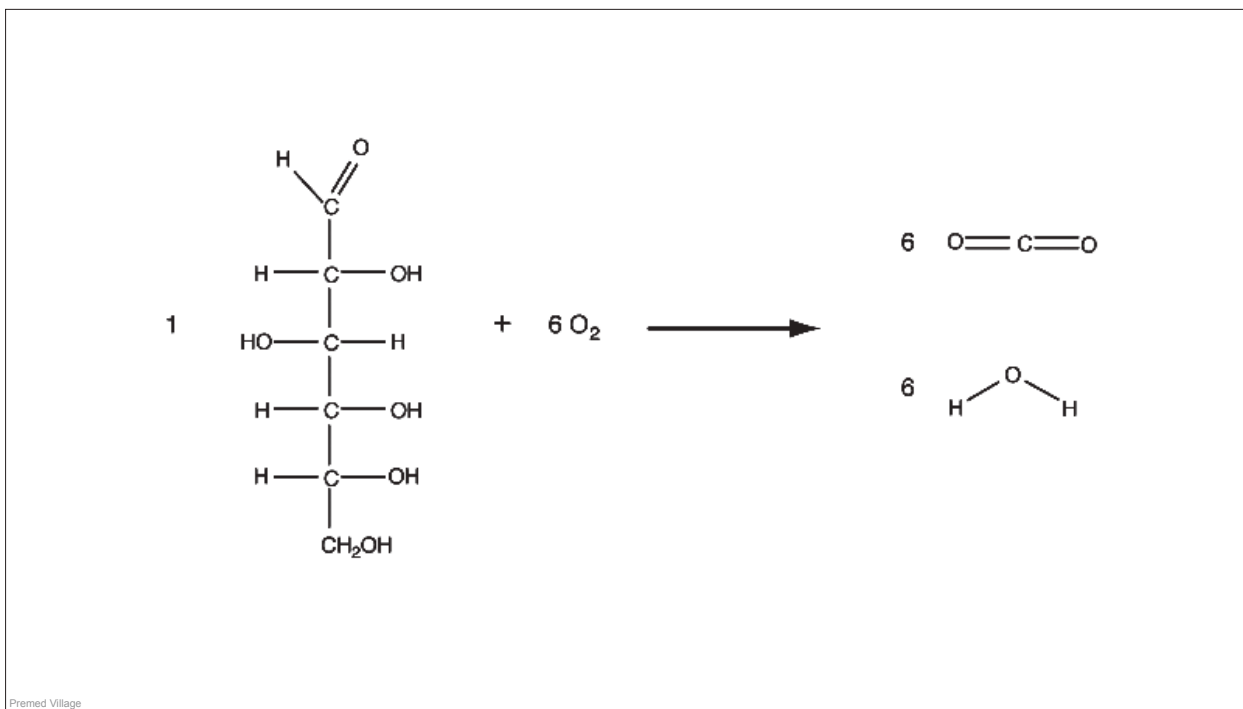
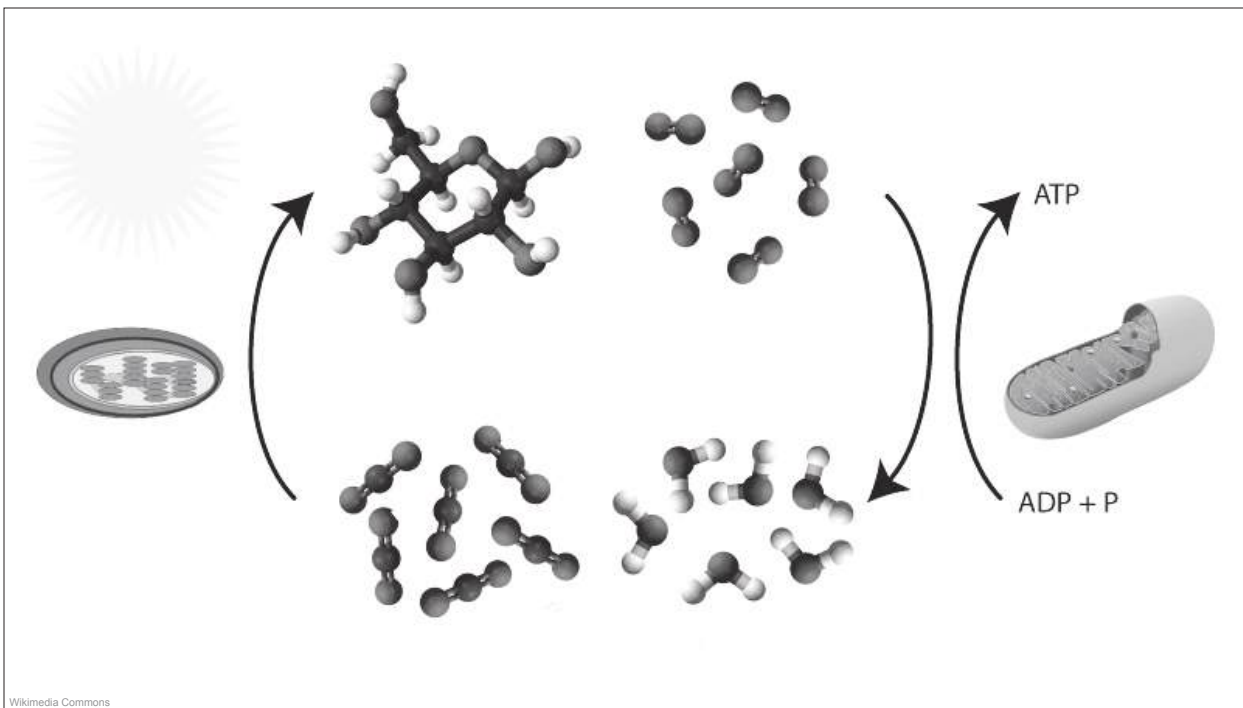
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$$\Delta S = \frac{\Delta H}{T}$$

$$\Delta G = \Delta H - T \Delta S$$

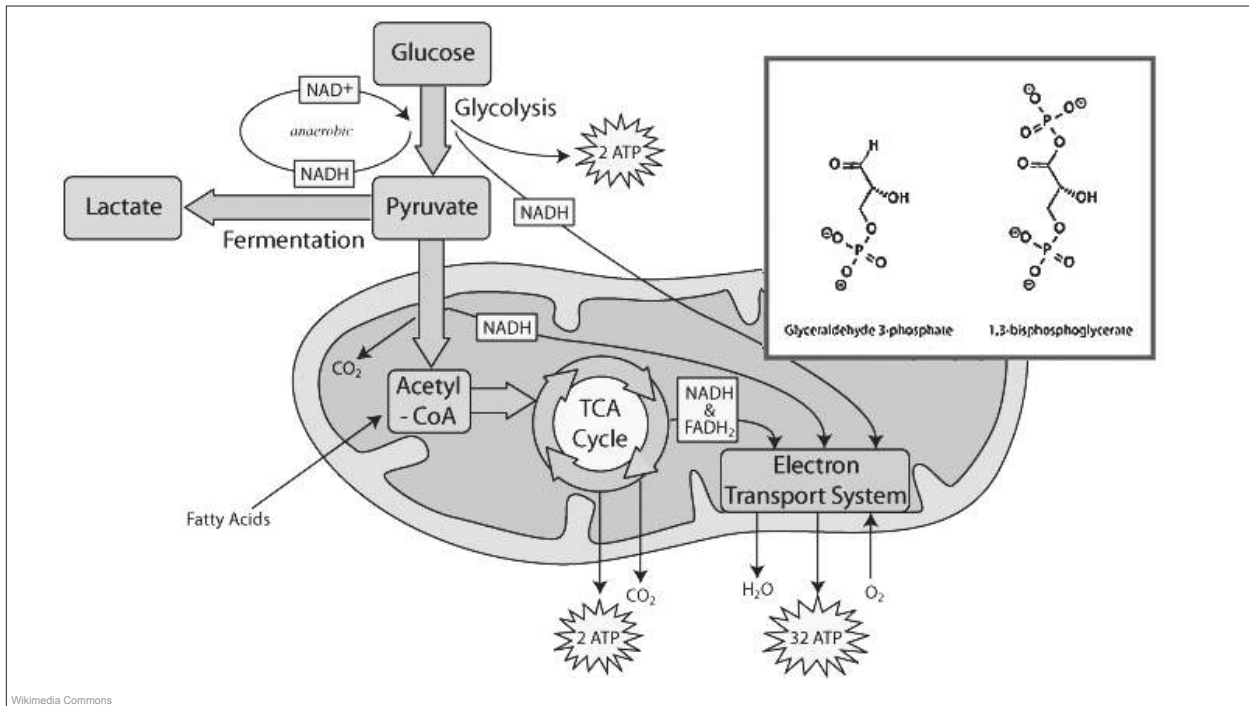
$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = -RT \ln K_{eq}$$

$$K_{eq} = e^{\left(\frac{-\Delta G^\circ}{RT}\right)}$$

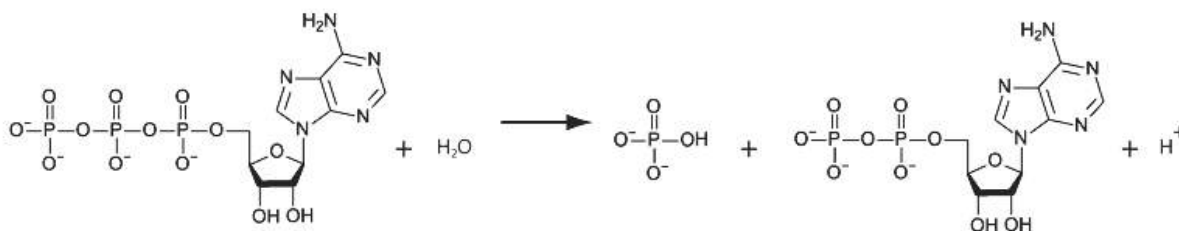


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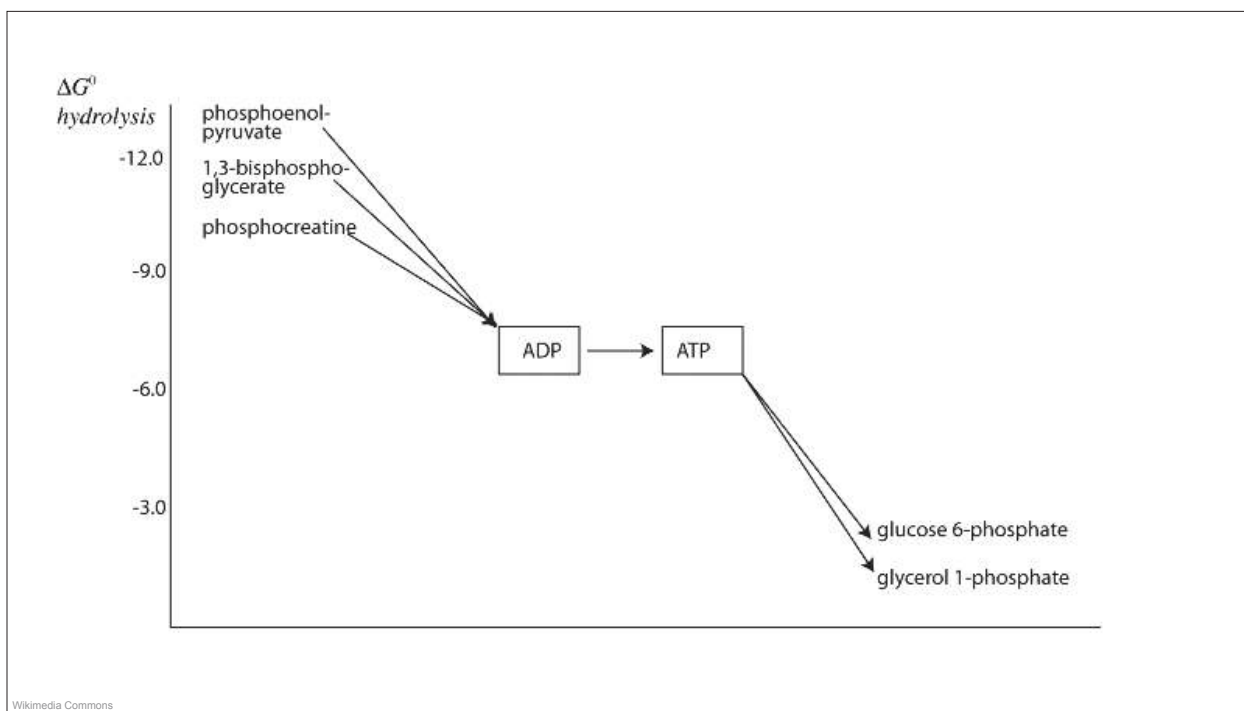


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Hydrolysis of ATP

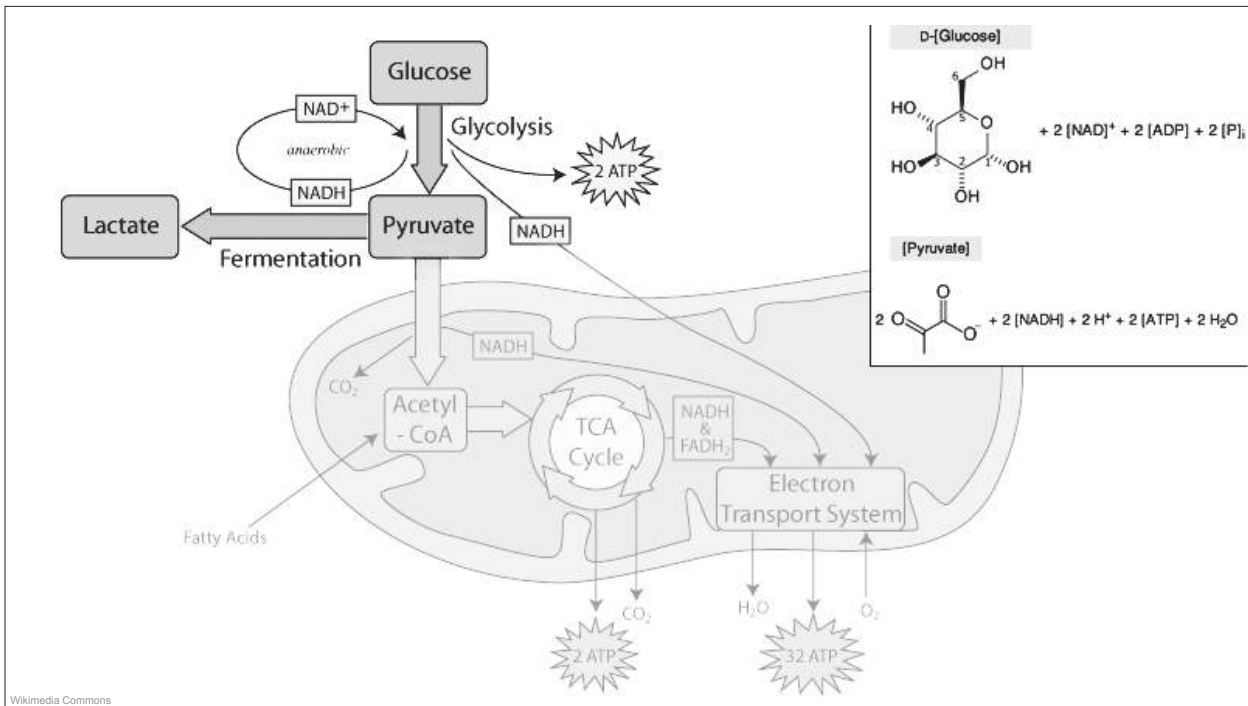
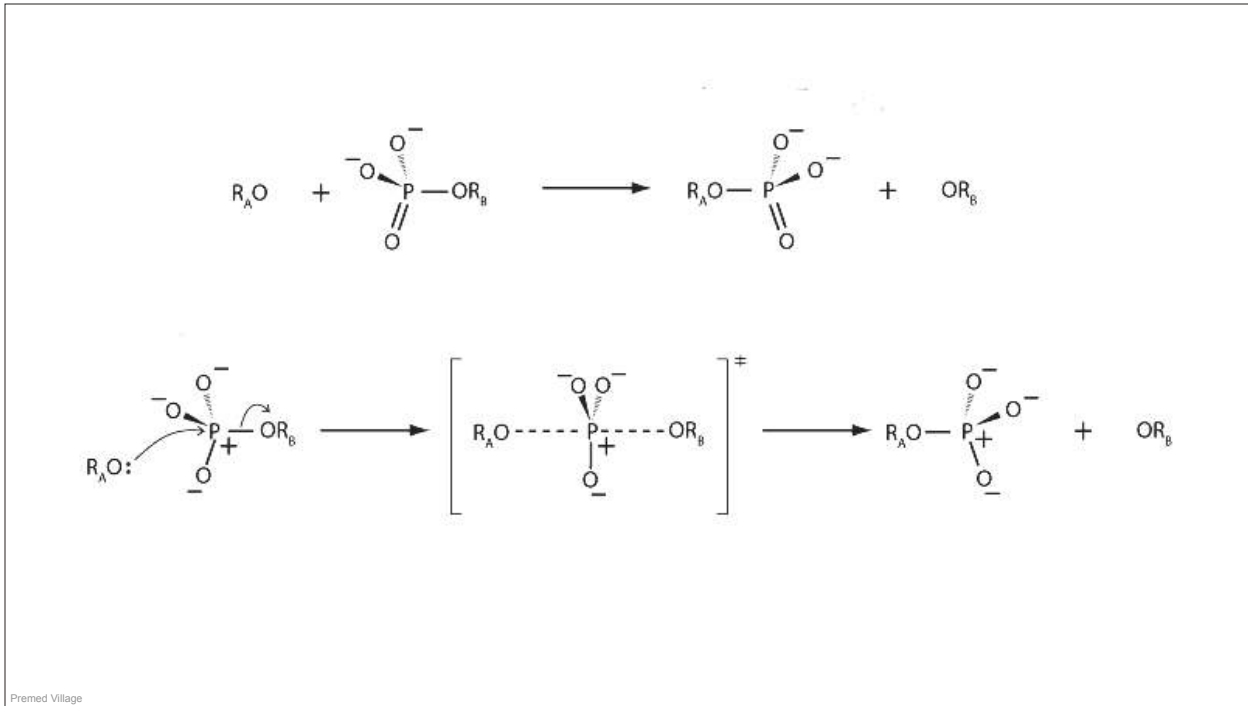


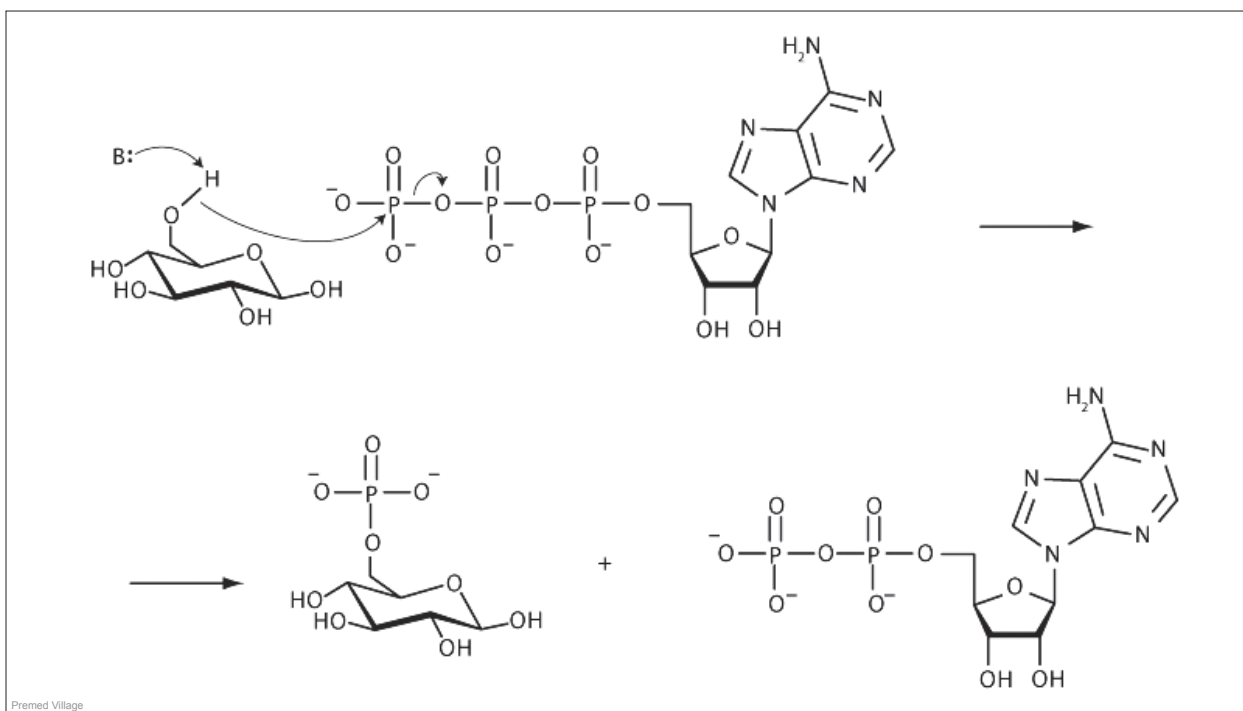
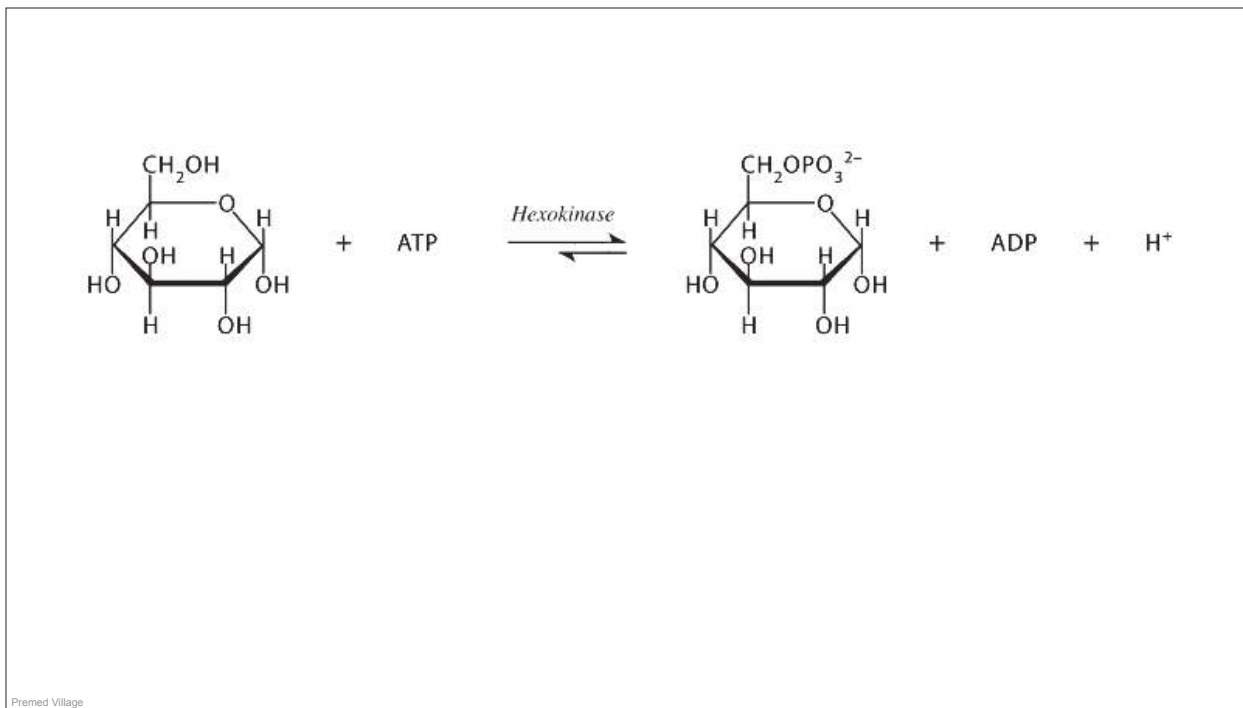
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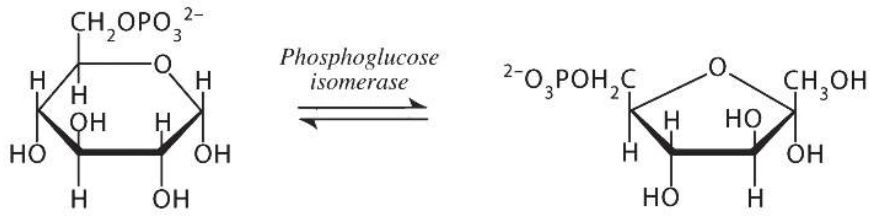
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Glycolysis

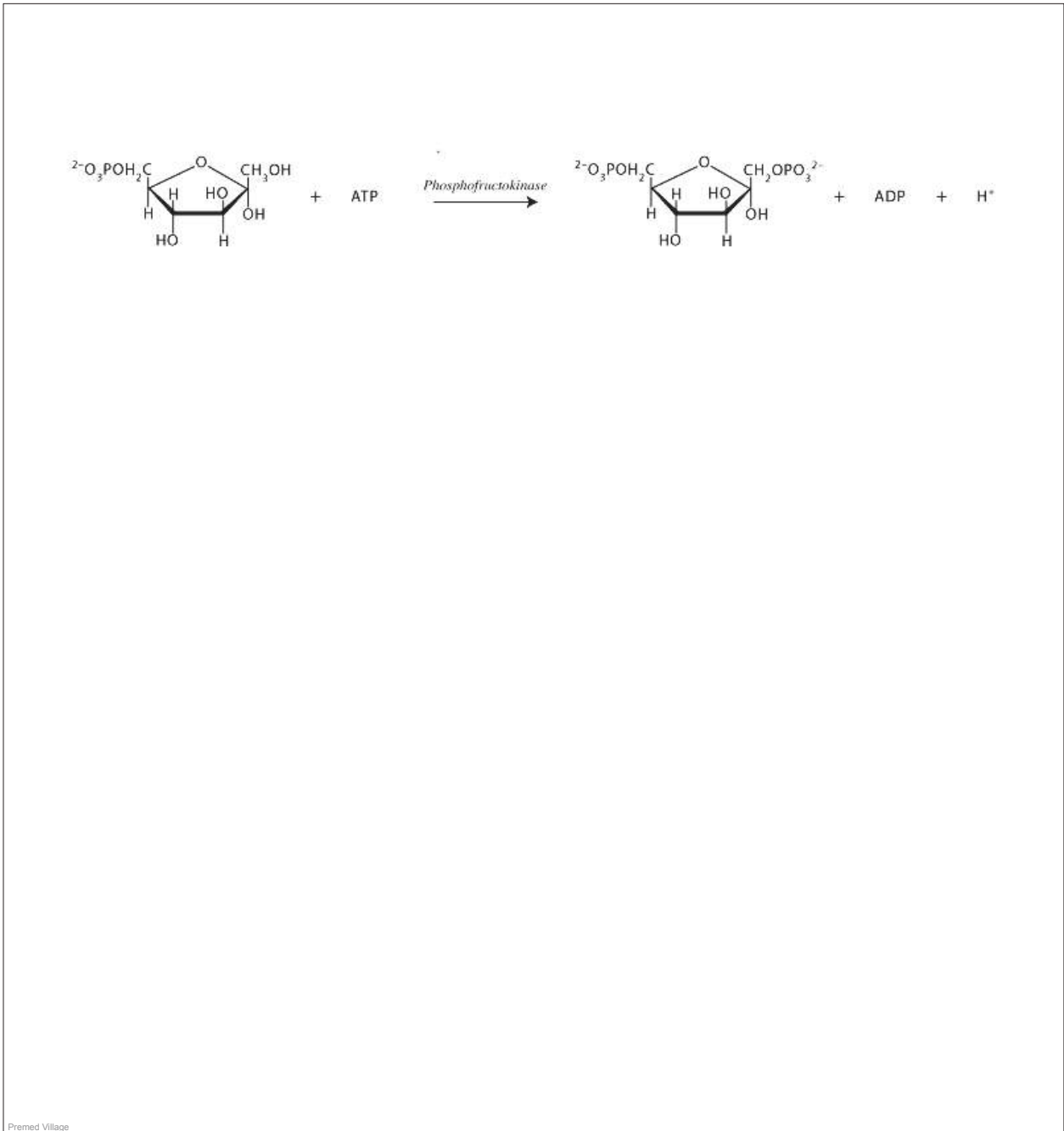




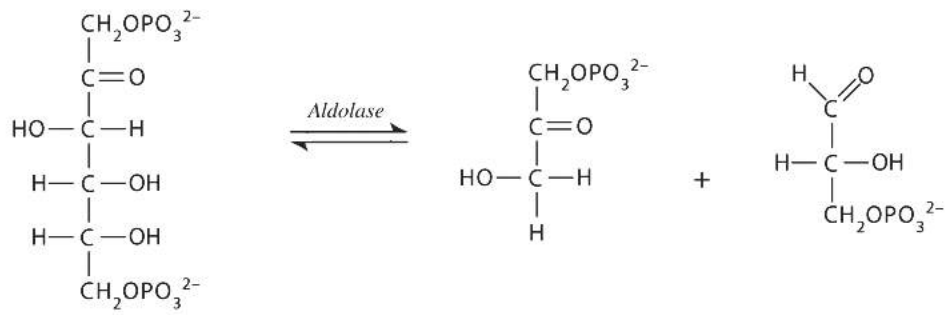
Glycolysis



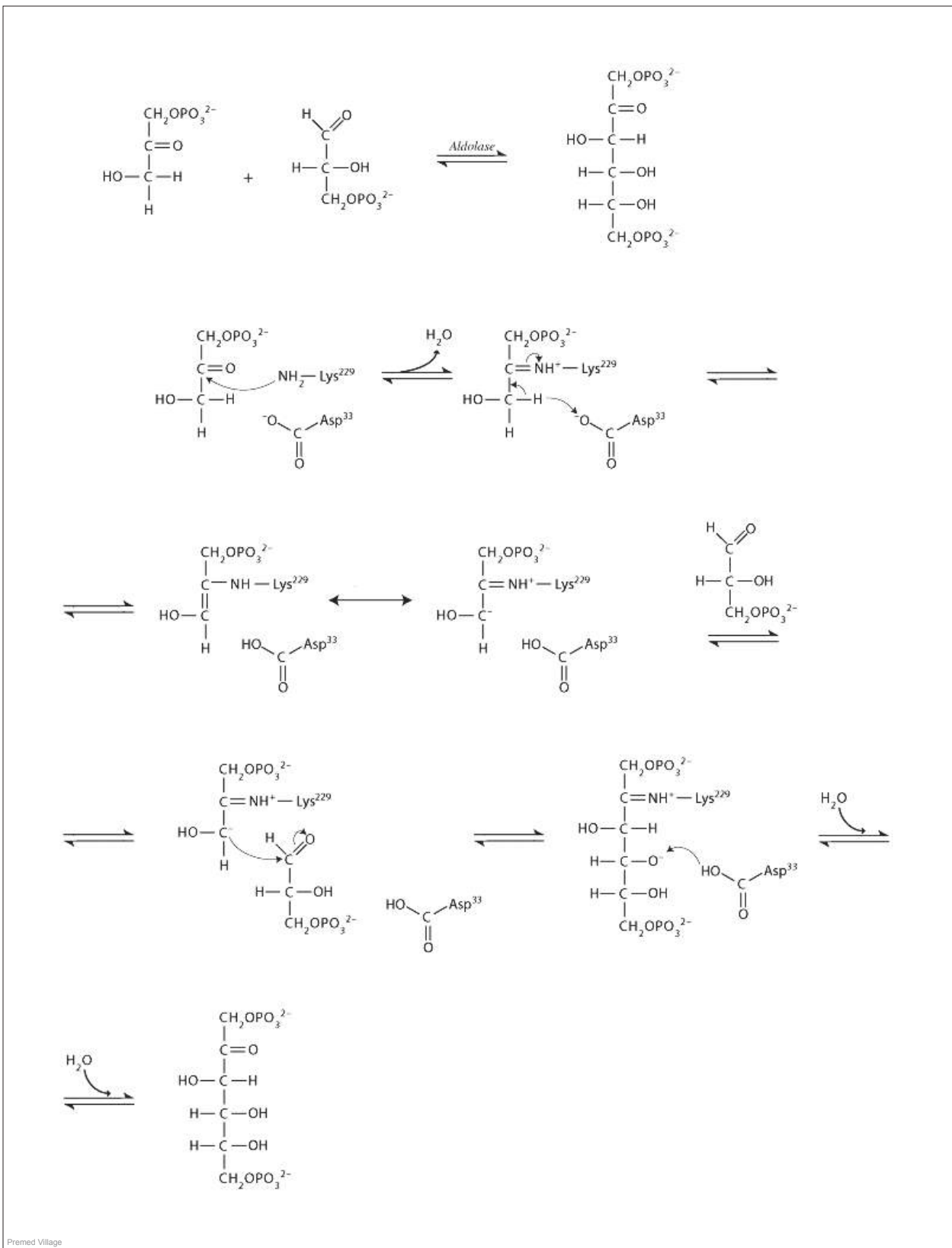
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Glycolysis

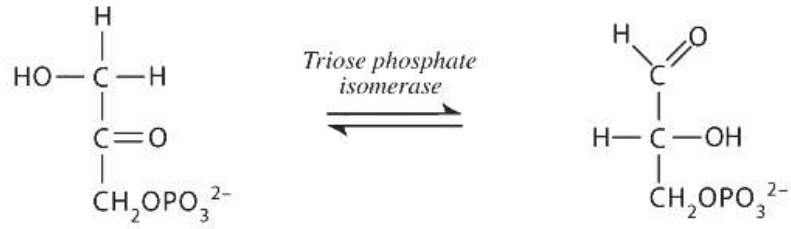


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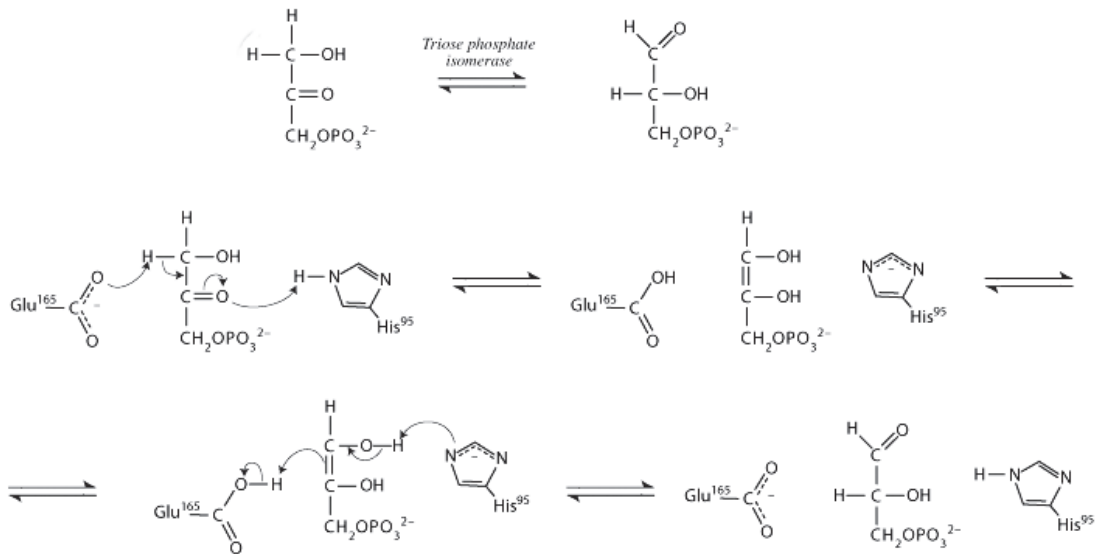


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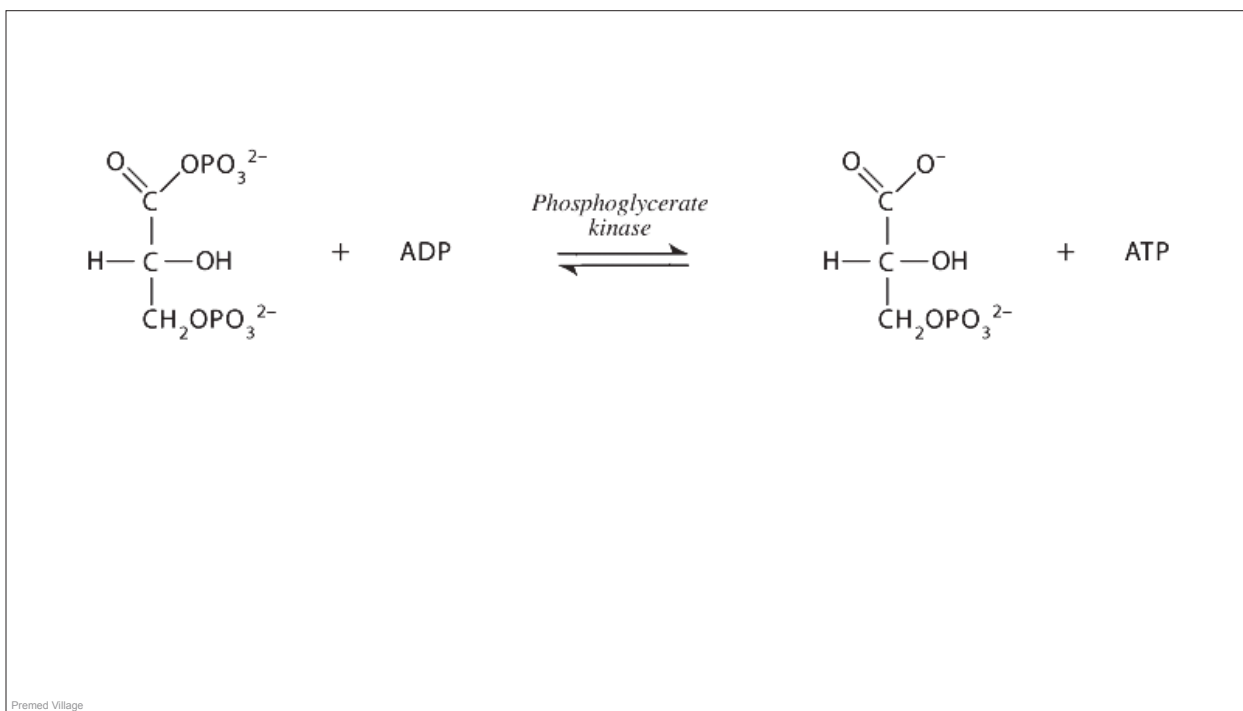
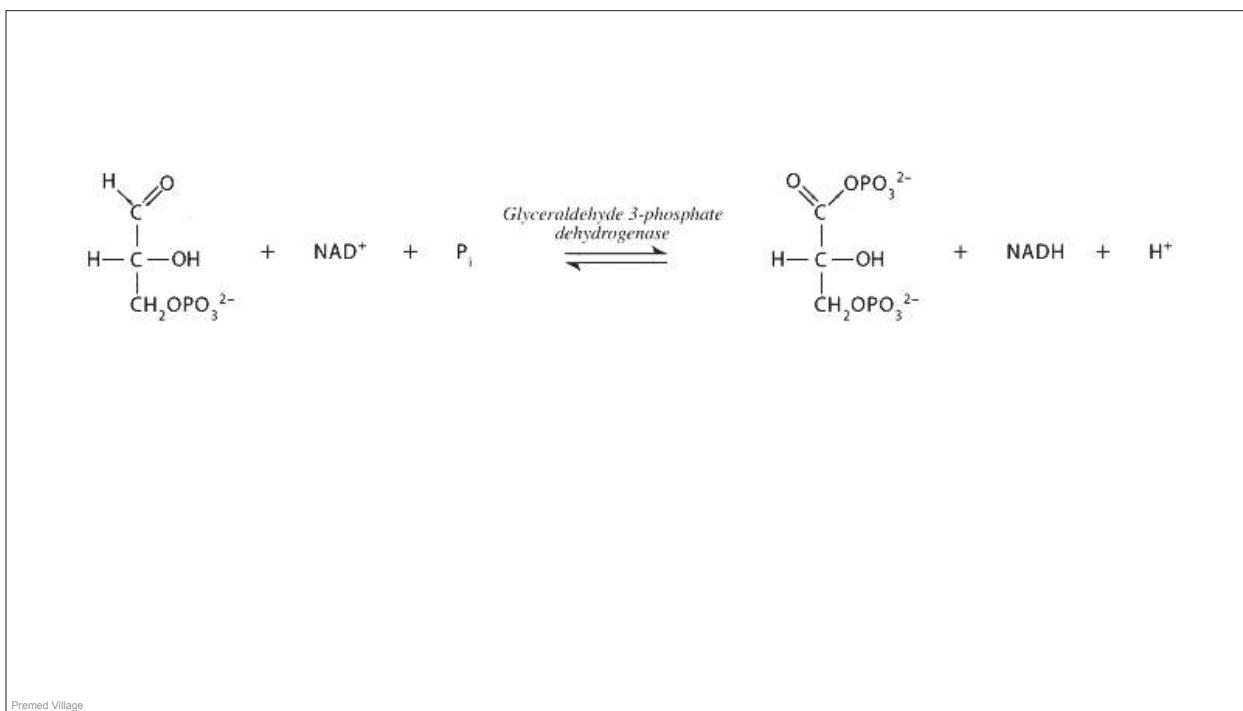
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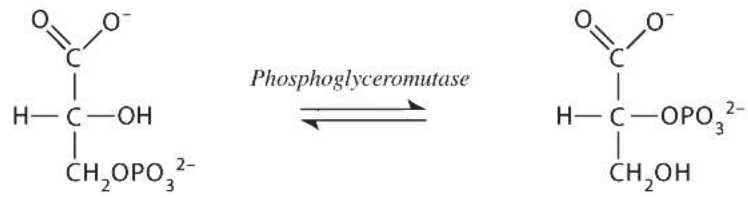
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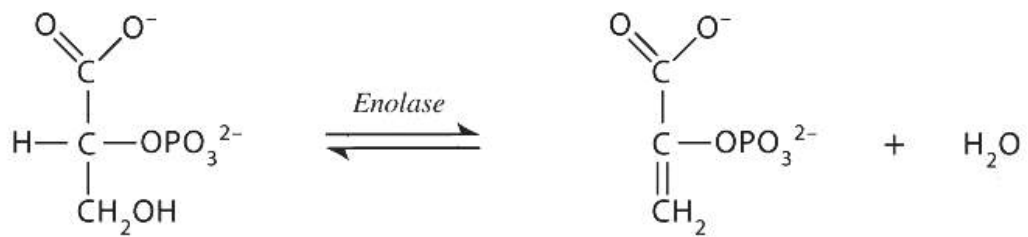
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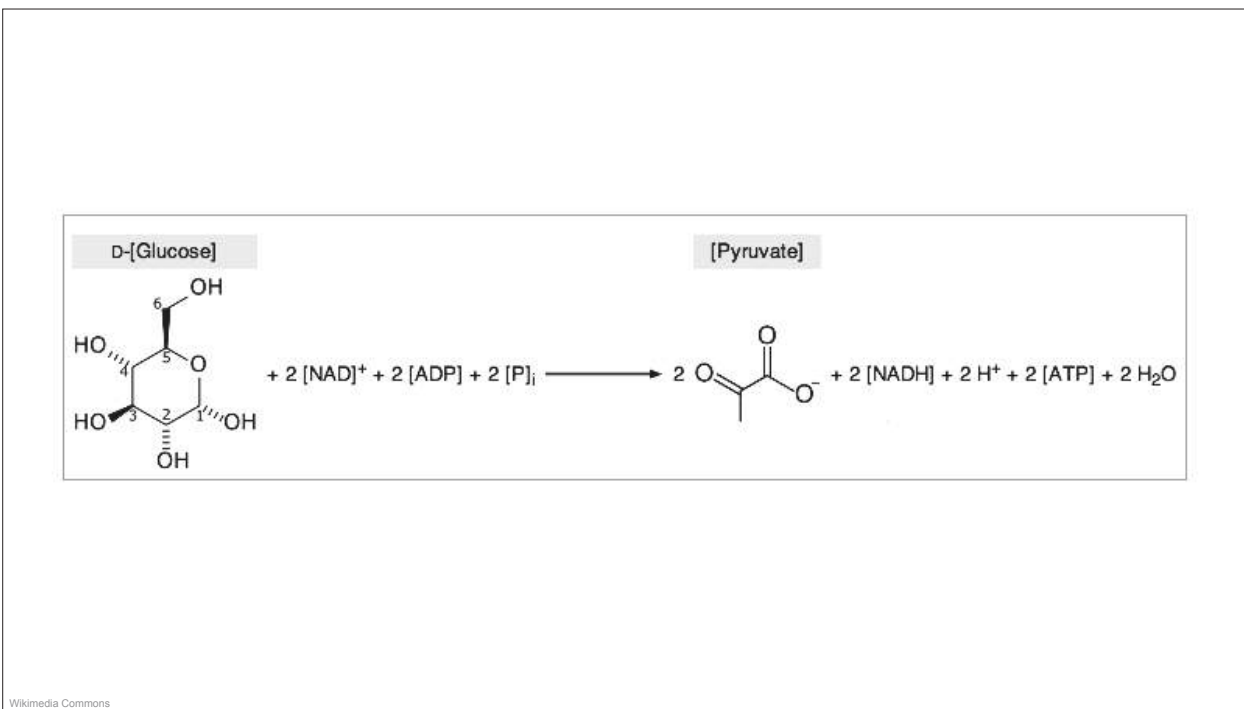
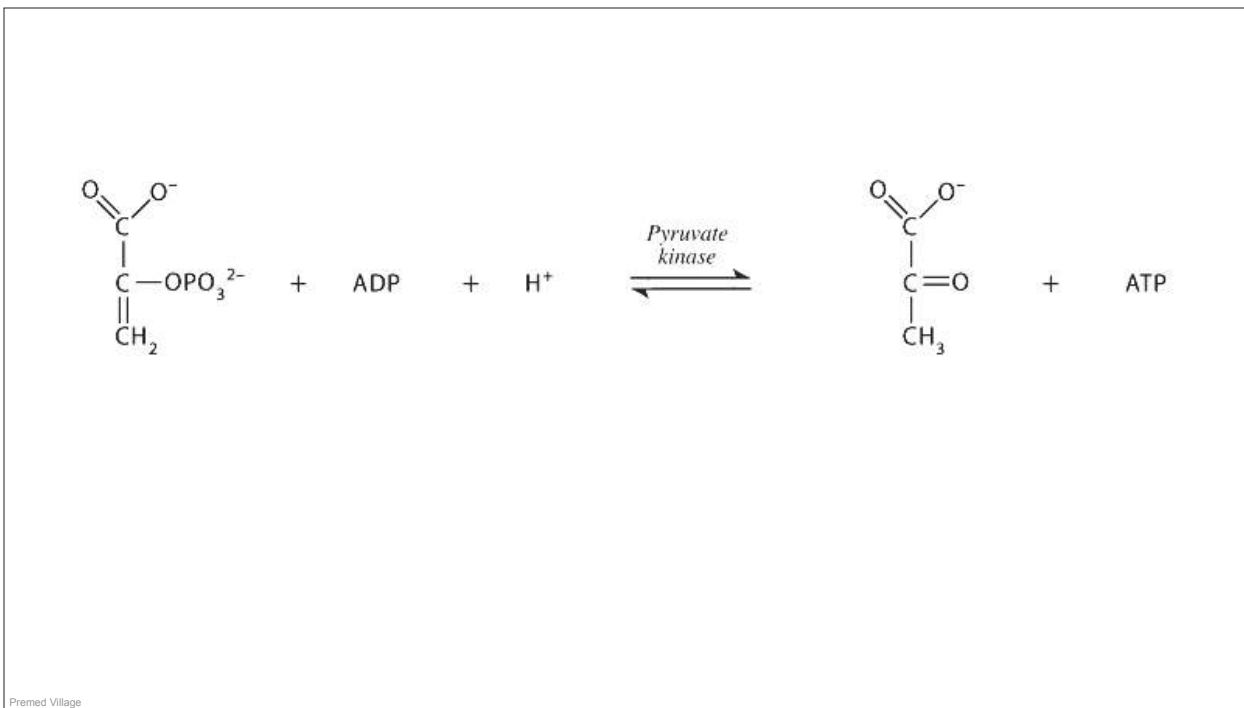
Glycolysis



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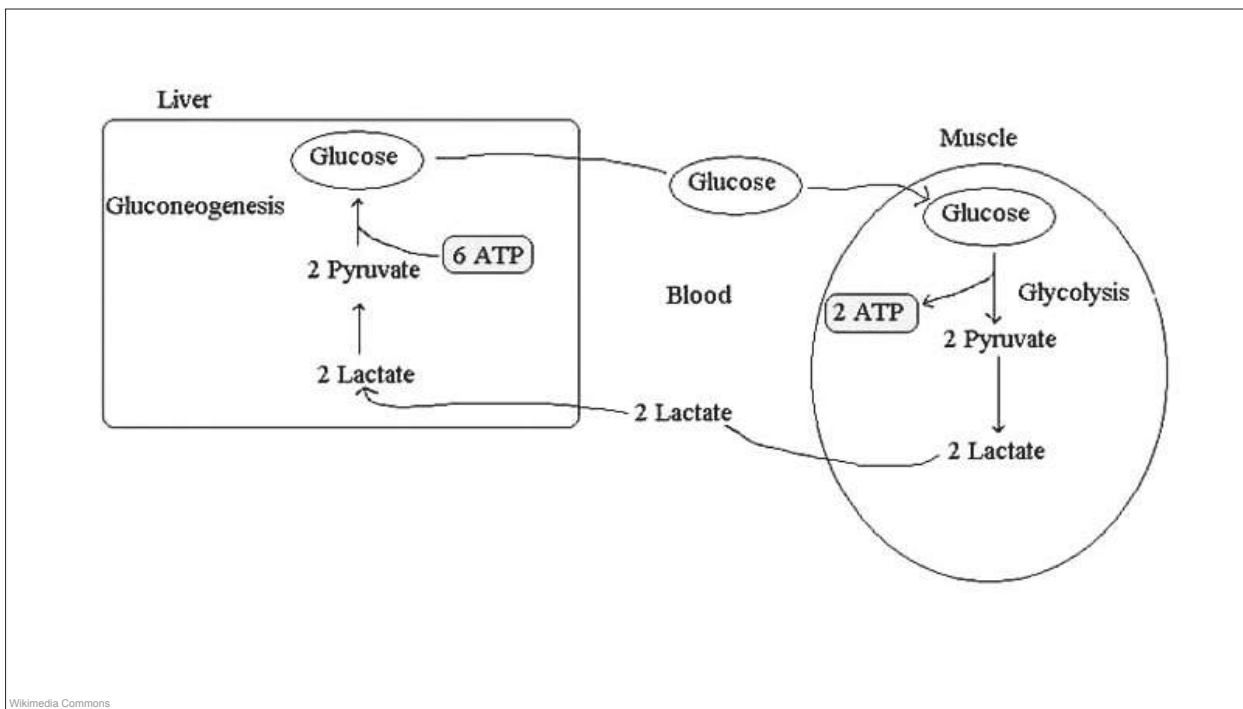
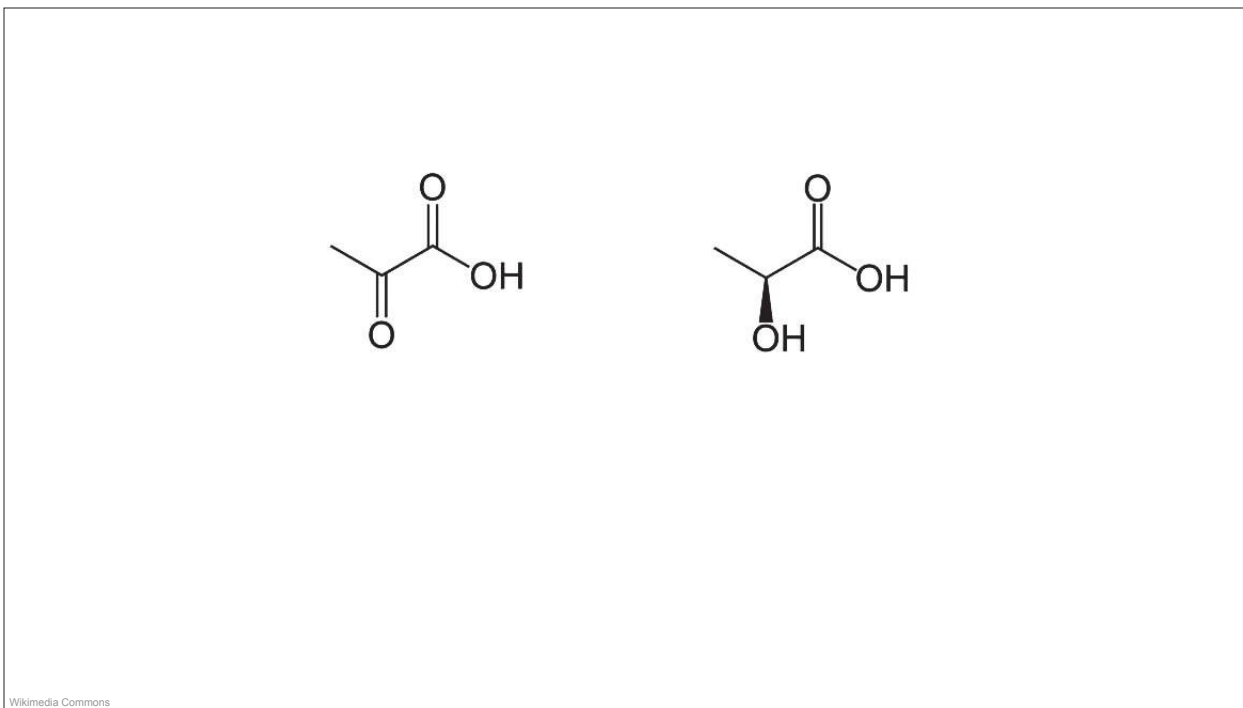
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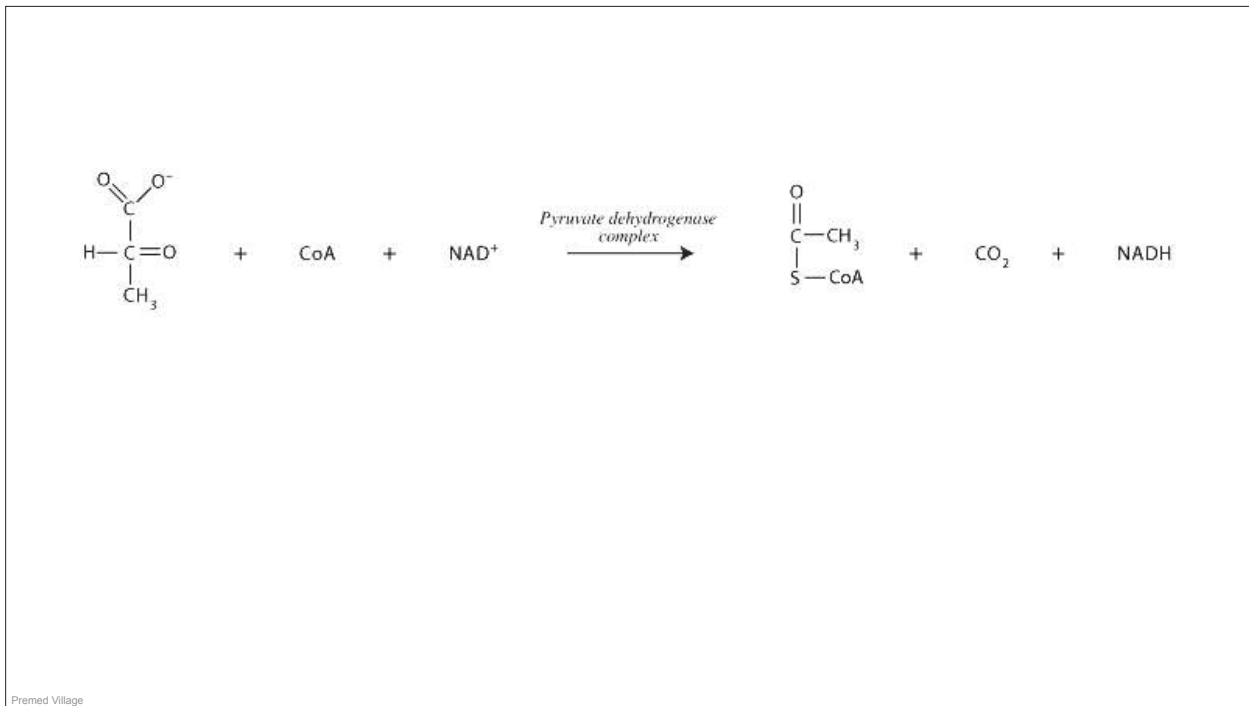
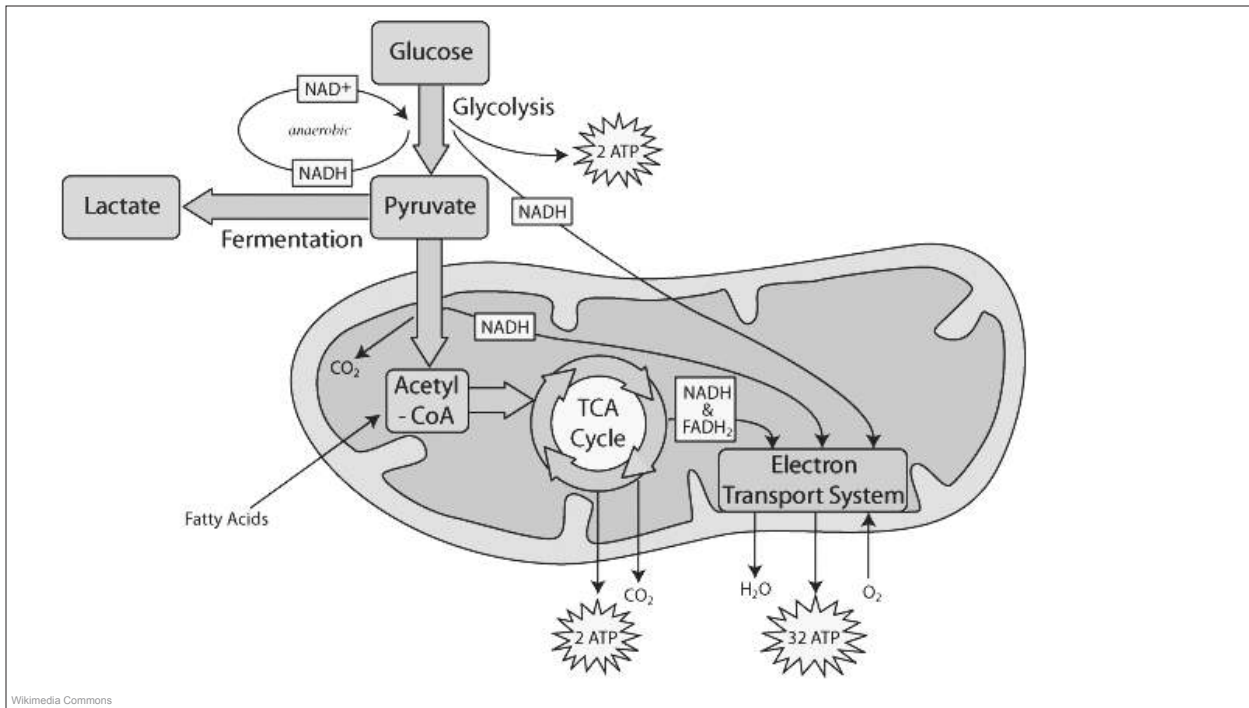
Change in free energy for each step of glycolysis

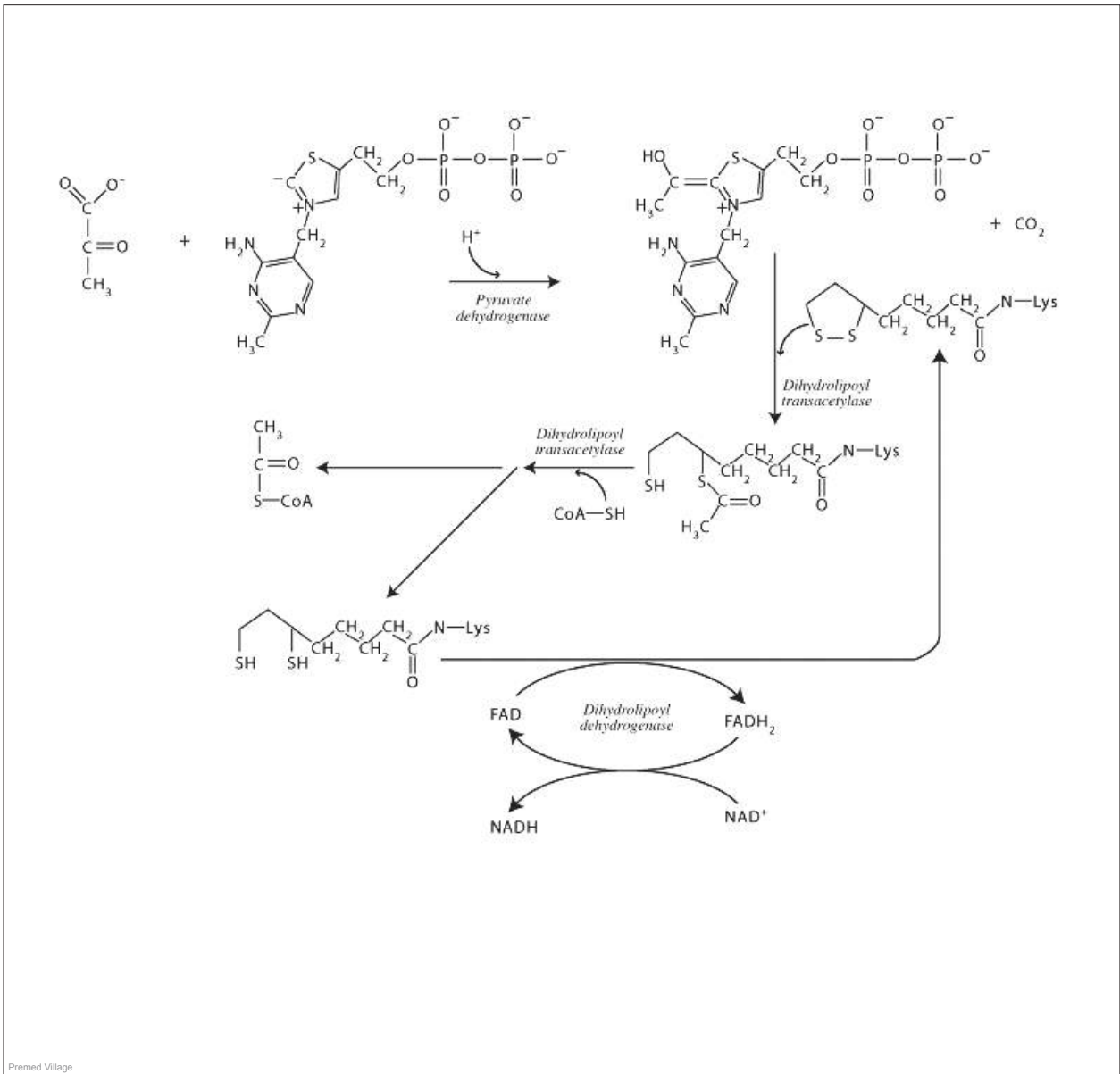
Step	Reaction	$\Delta G^\circ /$ (kJ/mol)	$\Delta G /$ (kJ/mol)
1	glucose + ATP ⁴⁻ → glucose-6-phosphate ²⁻ + ADP ³⁻ + H ⁺	-16.7	-34
2	glucose-6-phosphate ²⁻ → fructose-6-phosphate ²⁻	1.67	-2.9
3	fructose-6-phosphate ²⁻ + ATP ⁴⁻ → fructose-1,6-bisphosphate ⁴⁻ + ADP ³⁻ + H ⁺	-14.2	-19
4	fructose-1,6-bisphosphate ⁴⁻ → dihydroxyacetone phosphate ²⁻ + glyceraldehyde-3-phosphate ²⁻	23.9	-0.23
5	dihydroxyacetone phosphate ²⁻ → glyceraldehyde-3-phosphate ²⁻	7.56	2.4
6	glyceraldehyde-3-phosphate ²⁻ + P _i ²⁻ + NAD ⁺ → 1,3-bisphosphoglycerate ⁴⁻ + NADH + H ⁺	6.30	-1.29
7	1,3-bisphosphoglycerate ⁴⁻ + ADP ³⁻ → 3-phosphoglycerate ³⁻ + ATP ⁴⁻	-18.9	0.09
8	3-phosphoglycerate ³⁻ → 2-phosphoglycerate ³⁻	4.4	0.83
9	2-phosphoglycerate ³⁻ → phosphoenolpyruvate ³⁻ + H ₂ O	1.8	1.1
10	phosphoenolpyruvate ³⁻ + ADP ³⁻ + H ⁺ → pyruvate ⁻ + ATP ⁴⁻	-31.7	-23.0

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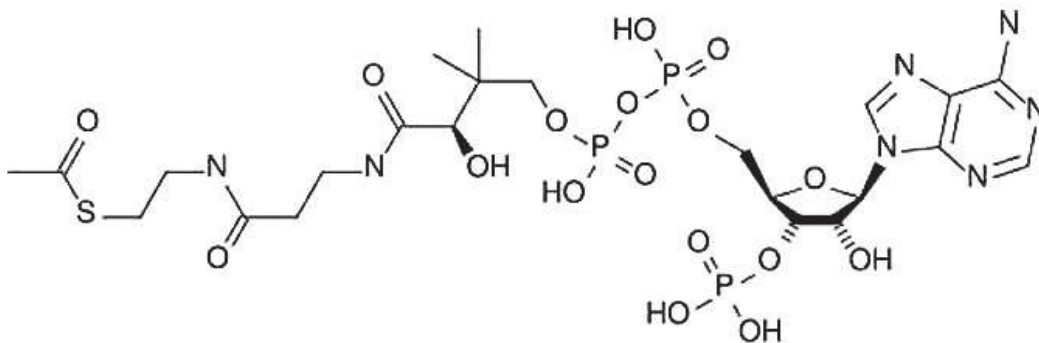
Pyruvate Dehydrogenase



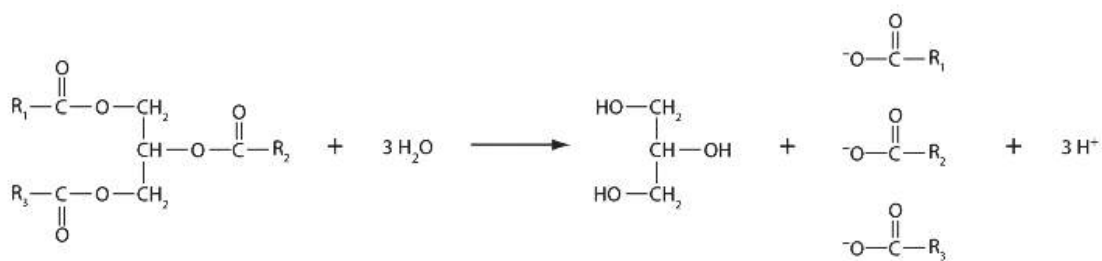


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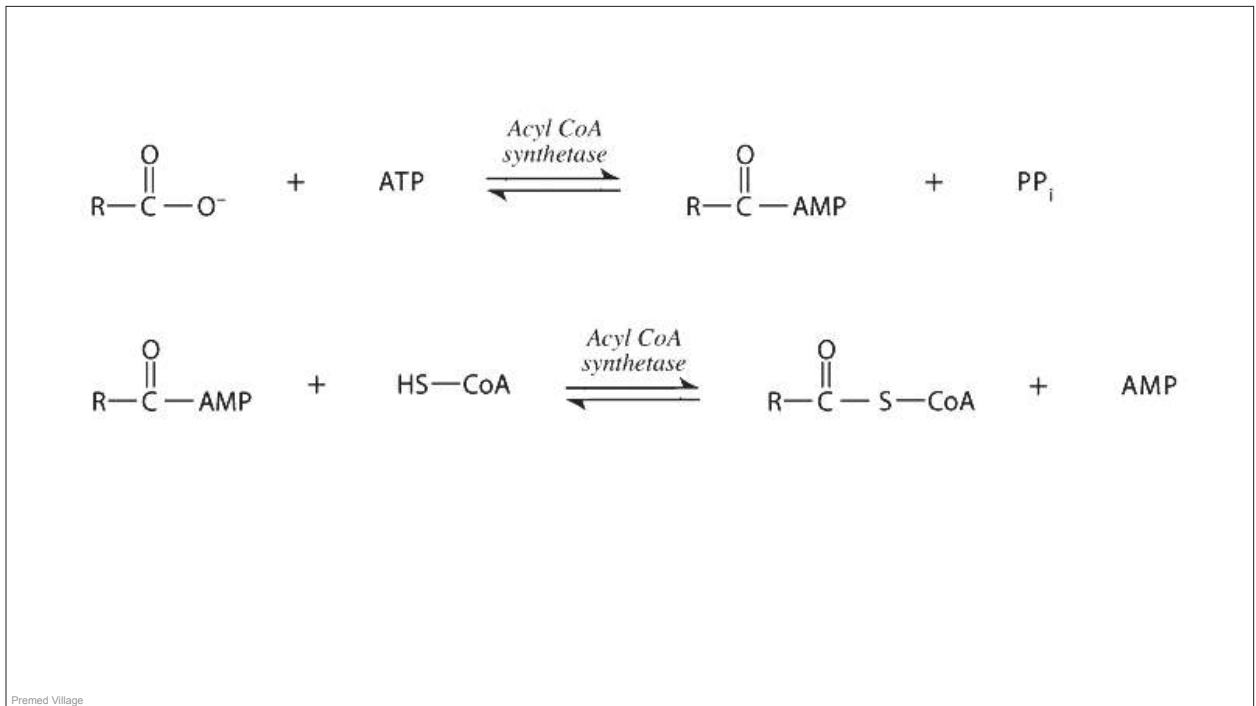
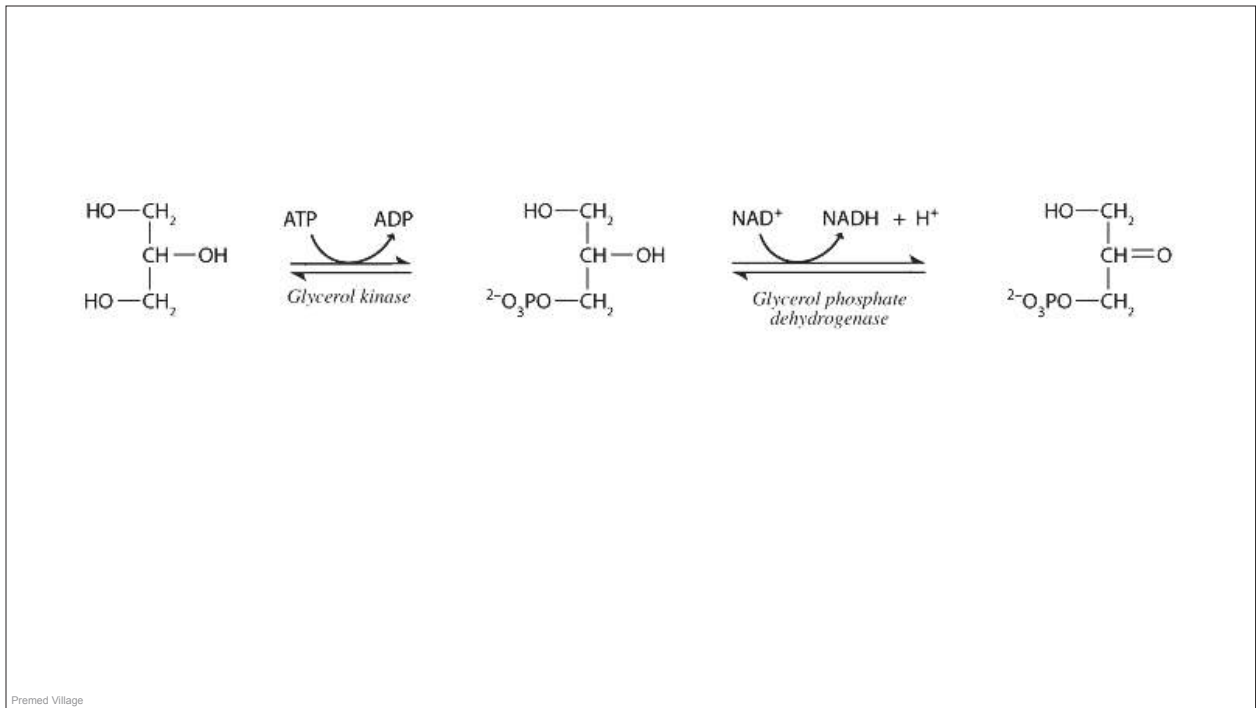
Beta Oxidation of Fatty Acids



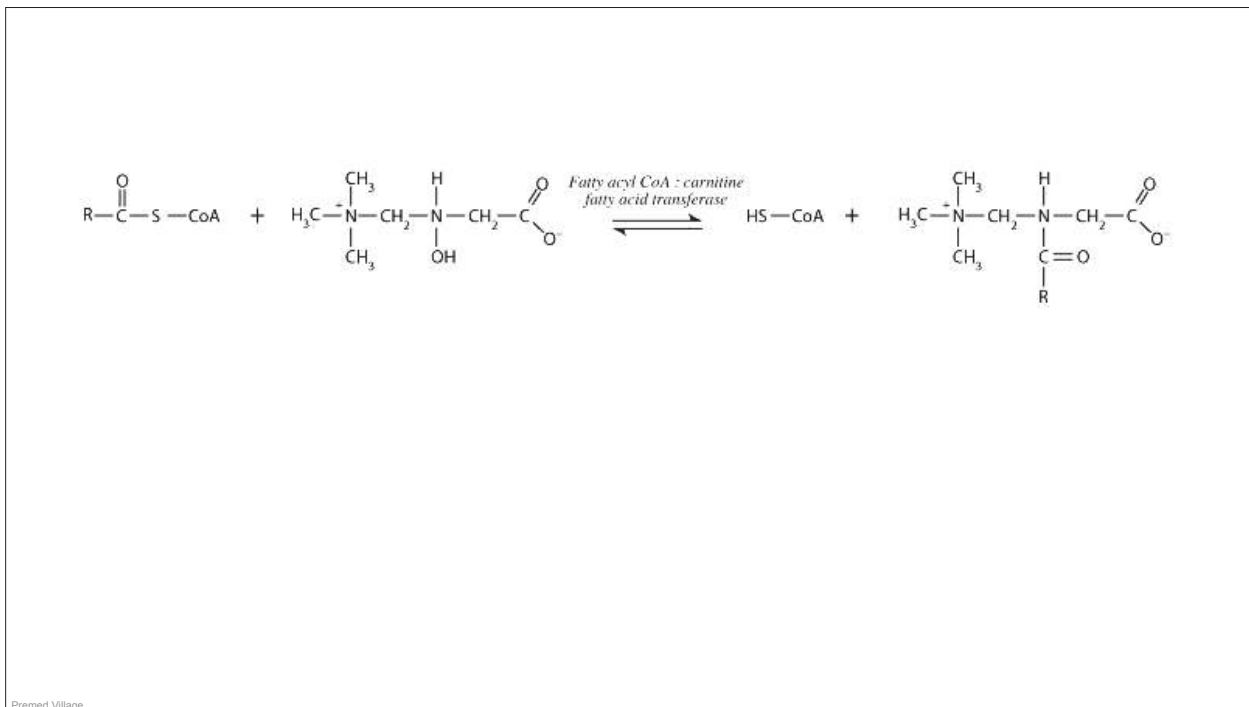
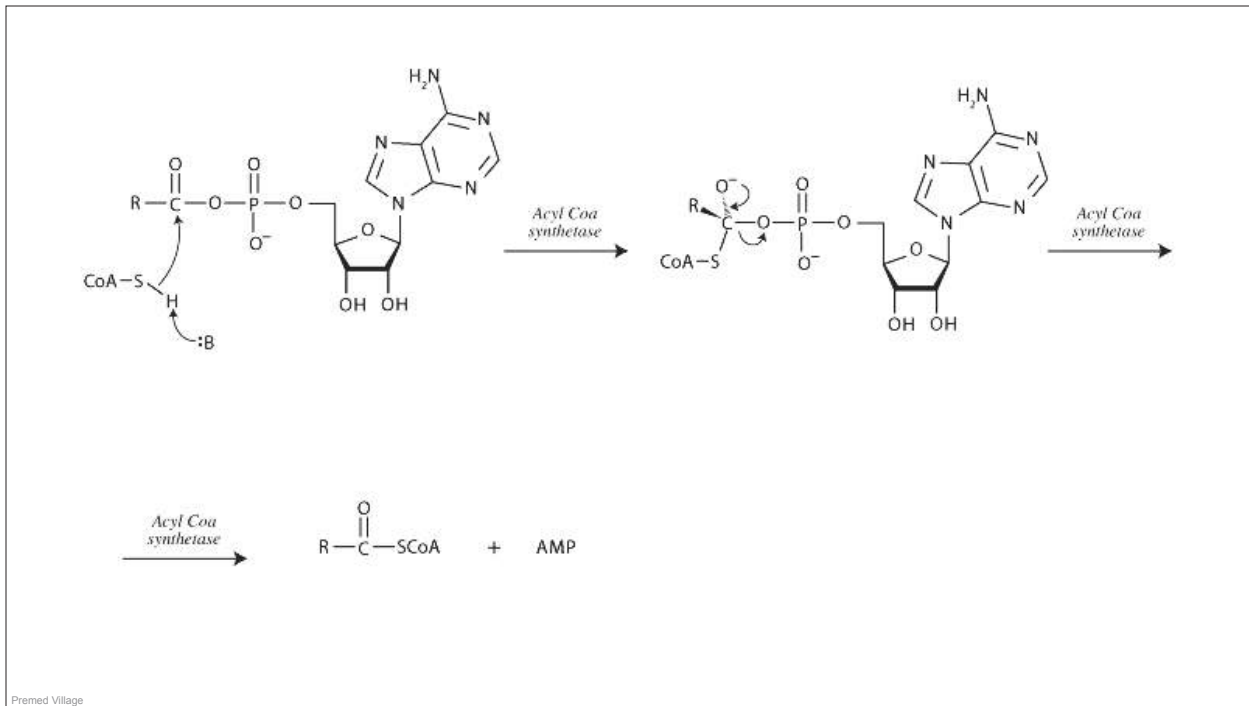
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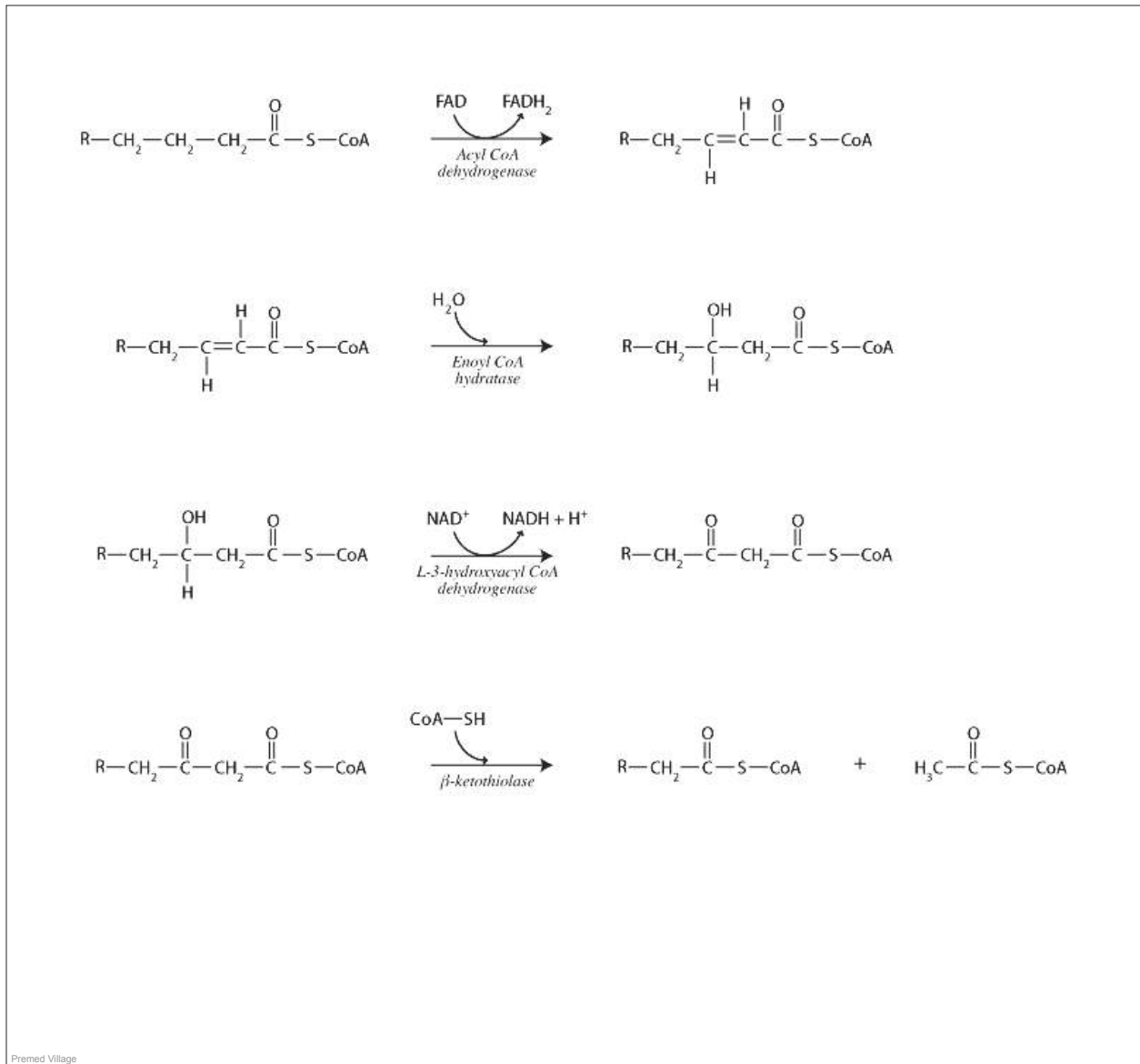


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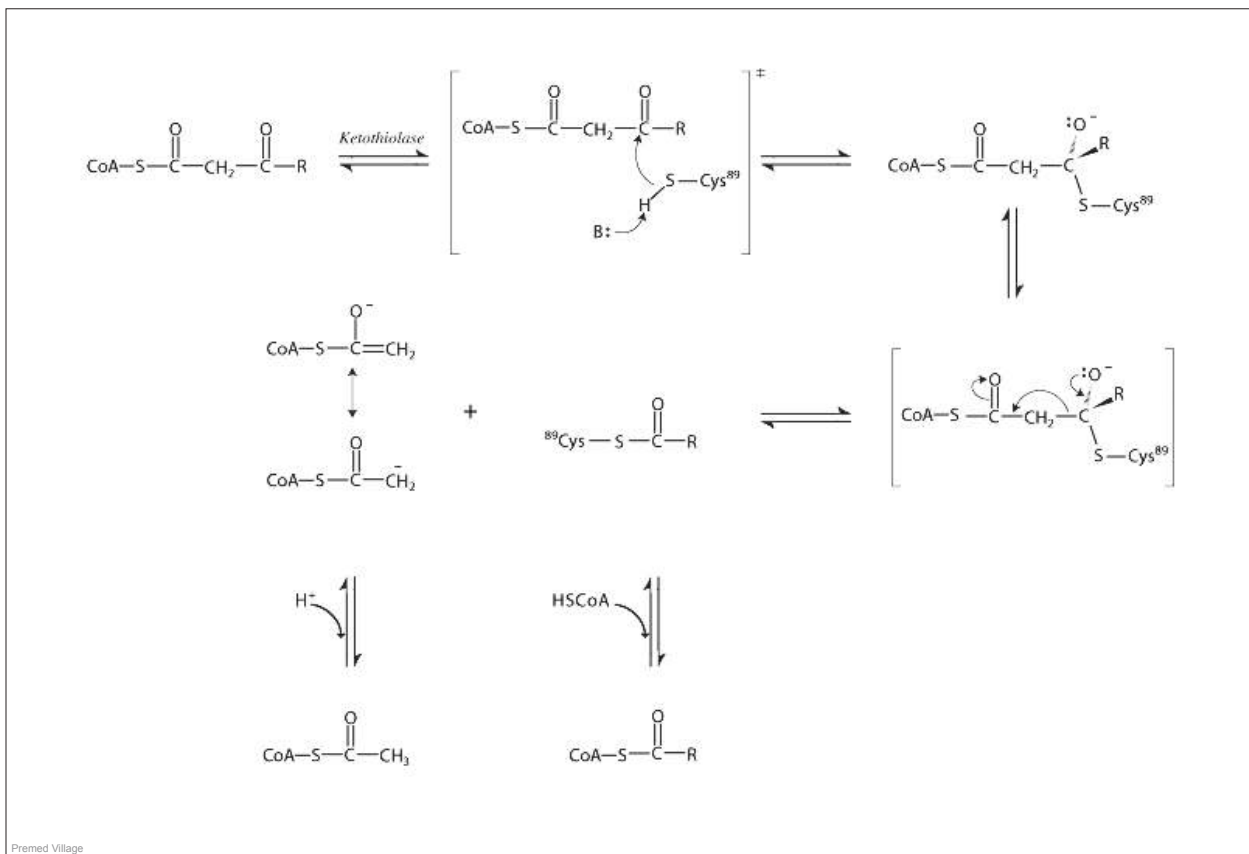
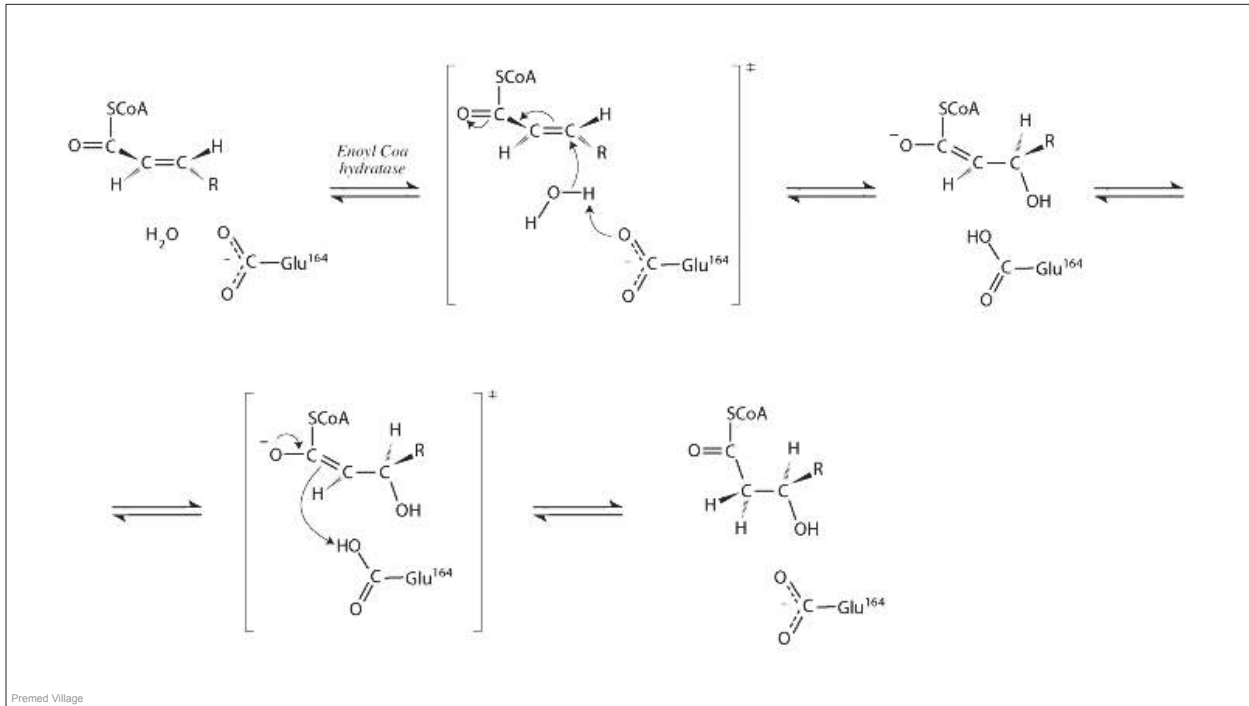


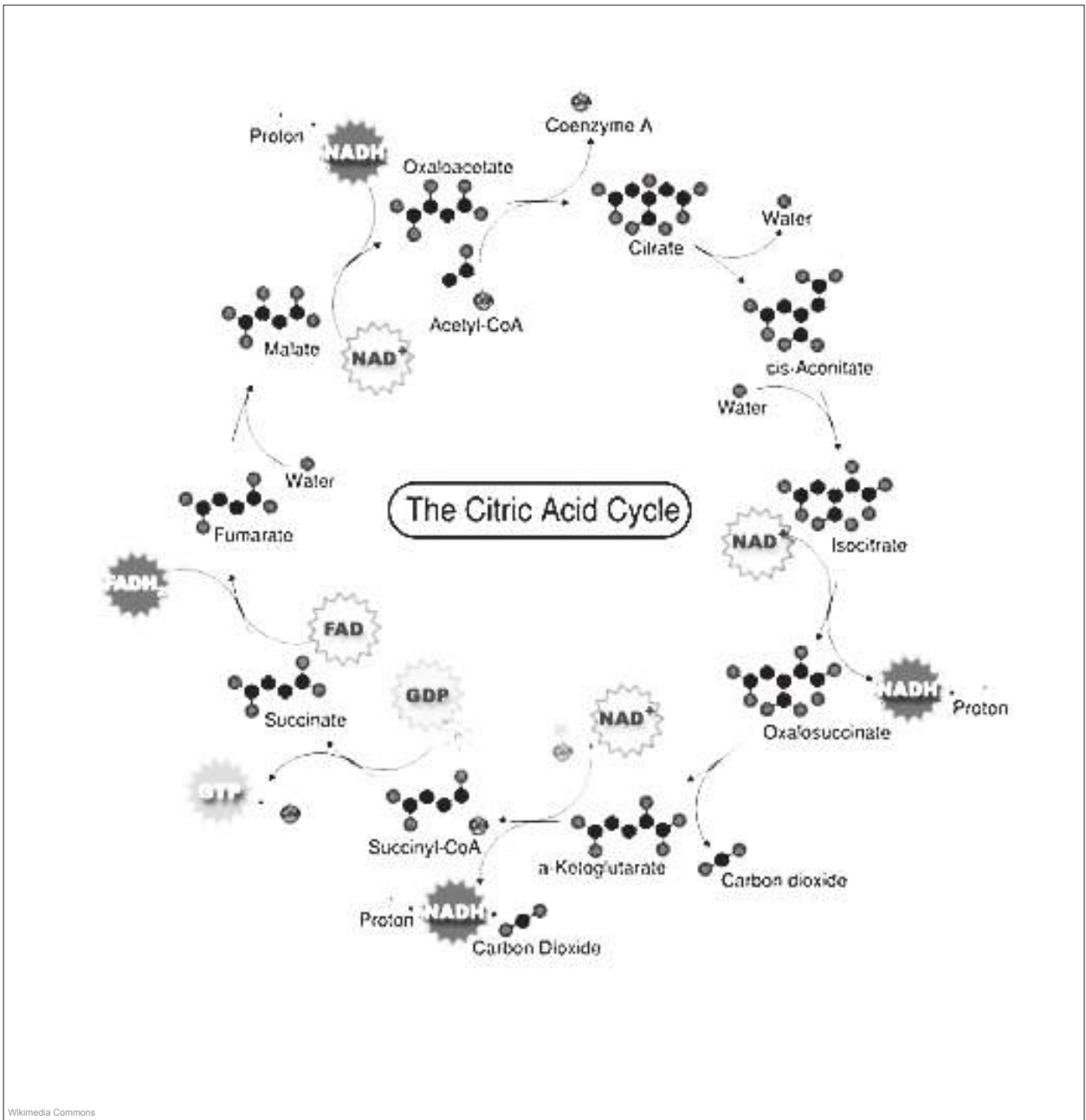
Beta Oxidation of Fatty Acids



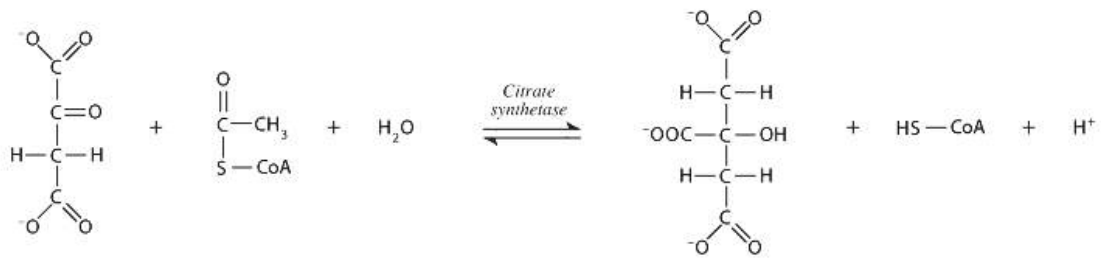


Beta Oxidation of Fatty Acids

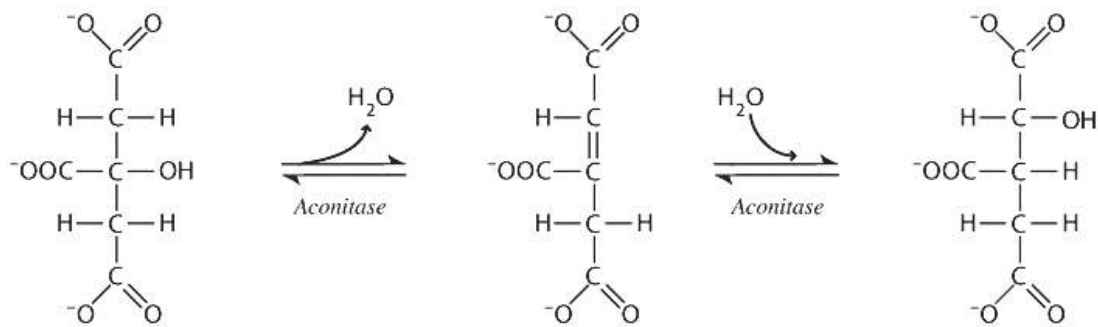




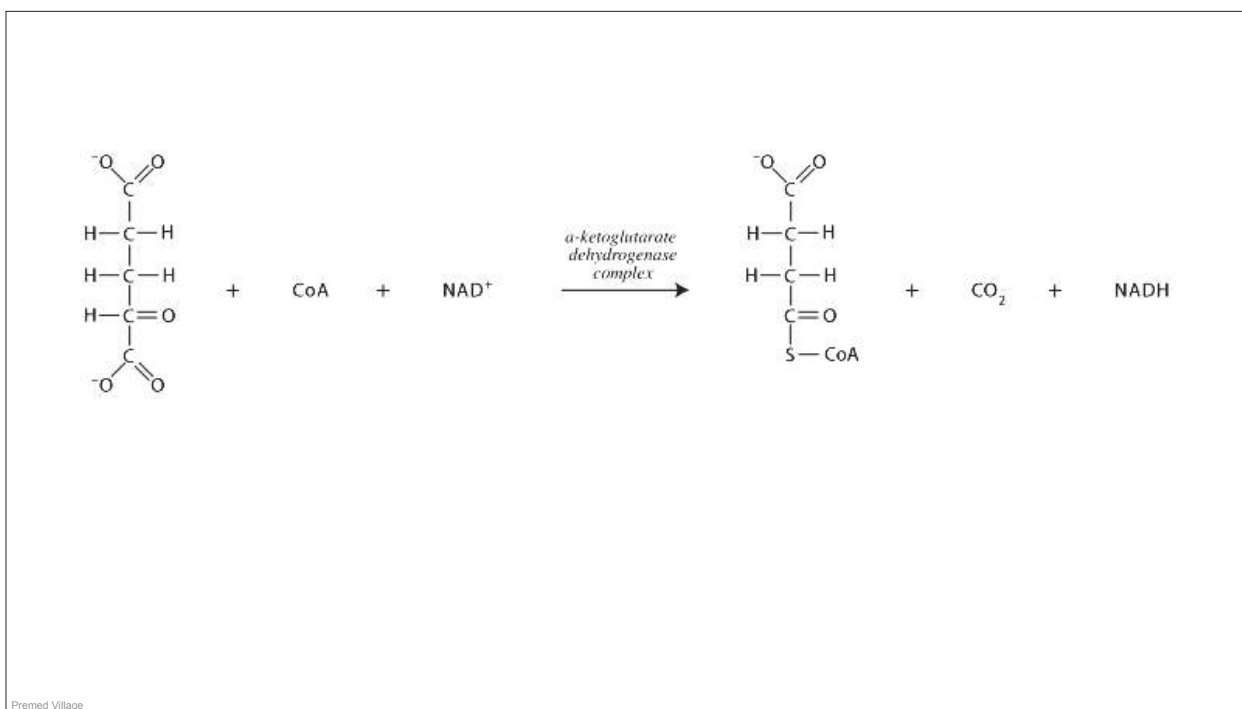
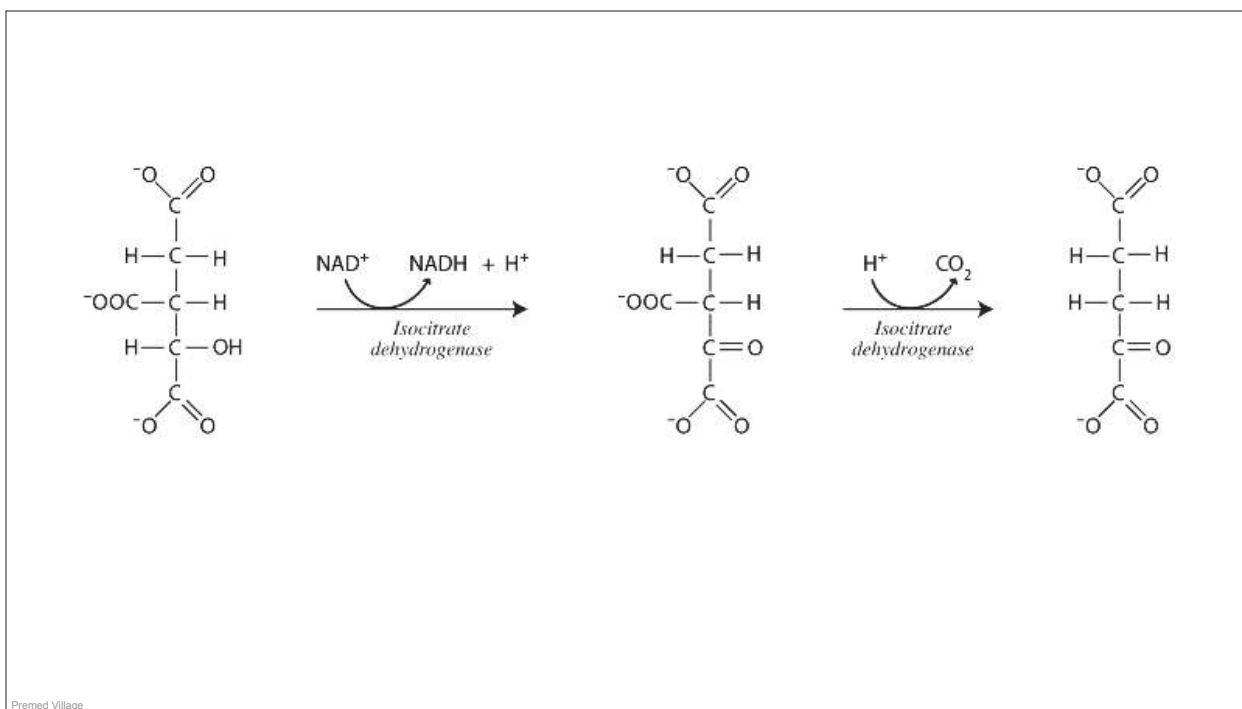
Citric Acid Cycle



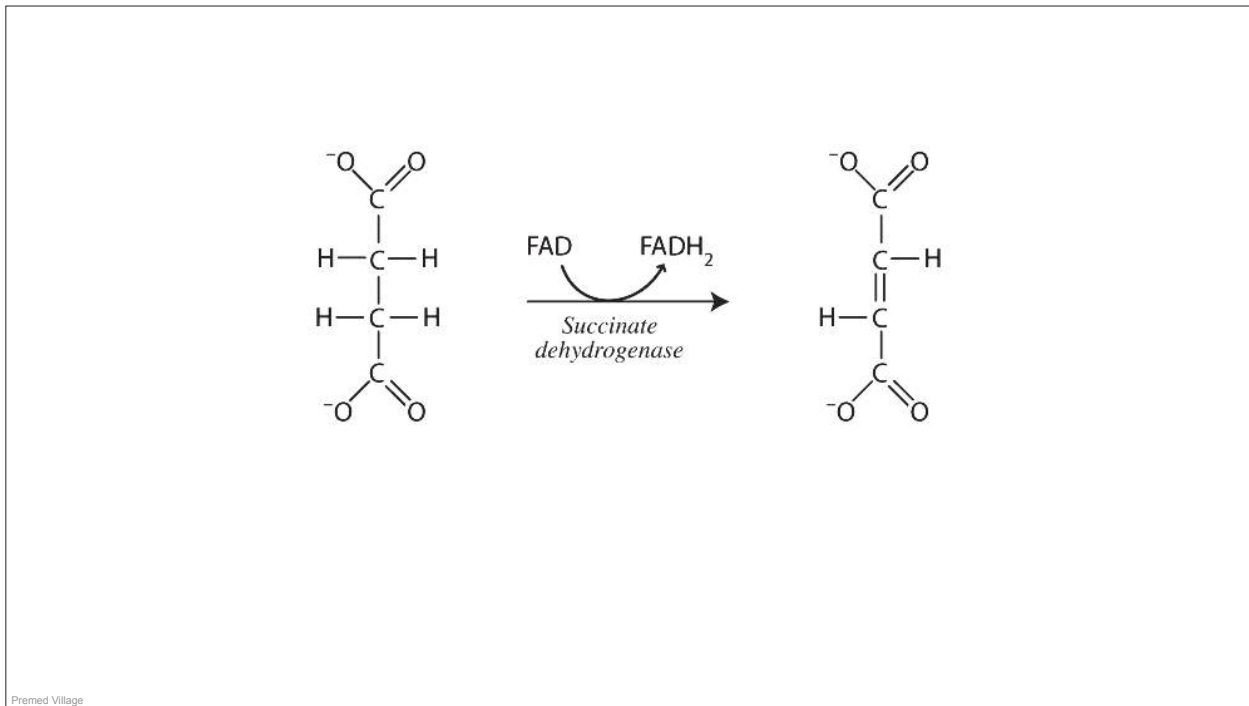
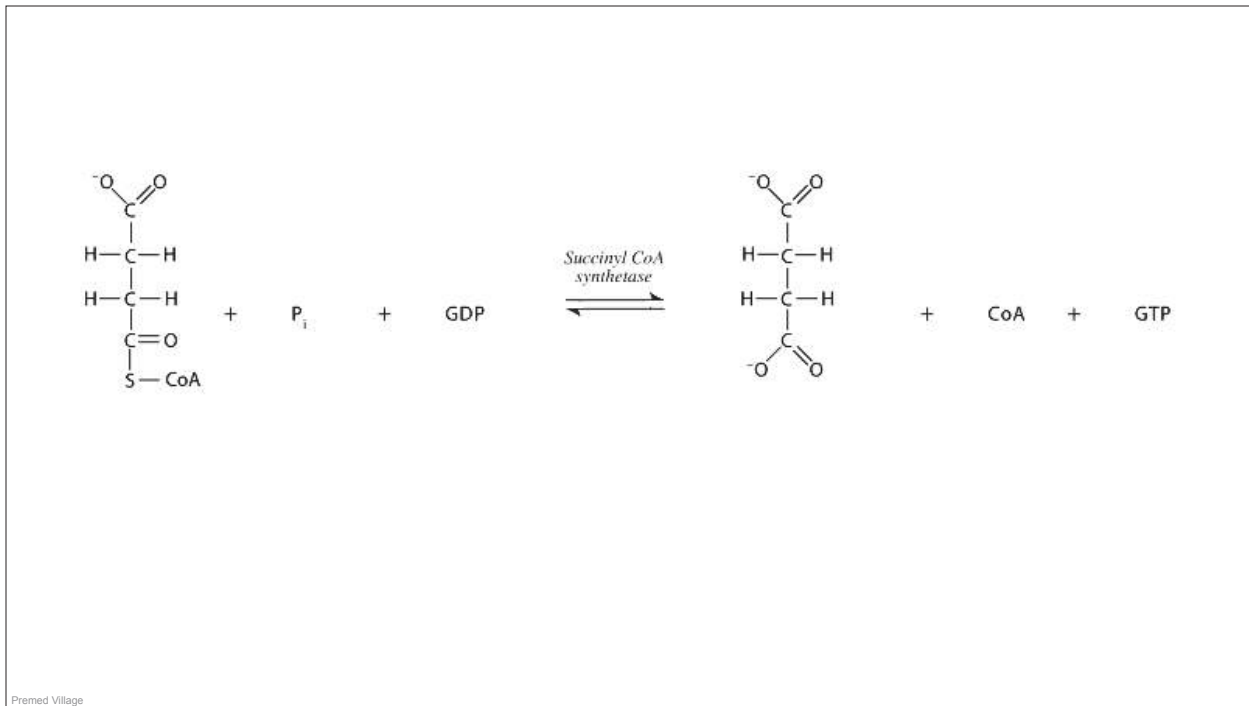
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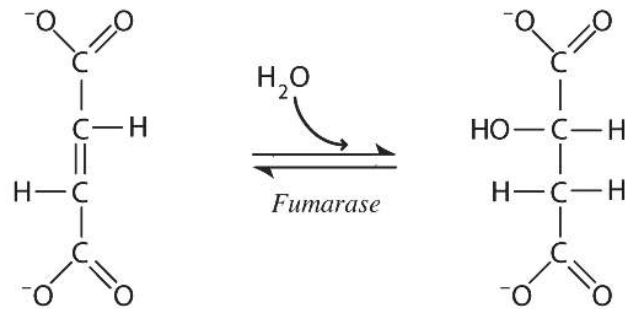


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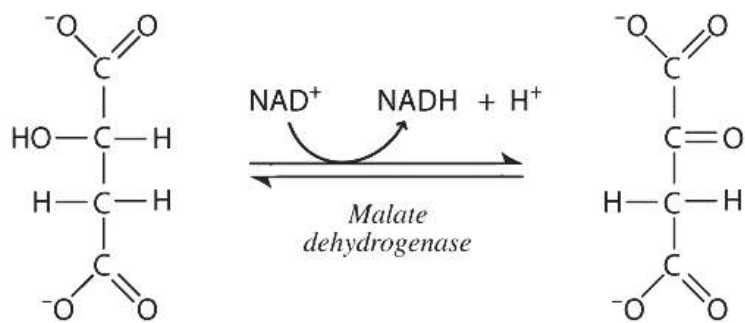


Citric Acid Cycle



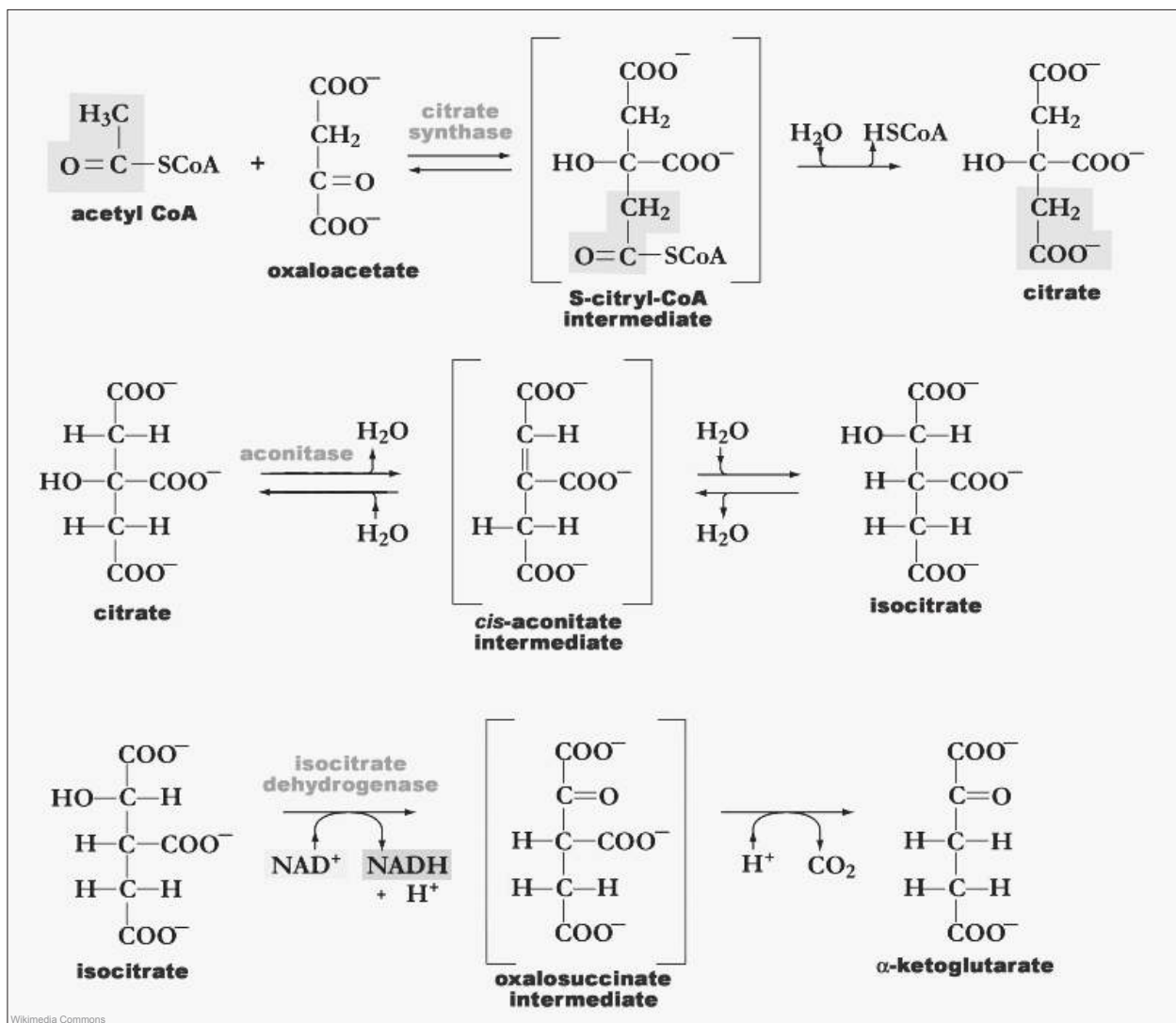
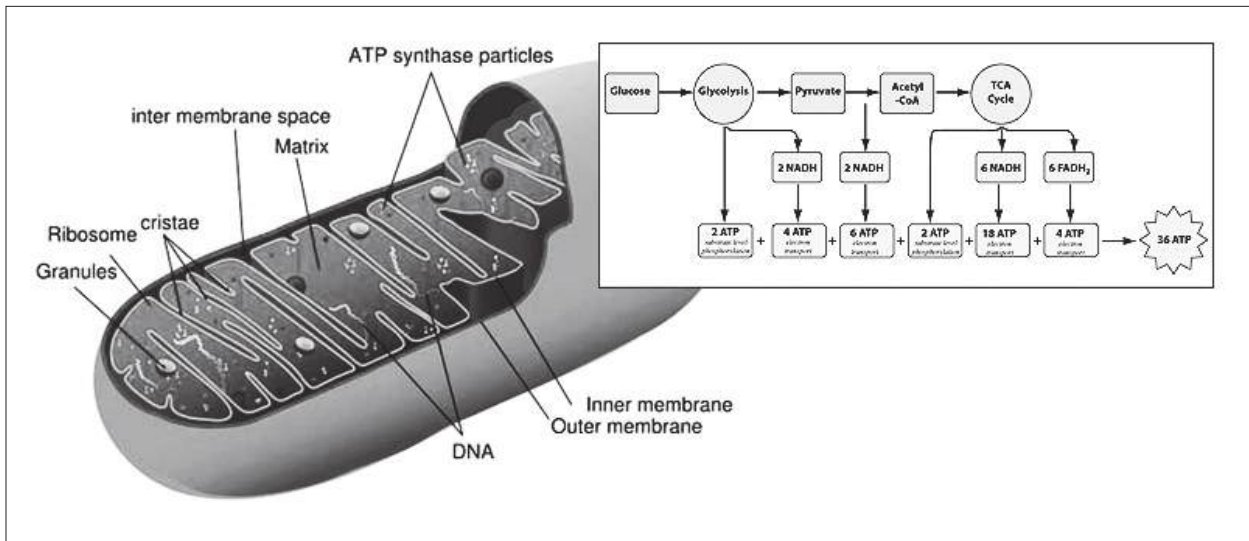


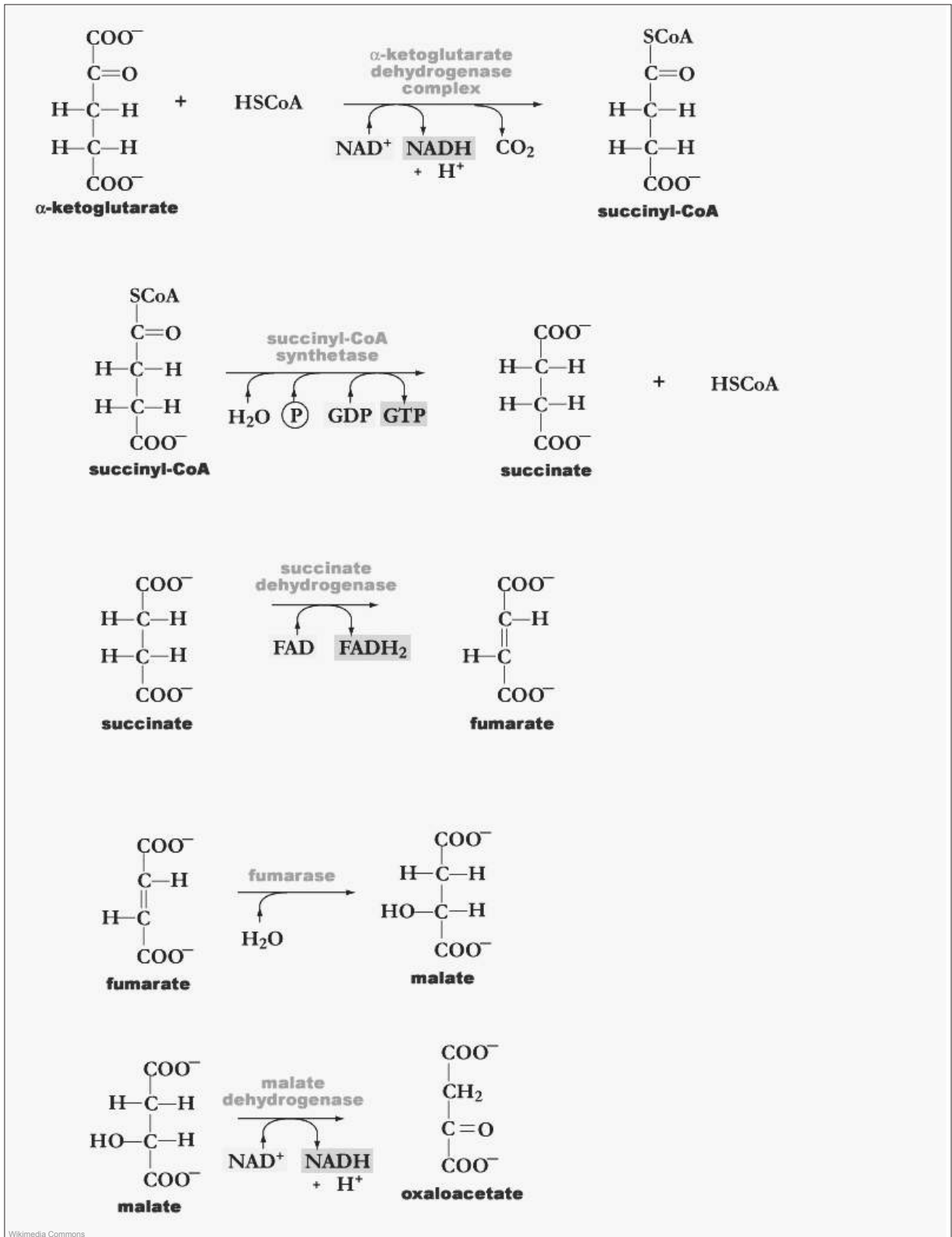
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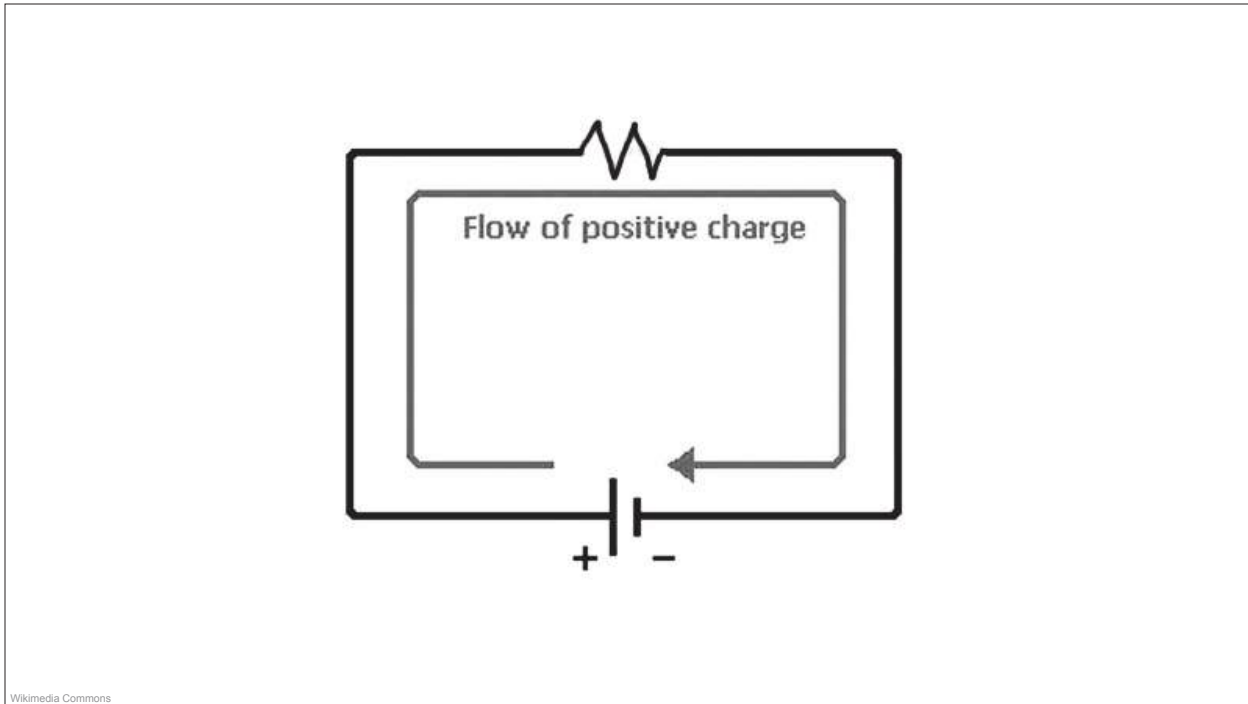


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Citric Acid Cycle







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Ohm's Law

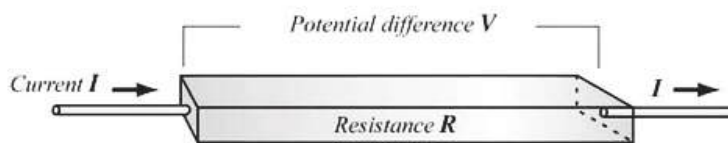
$$V = IR$$

$$I = \frac{V}{R}$$

V = electric potential

I = current

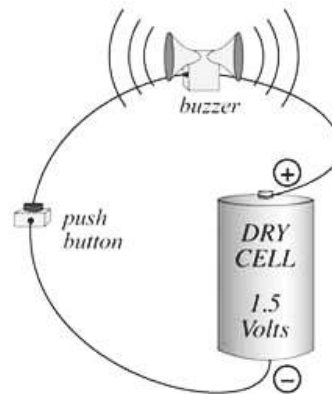
R = resistance



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When the push button at right is depressed, the 1.5 V battery causes the 50 Ω buzzer to sound. What current flows through the circuit?

- a. 15 mA
- b. 30 mA
- c. 75 A
- d. 150 A



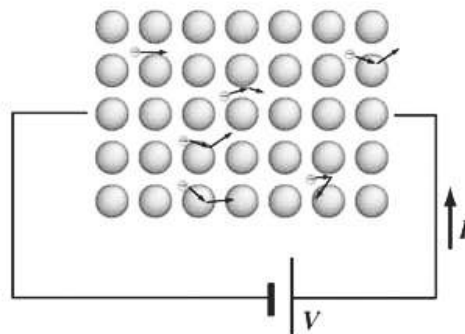
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Resistance of a Uniform Conductor

$$R = \frac{L}{\sigma A}$$

$$= \rho \frac{L}{A}$$

R = resistance
 L = resistor length
 A = resistor cross-sectional area
 σ = conductivity
 ρ = resistivity ($1/\sigma$)



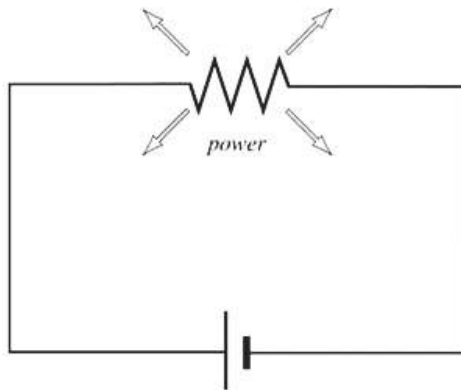
By convention, the direction of current is expressed as the flow of positive charge, which is opposite the direction of electron flow in a metallic conductor.

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Electric Power

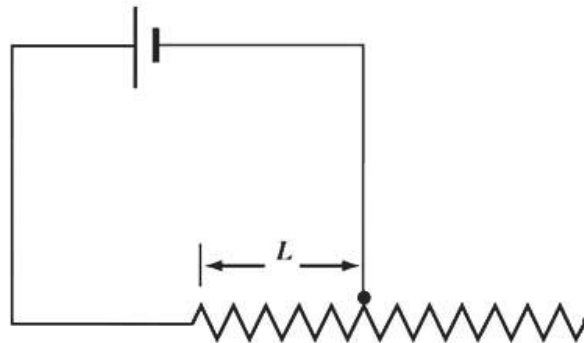
$$P = IV = I^2R = \frac{V^2}{R}$$

P = power
 I = current
 V = potential
 R = resistance



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With negligible internal resistance, a battery delivers a steady voltage to a variable resistor. With P_i representing the initial power output, what is the final power of the circuit when the length of the variable resistor is halved?

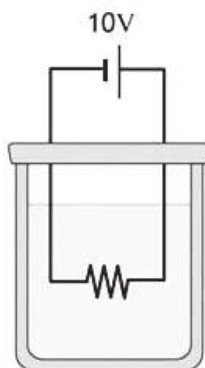


- a. $\frac{P_i}{4}$ b. $\frac{P_i}{\sqrt{2}}$ c. $2P_i$ d. $4P_i$

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A 10V battery delivers current to a resistor immersed in 100g water within a Dewar flask. What is the approximate current if the temperature of the water rises by one degree celsius (1°C) per second?

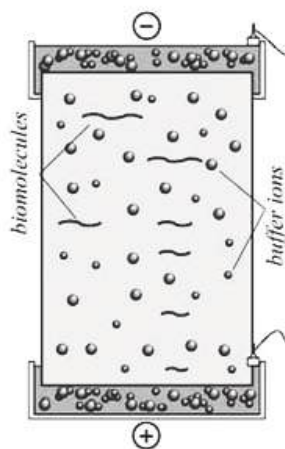
- a. 1 A
- b. 2.5 A
- c. 10 A
- d. 40A



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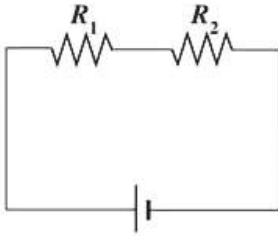
The varying mobility of biomolecules impelled by an electric field to migrate through a gel matrix enables their separation in gel electrophoresis. A buffered electrolyte solution provides the majority of electrical conductivity to the matrix. If a researcher inadvertently used a buffer solution of half normal concentration with the power supply set to its normal rate of constant current, which of the following would occur? (*Biomolecule charge-to-mass ratio unaffected*).

- a. Slower migration of biomolecules
- b. Increased apparatus temperature
- c. Unchanged electrical parameters
- d. Decreased electric field strength



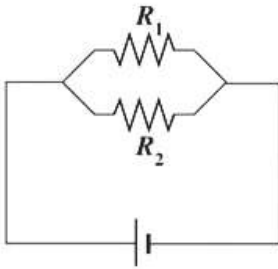
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Equivalent Resistance of Series or Parallel Resistors



$$R_{\text{ser}} = R_1 + R_2 + R_3 + \dots$$

The equivalent resistance of resistors in series is greater than the resistance of any individual resistor in the series.



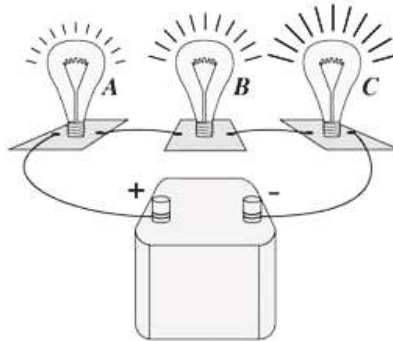
$$\frac{1}{R_{\text{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

The equivalent resistance of resistors in parallel is less than the resistance of any individual resistor in parallel.

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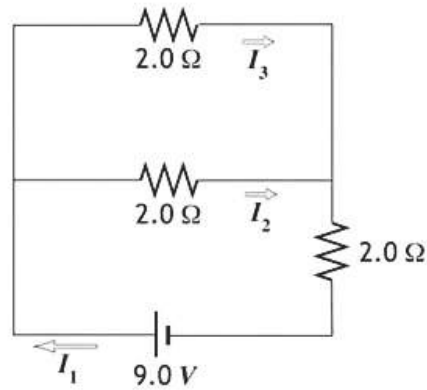
When three light bulbs of different wattage are attached in series to a steady DC power source, the order of brightness is $C > B > A$. If the circuit is then reconfigured so that the three bulbs are arranged in parallel, what would be the order of brightness in the new configuration?

- $A > B > C$
- $B > A > C$
- $C > B > A$
- $A = B = C$



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What is the value of the primary current, I_1 ?



- a. 1.5 A b. 2.25 A c. 3.0 A d. 4.5 A

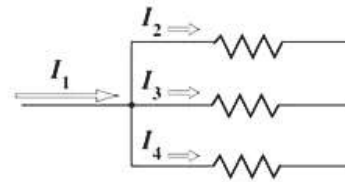
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Kirchhoff's Rules

Kirchhoff's First Rule (Branch Theorem)

$$I_1 = I_2 + I_3 + I_4$$

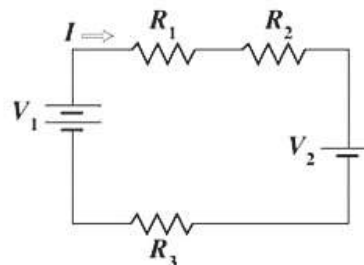
The sum of the currents into a junction equals the sum of currents out of the junction.



Kirchhoff's Second Rule (Loop Theorem)

$$V_1 - IR_1 - IR_2 - V_2 - IR_3 = 0$$

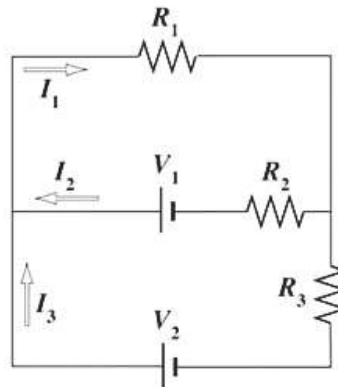
The sum of the changes in potential around any closed path is zero.



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Which of the following statements validly describes the circuit at right?

- I. $V_1 - I_1 R_1 - I_2 R_2 = 0$
- II. $V_1 - V_2 + I_3 R_3 - I_2 R_2 = 0$
- III. $I_1 = I_2 + I_3$
- IV. $V_2 - I_1 R_1 - I_3 R_3 = 0$



- a. I only
- b. I and II
- c. I, II and III
- d. I, II, III, and IV

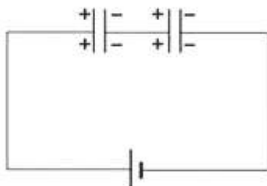
Premed Village

Capacitance

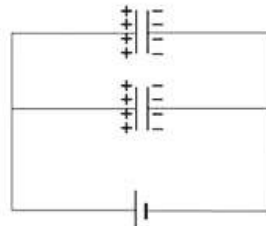
A capacitor with a high capacitance can hold a large amount of charge without requiring a high voltage.

$$C = \frac{Q}{V}$$

- C = capacitance
- Q = electric charge on a single plate
- V = voltage



$$\frac{1}{C_{\text{ser}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

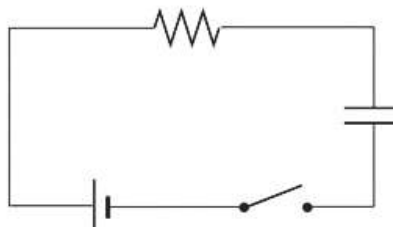


$$C_{\text{par}} = C_1 + C_2 + C_3 + \dots$$

Placing capacitors in series decreases the total capacitance, while placing capacitors in parallel increases the total capacitance.

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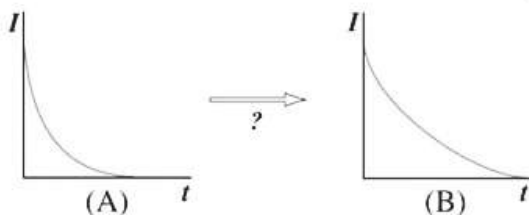
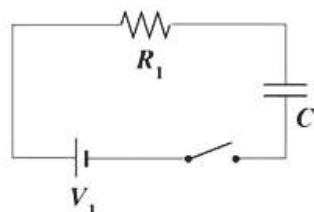
The RC circuit at right consists of a capacitor in series with a battery, resistor and a switch. What occurs within the circuit after the switch is closed?



- The voltage drop across the resistor decreases with time until there is no voltage acting across the resistor.
- The current is not steady state. It slowly increases with time.
- After the capacitor has fully charged, the current flows in the opposite direction.
- The work done by the external voltage of the battery becomes stored potential energy in the charged capacitor.

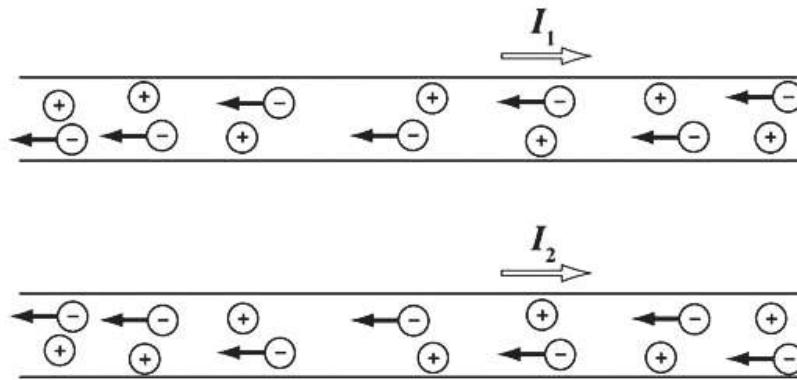
Premed Village

Graph (A) shows the current vs. time that occurs after the switch is closed in the circuit at right. How could the circuit be altered to transform the current vs. time graph into graph (B)?



- Include another resistor in series with R_1
- Include another resistor in parallel with R_1
- Include another capacitor in series with C_1
- Include another capacitor in parallel with C_1

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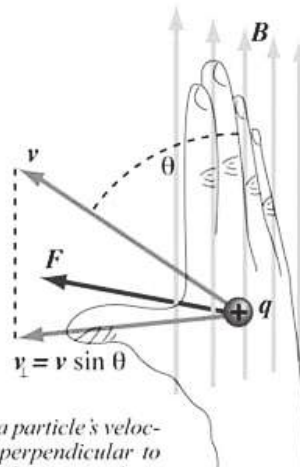


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Magnetic Force on a Moving Charge

$$F = qB v \sin \theta$$

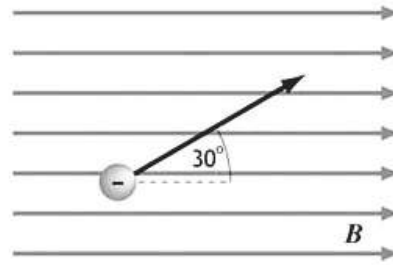
- F = magnetic force
- q = particle charge
- B = magnetic field strength
- v = particle speed
- θ = angle between particle velocity and the magnetic field



To produce a magnetic force, a particle's velocity must have a component perpendicular to the magnetic field. If that is the case, a force is produced perpendicular to both the field and the particle's velocity.

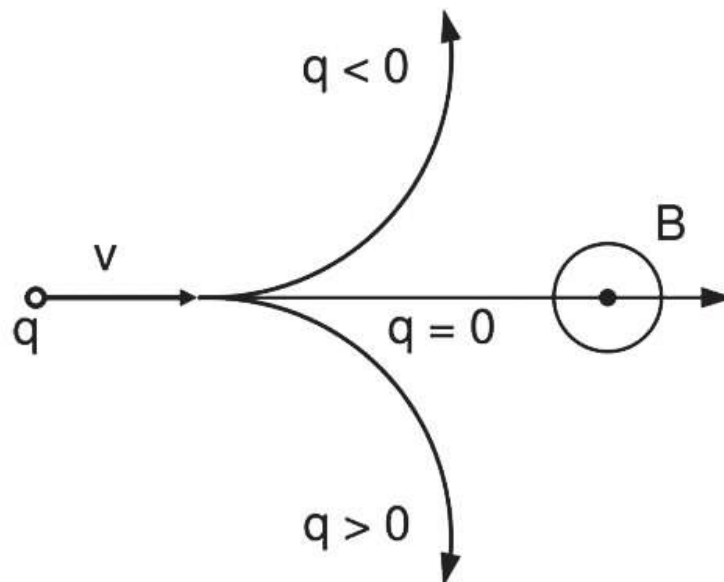
Premed Village

A beta (β^-) particle (charge $-1.6 \times 10^{-19} \text{ C}$) moves at a speed of $1 \times 10^5 \text{ m/s}$ at an angle of 30° to a uniform 20 T magnetic field in the plane of the image at right. What is the magnetic force on the particle?



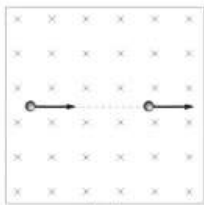
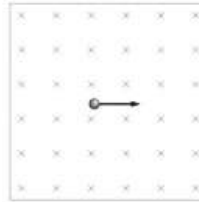
- $1.6 \times 10^{-13} \text{ N}$ directed out of the plane
- $1.6 \times 10^{-13} \text{ N}$ directed into the plane
- $\sqrt{3} \times 10^{-13} \text{ N}$ directed out of the plane
- there is no magnetic force on the particle

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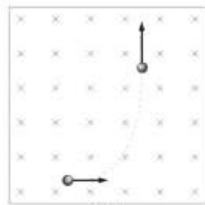


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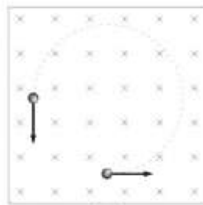
The figure at right shows the instantaneous velocity of a positively charged particle within a uniform magnetic field. Particle velocity is perpendicular to the magnetic field (directed into the plane). Which of the following images best represents possible subsequent motion of the particle?



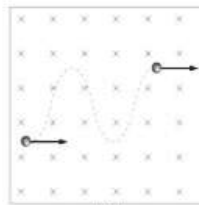
(a)



(b)



(c)



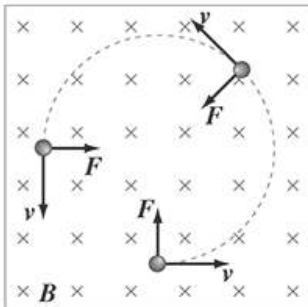
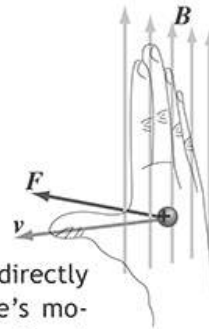
(d)

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The answer is (C)

The magnetic force is perpendicular both to the particle velocity and to the magnetic field. The particle moves in a circle. The magnetic force is a centripetal force.

$$F = qvB = \frac{mv^2}{r}$$



The radius of the circle is directly proportional to the particle's momentum, and inversely proportional to the charge and magnetic field strength.

$$r = \frac{mv}{qB}$$

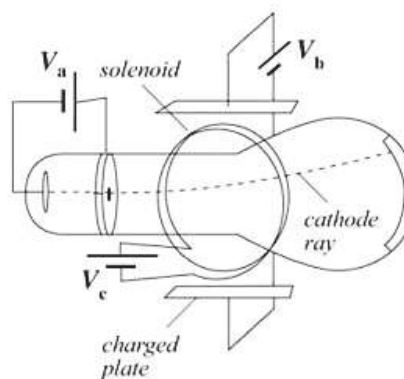
The angular frequency of a particle trapped in circular motion within a uniform magnetic field is called the cyclotron frequency.

NOTE THAT THE MAGNETIC FORCE IS PERPENDICULAR TO VELOCITY (AND INSTANTANEOUS DISPLACEMENT), SO A STEADY MAGNETIC FIELD DOES NO WORK ON A CHARGED PARTICLE. ITS DIRECTION CHANGES, BUT WITH NO DISSIPATION, KINETIC ENERGY IS CONSTANT.



Premed Village

The magnetic force produced by the solenoid current upon the cathode ray at right opposes the electrostatic force produced by the charged plates. Which of the following by itself could straighten the beam so that it strikes the center of the phosphorescent screen?



- I. Increasing V_a
- II. Decreasing V_a
- III. Increasing V_b
- IV. Increasing V_c

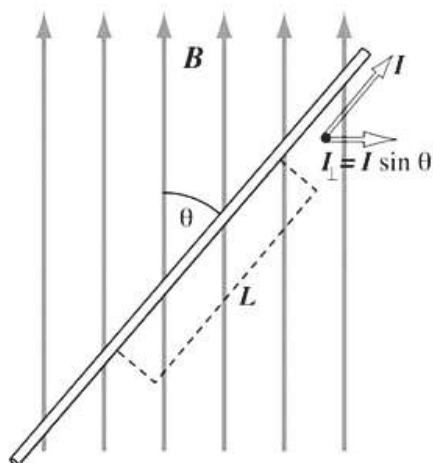
- a. II only b. IV only c. I or IV d. I, II or III

Premed Village

Magnetic Force on a Segment of Current Carrying Wire

$$F = LB I \sin \theta$$

- F = magnetic force on wire segment
 L = segment length
 B = magnetic field strength
 I = current
 θ = angle between the current and the magnetic field



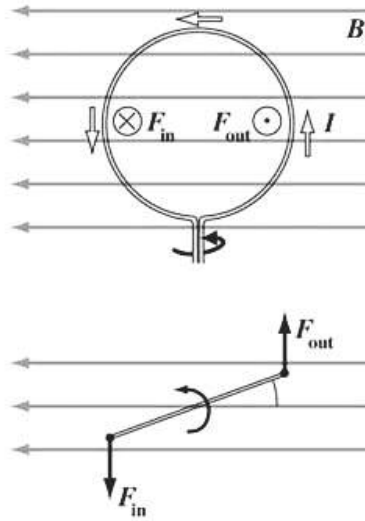
Magnetic force is directed out of the plane of the image.

Premed Village

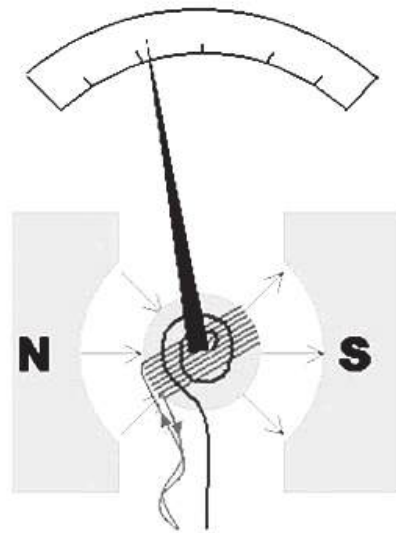
Torque on a Current Loop within a Uniform Magnetic Field

$$\tau = IAB \cos \phi$$

- τ = torque on current loop
- I = current
- A = area of loop
- B = magnetic field strength
- ϕ = angle between the loop plane and the magnetic field



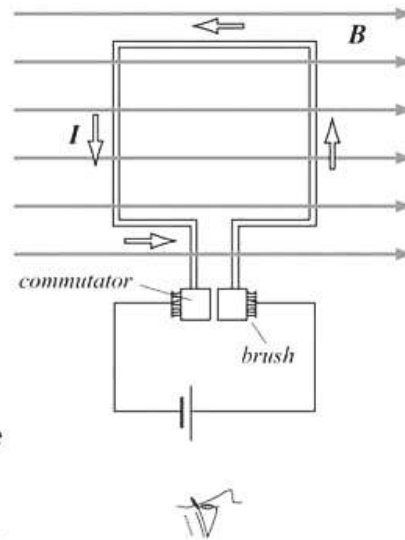
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From the point of view depicted in the figure at right, which of the following occurs when current is supplied to the loop at right?

- the loop rotates clockwise
- the loop rotates counter-clockwise
- the loop is compressed
- there is no net torque on the loop



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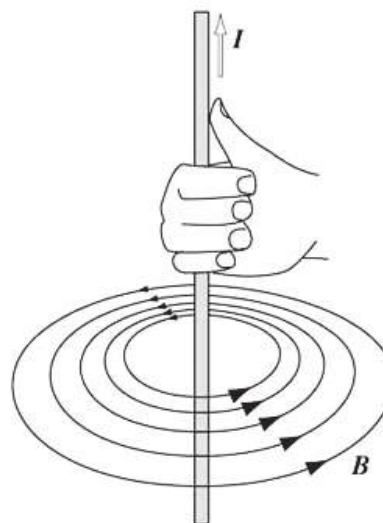
Magnetic Field of a Straight Current Carrying Wire

$$B = \frac{\mu_0 I}{2\pi d}$$

- B = magnetic field strength at distance d
 I = current
 μ_0 = permeability of free space
 ($4\pi \times 10^{-7}$ T m/A)
 d = distance from the wire

Ampere's Law

For any closed loop path, the sum of the products of the length elements and the magnetic field in the direction of the length elements is proportional to the electric current enclosed in the loop (magnetic permeability, μ_0 is the constant of proportionality).



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When electric current is flowing in the same direction through two, adjacent, parallel wires:



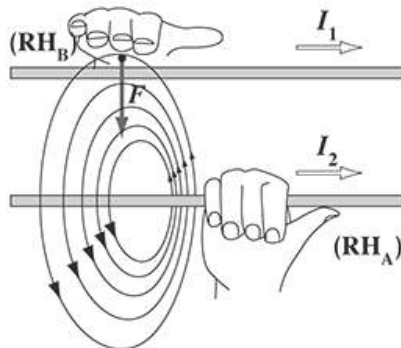
- a. The wires attract each other
- b. The wires repel each other
- c. The wires do not interact
- d. The wires generate an alternating current

Premed Village

The answer is (a)

Use both right hand rules: Use the first rule, (RH_A), to predict the orientation of a field produced by the current of one of the wires. The second rule, (RH_B), predicts the orientation of the magnetic force (of course, each wire feels an equal and opposite attractive force).

With your thumb of your right hand in the direction of the component of the current that is perpendicular to the magnetic field from the other wire and your fingers in the direction of that field, the direction of the magnetic force is out of your palm.




Point the thumb of your right hand in the direction of positive current, then wrap your fingers around the wire to show orientation of the magnetic field.

PARALLEL WIRES WITH CURRENT IN THE SAME DIRECTION ATTRACT EACH OTHER. PARALLEL WIRES WITH CURRENT IN THE OPPOSITE DIRECTION REPEL EACH OTHER. PERPENDICULAR WIRES DO NOT INTERACT.



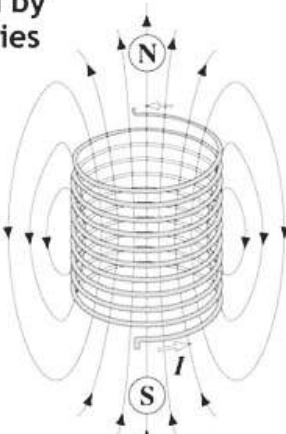
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Magnetic Fields Produced by Various Current Geometries



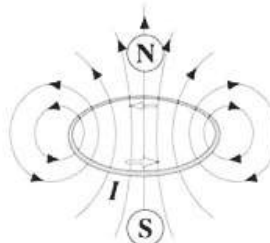
$$B = \frac{\mu_0 I}{2\pi d}$$

B = magnetic field strength
 I = current
 μ_0 = permeability of free space
 $(4\pi \times 10^{-7} \text{ T m/A})$
 d = distance from the wire



$$B = n\mu_0 I$$

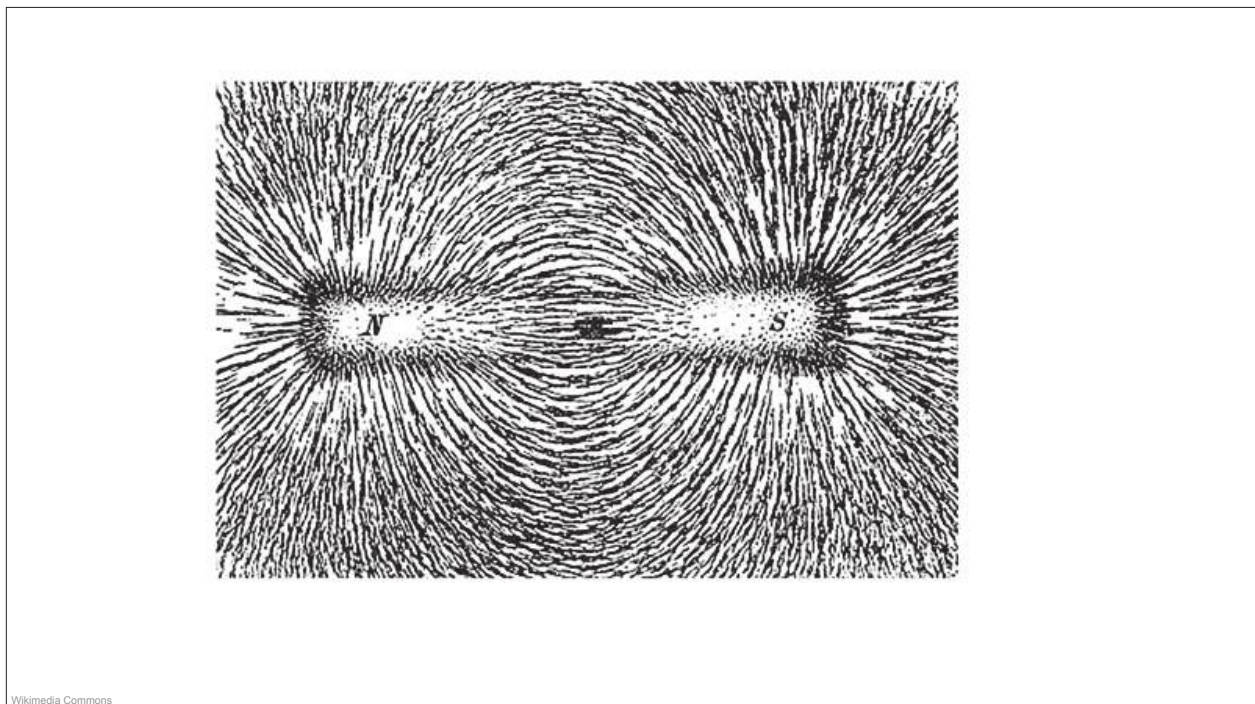
B = magnetic field strength within the solenoid
 n = turns per unit length



$$B = \frac{\mu_0 I}{2r}$$

B = magnetic field strength at loop center
 r = radius

Premed Village



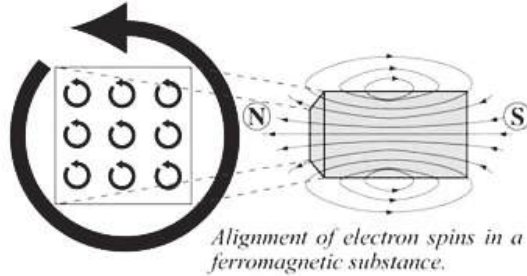
Magnetism in Matter

Paramagnetism

Paramagnetic substances contain electrons within atomic or molecular orbitals that are unpaired, producing net electron spin. Paramagnetic substances are weakly attracted by magnetic fields.

Ferromagnetism

Ferromagnetic substances can be permanently magnetized as randomly oriented electron spins align cooperatively in domains. Ferromagnetism is much stronger than paramagnetism.

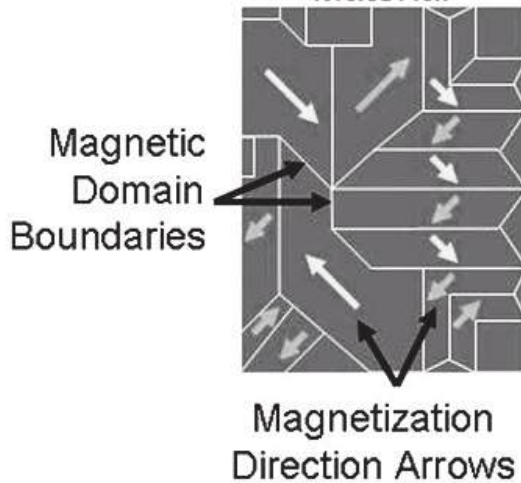


Diamagnetism

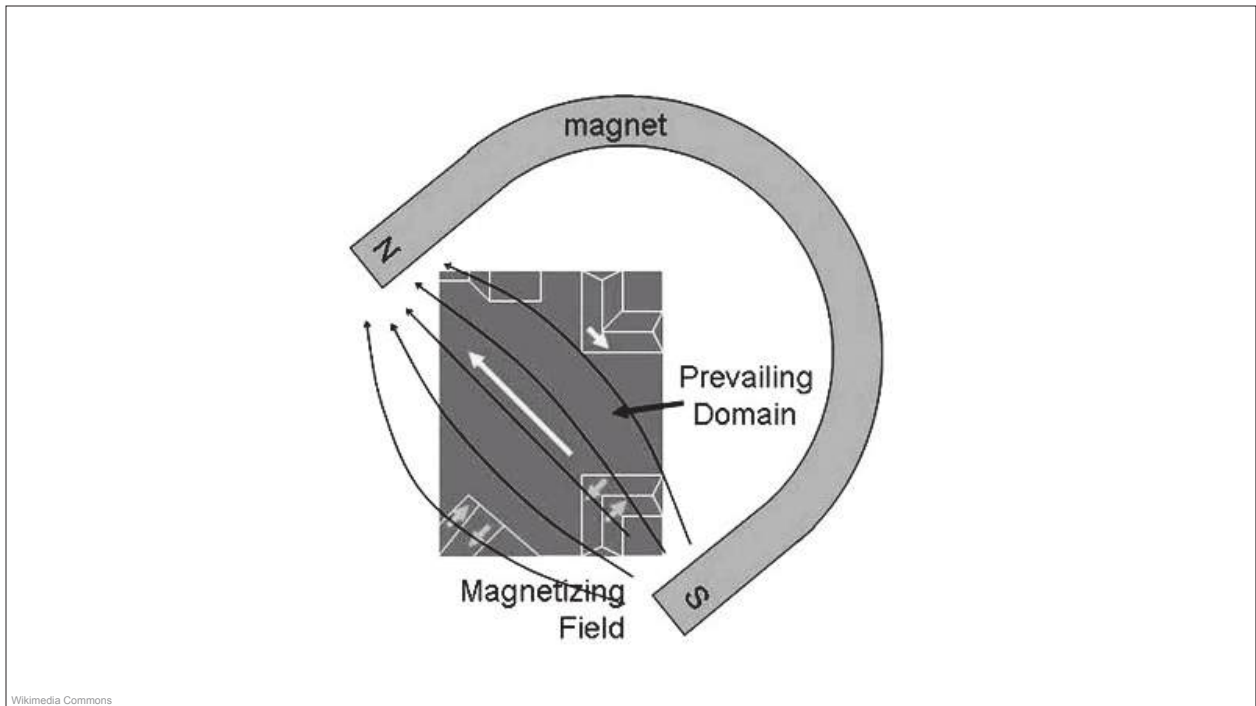
In diamagnetic substances all electrons are paired. Diamagnetic substances are very, very weakly repelled by magnetic fields, a much weaker interaction than either paramagnetism or ferromagnetism.

Premed Village

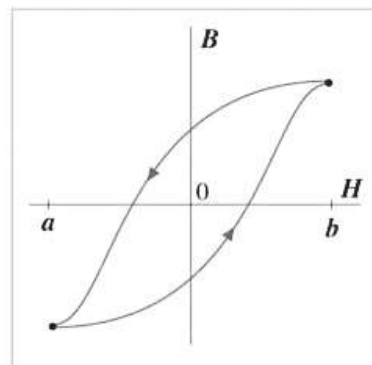
Ferromagnetic Material



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The graph at right shows the total magnetic field, B , within a volume element of Substance X as Substance X is subjected to a changing external magnetic field, H , which oscillates between the extreme values a and b . Substance X is



- paramagnetic
- ferromagnetic
- diamagnetic
- polar

Fremed Village

H 2.20																	He
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne
Na 0.93	Mg 1.31											Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16	Ar
K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66	Xe 2.60
Cs 0.79	Ba 0.89	*	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.20	Pt 2.28	Au 2.54	Hg 2.00	Tl 1.62	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn 2.2
Fr 0.7	Ra 0.9	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
*	La 1.1	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.2	Gd 1.2	Tb 1.1	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.1	Lu 1.27		
**	Ac 1.1	Th 1.3	Pa 1.5	U 1.38	Np 1.36	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr 1.3		

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metathesis reaction



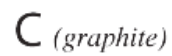
oxidation-reduction reaction

Premed Village



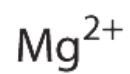
Premed Village

The oxidation number of an atom is zero in a neutral substance that contains atoms of only one element.



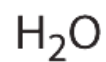
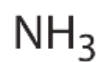
Premed Village

The oxidation number of simple ions is equal to the charge on the ion.



Premed Village

The oxidation number of hydrogen is +1 when it is combined with a nonmetal.



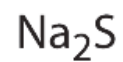
Premed Village

The oxidation number of hydrogen is -1 when combined with a metal.



Premed Village

In compounds the metals in Group IA have an oxidation number of +1.



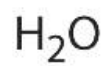
Premed Village

In compounds the metals in Group IIA have an oxidation number of +2.



Premed Village

Oxygen usually has an oxidation number of -2.



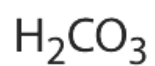
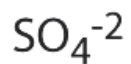
Premed Village

Halogens usually has an oxidation number of -1

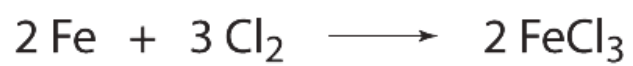


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The sum of the oxidation numbers in a neutral compound is zero, and the sum of the oxidation numbers in a polyatomic ion is equal to the charge on the ion.



Premed Village



Premed Village



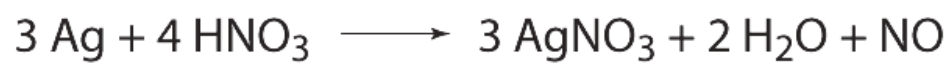
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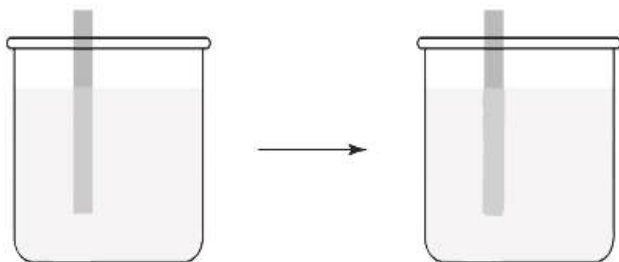
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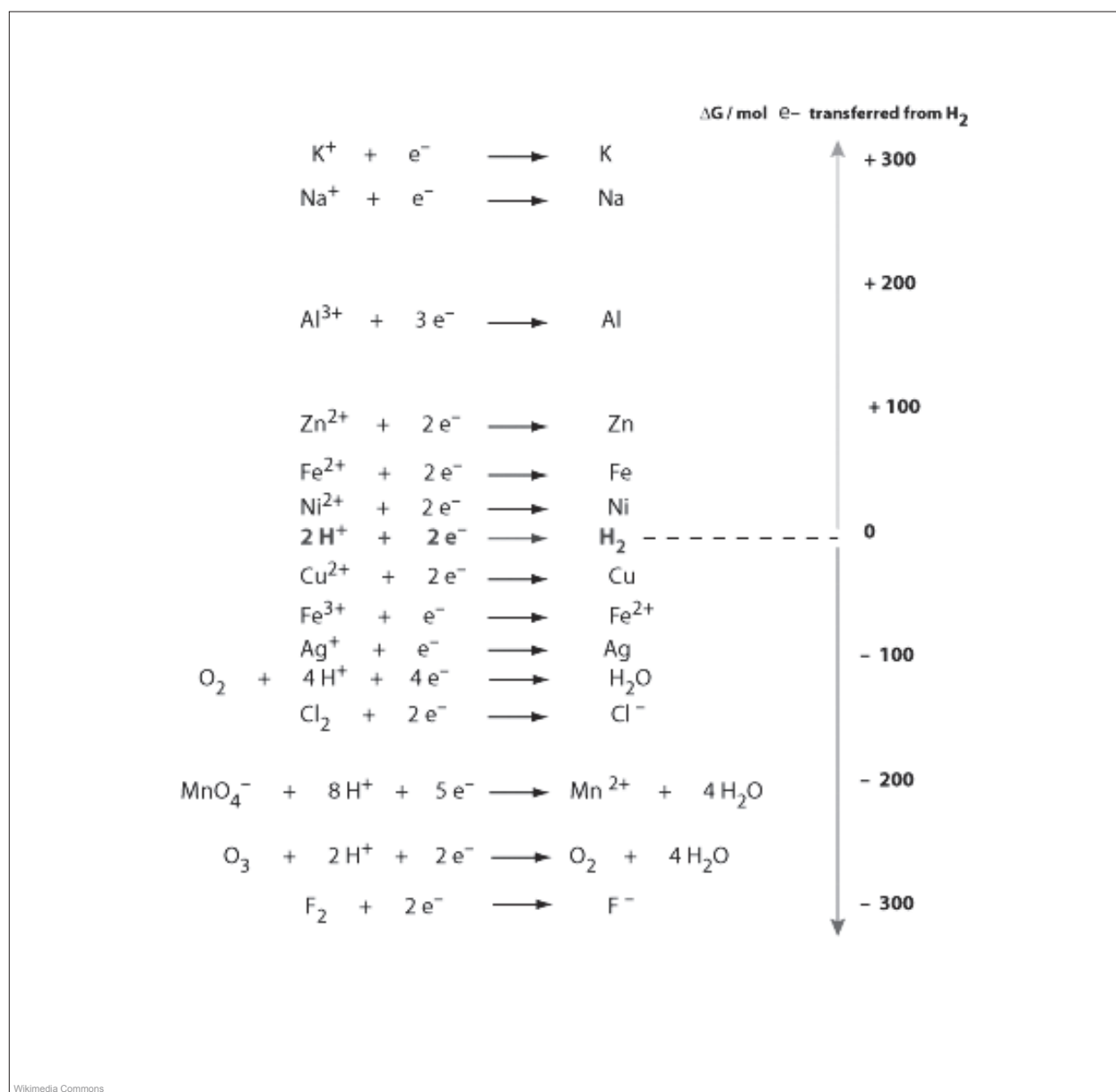
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Premed Village



Premed Village



Reacting potassium metal with pure water produces

- potassium oxide, K_2O
- a basic solution
- an acidic solution
- oxygen gas

Premed Village

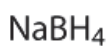
Reducing Agents



lithium aluminium hydride



sodium amalgam



sodium borohydride



hydrogen

Metals

Carbon

Hydrocarbons

Oxidizing Agents



oxygen



ozone



fluorine



chlorine



bromine



iodine



hypochlorite



chlorate



nitric acid



chromium trioxide



chromate



dichromate

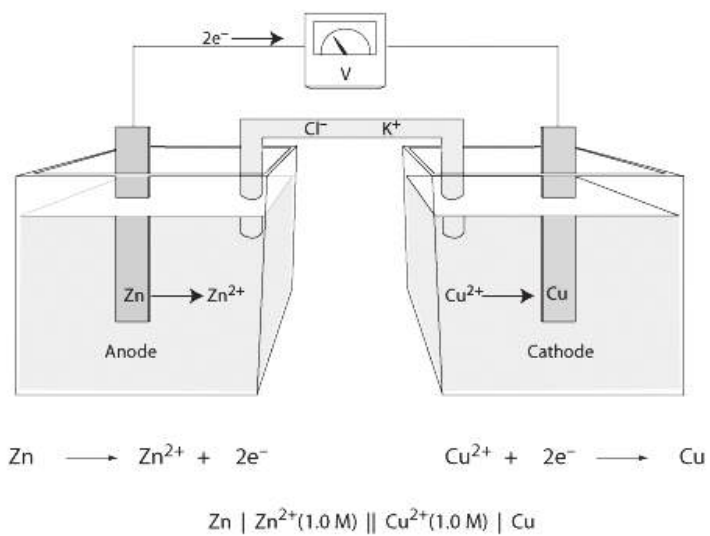


peroxides

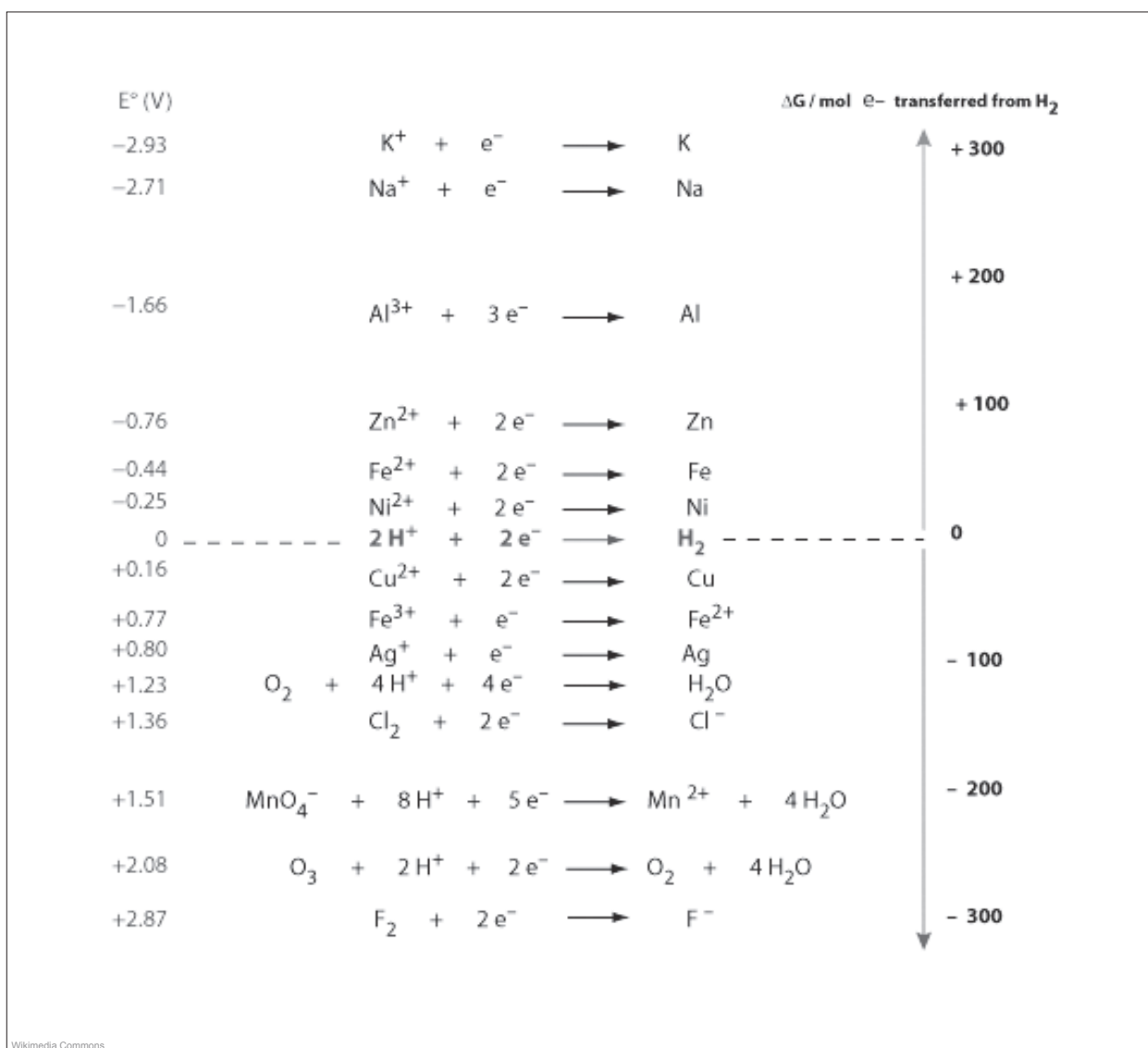


permanganate

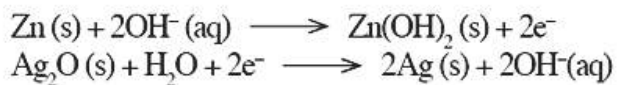
Premed Village



Premed Village



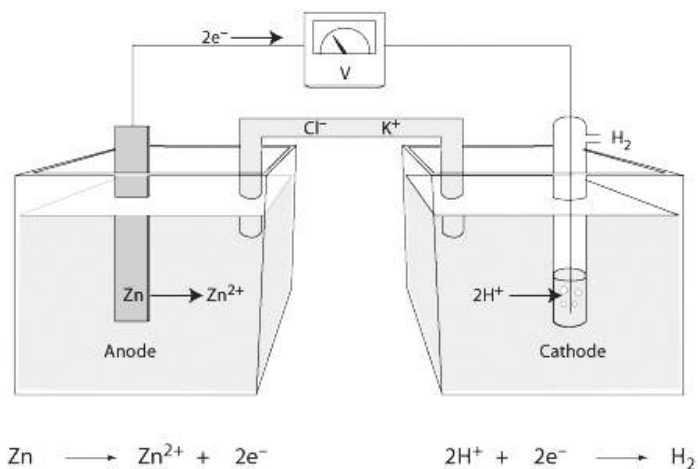
The anode and cathode reactions for the silver oxide battery are respectively as follows:



The standard reduction potential of Zn^{2+} is -0.762 , and the standard reduction potential of Ag^+ is 0.800 V. What is the approximate emf of the silver oxide battery?

- 0.04 V
- 0.8 V
- 1.6 V
- 2.4 V

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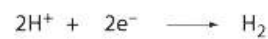
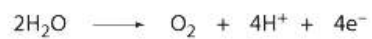
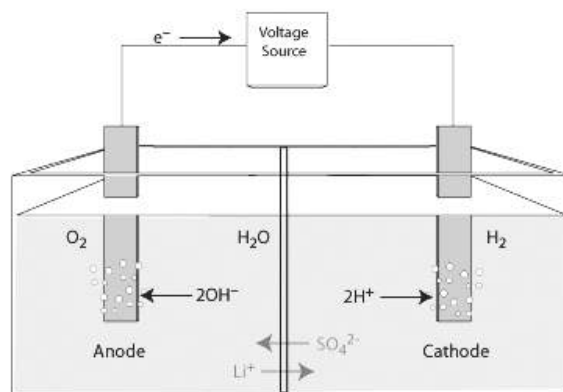
Premed Village

Commercial aluminum is formed electrolytically from aluminum oxide (Al_2O_3), which is reduced at the cathode. Approximately how long must a current of 965A be applied to form 27 g of aluminum?

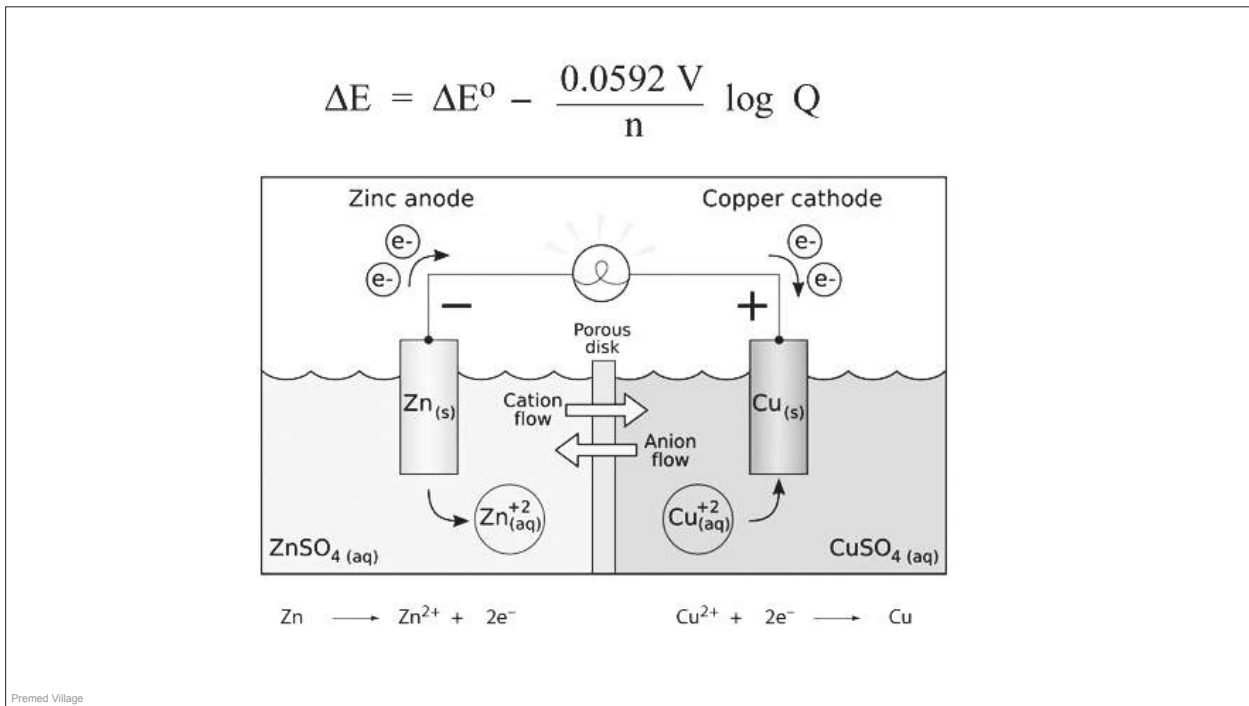
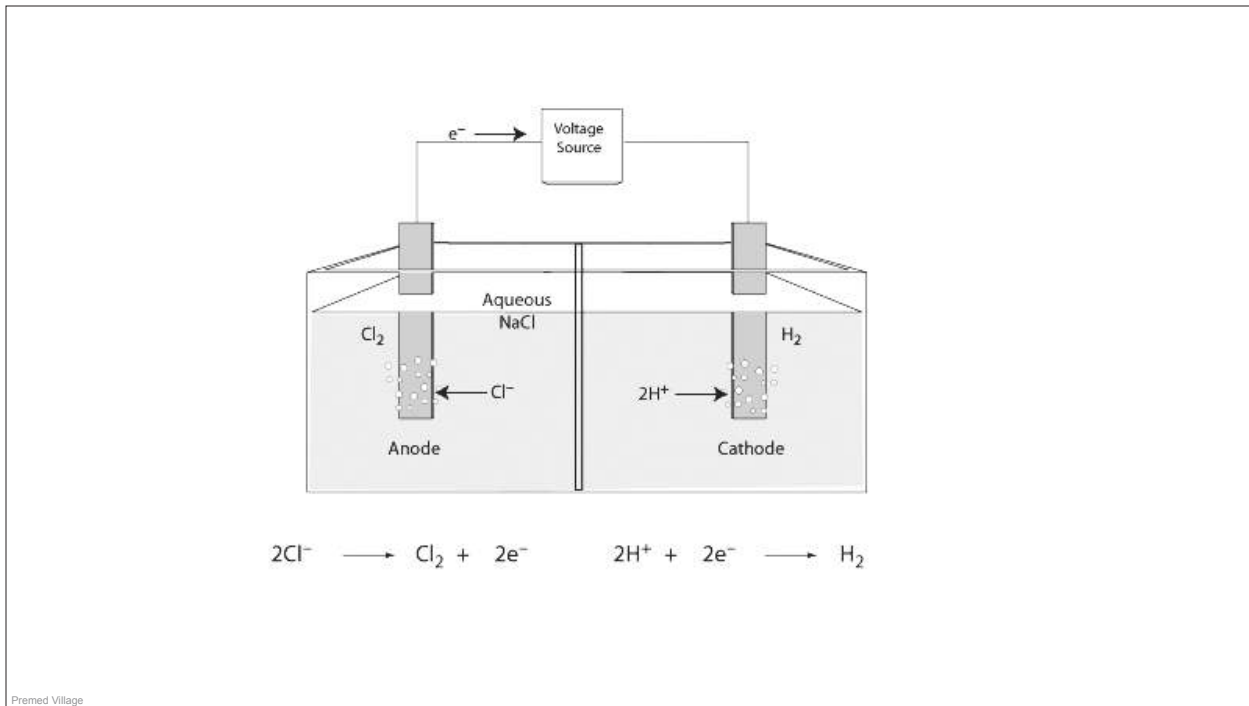
(Note that $96500 \text{ C} = 1 \text{ mole } e^-$)

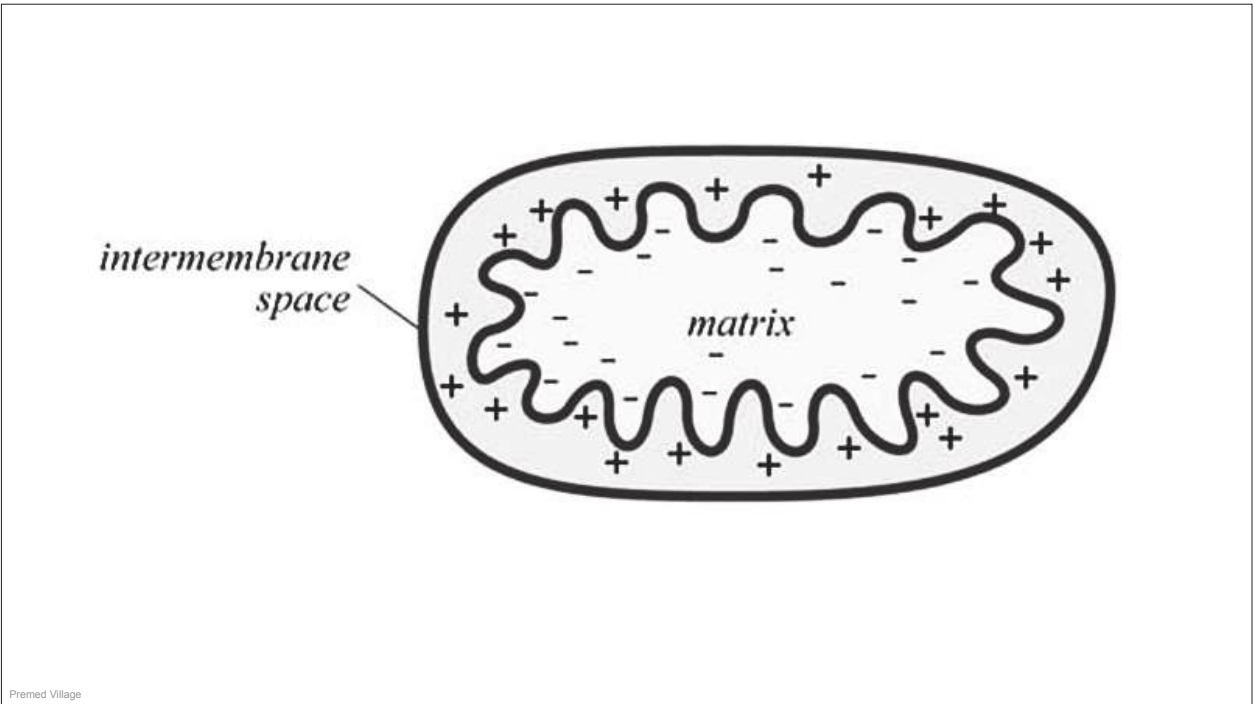
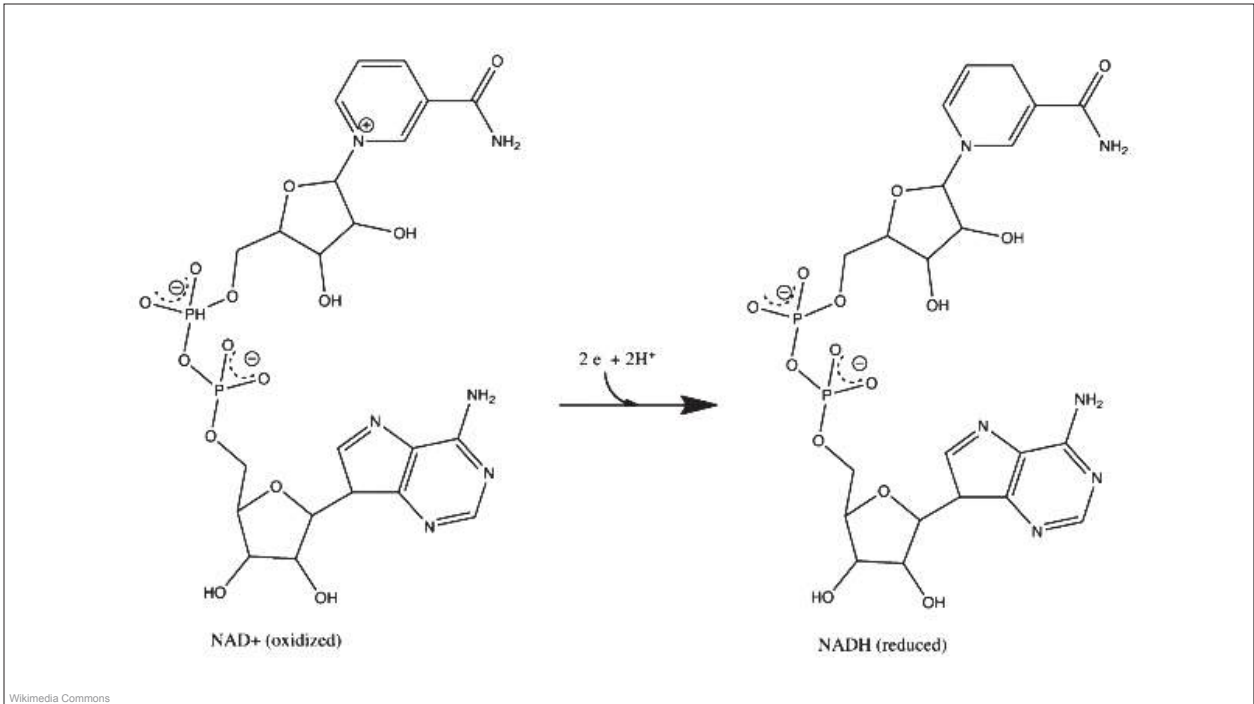
- 1 second
- 1 1/2 minutes
- 5 minutes
- 300,000 seconds

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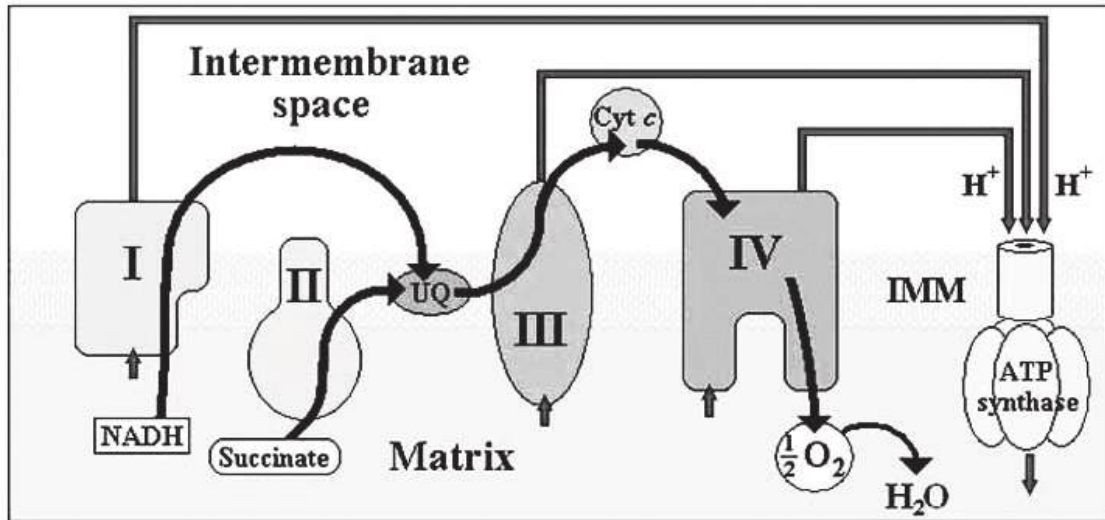


Premed Village

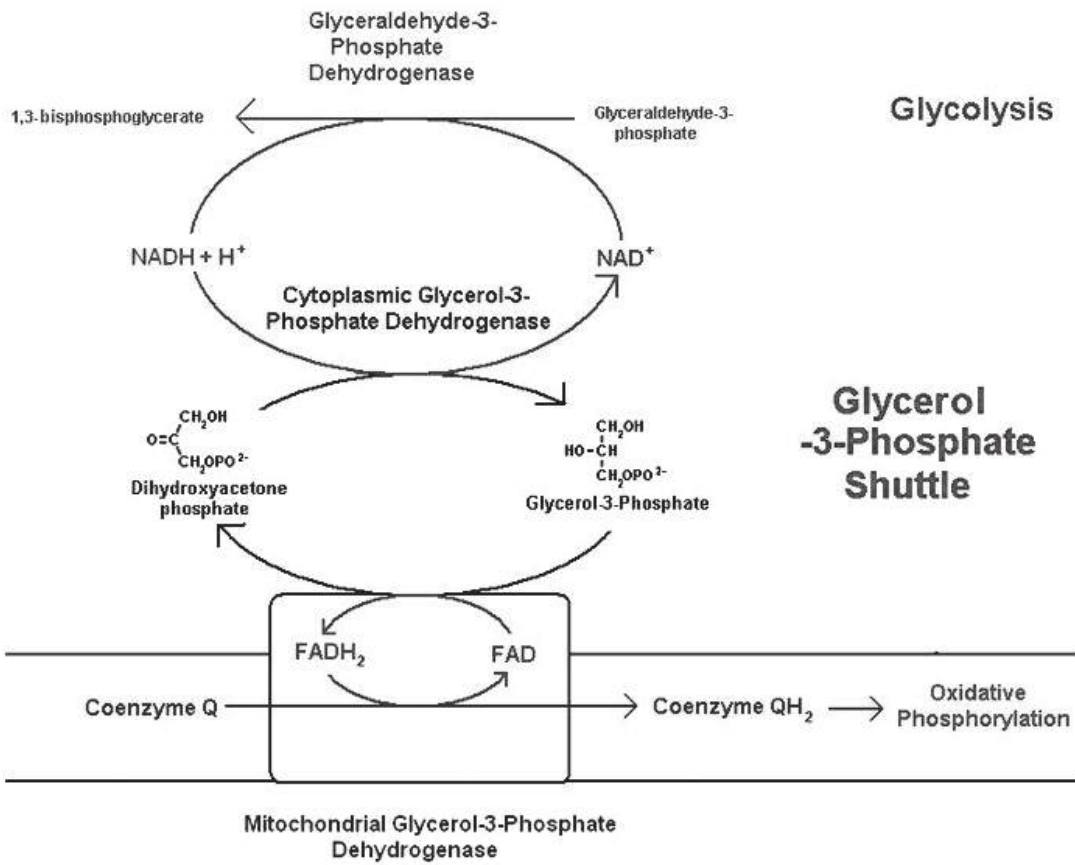




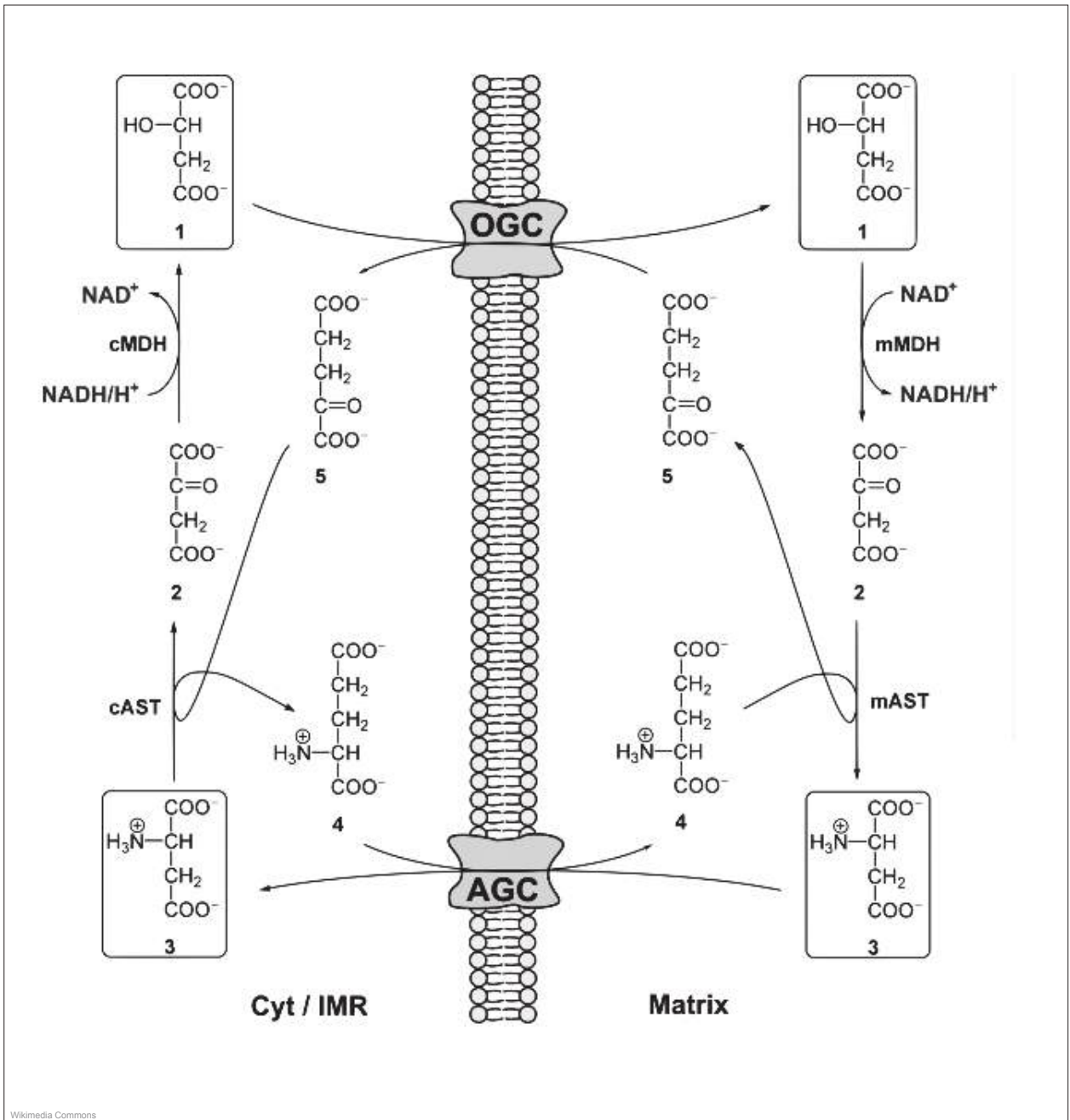
Oxidative Phosphorylation



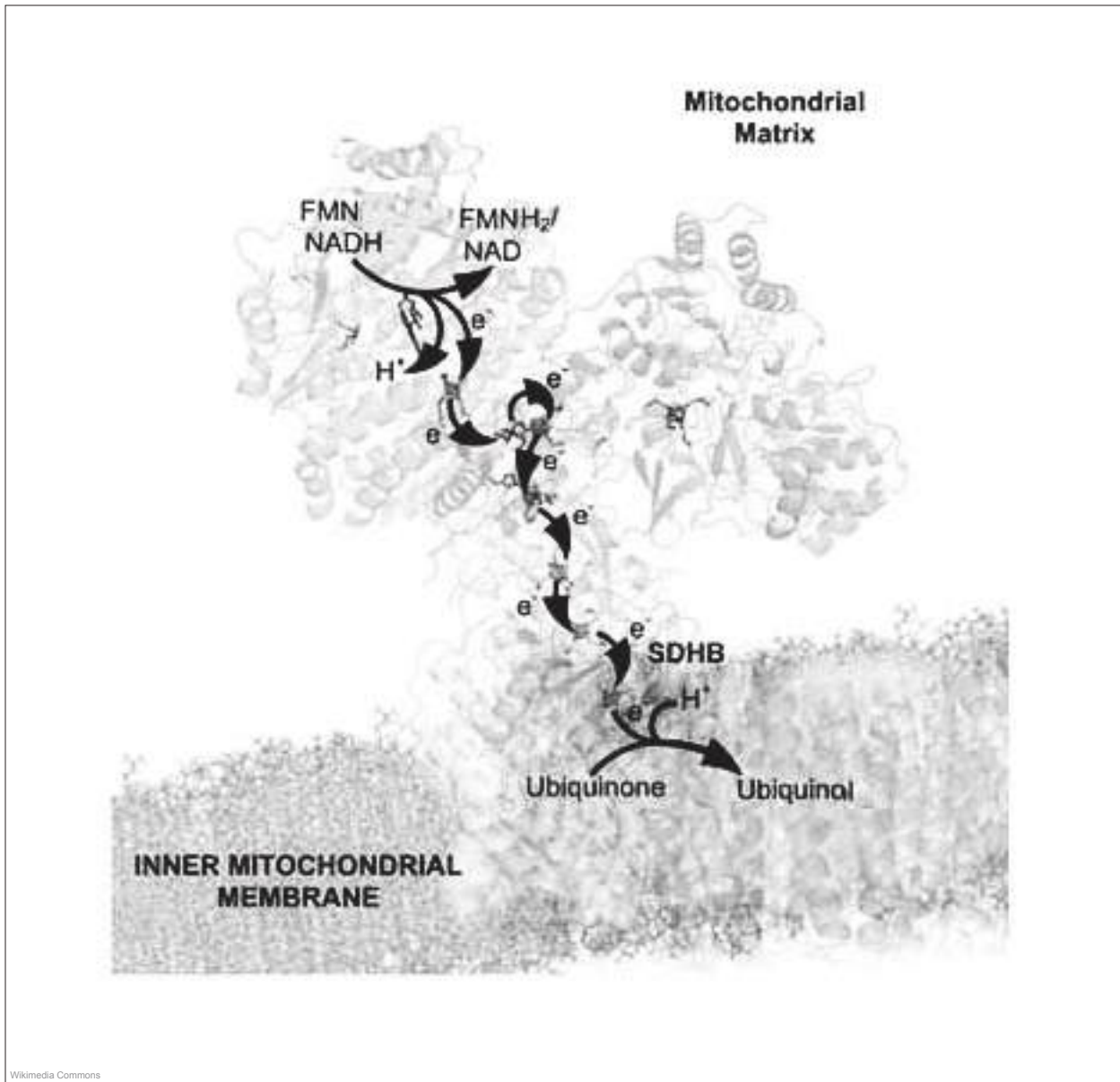
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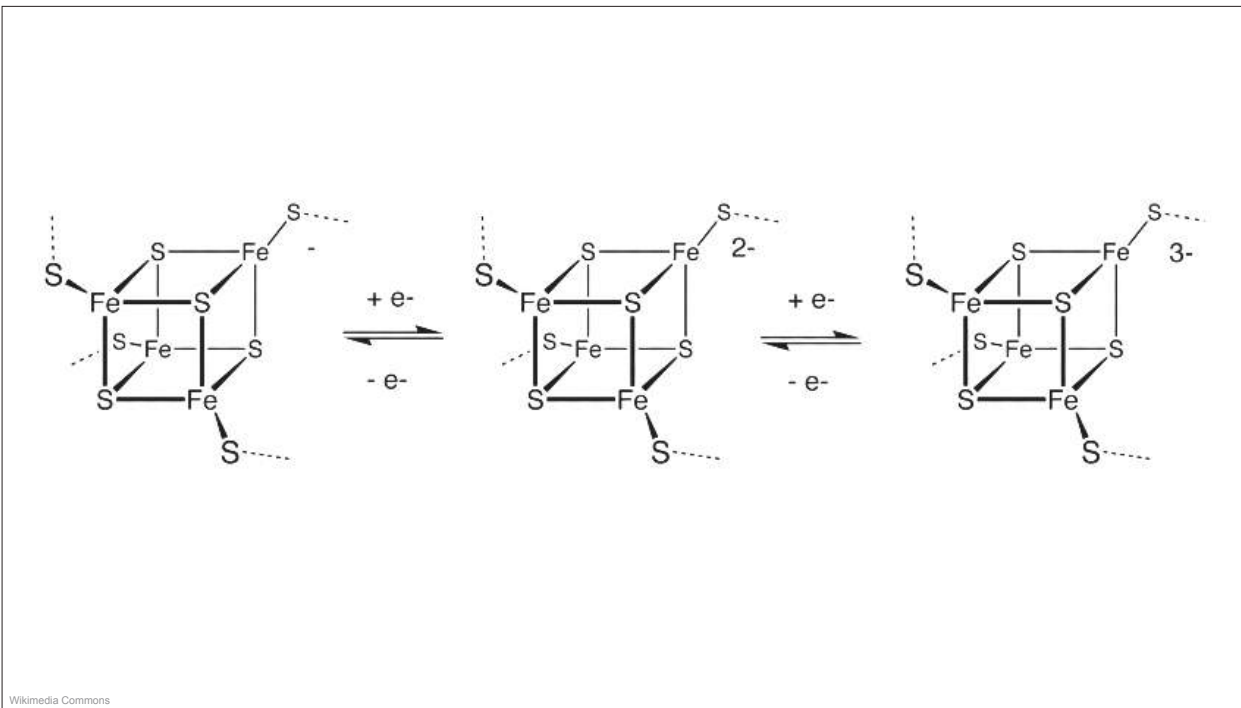
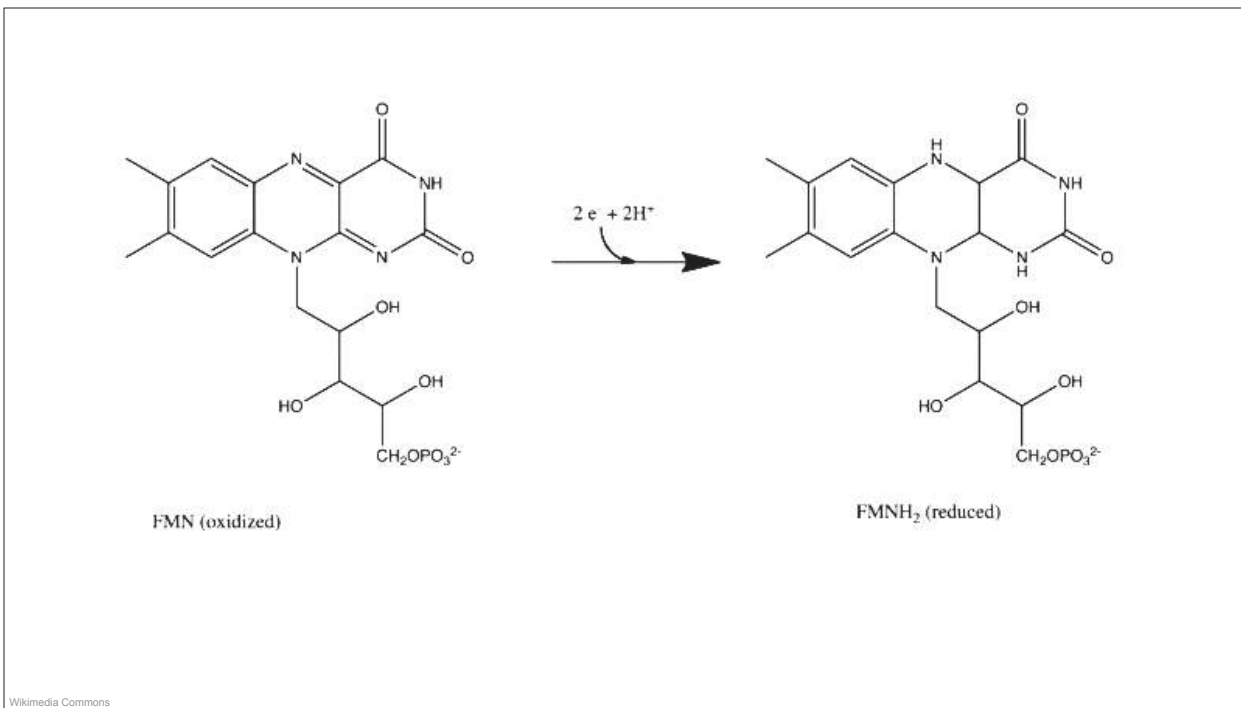


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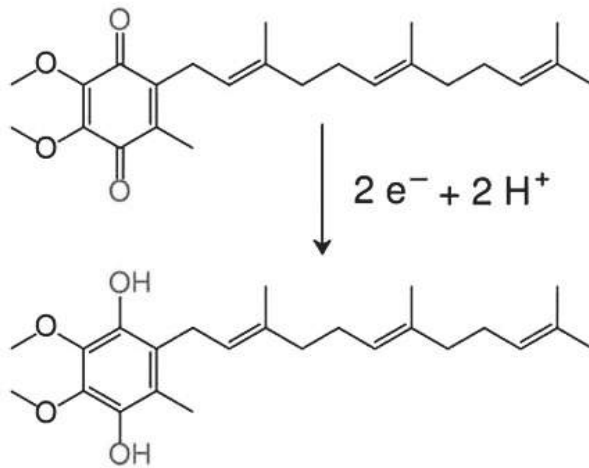


Oxidative Phosphorylation

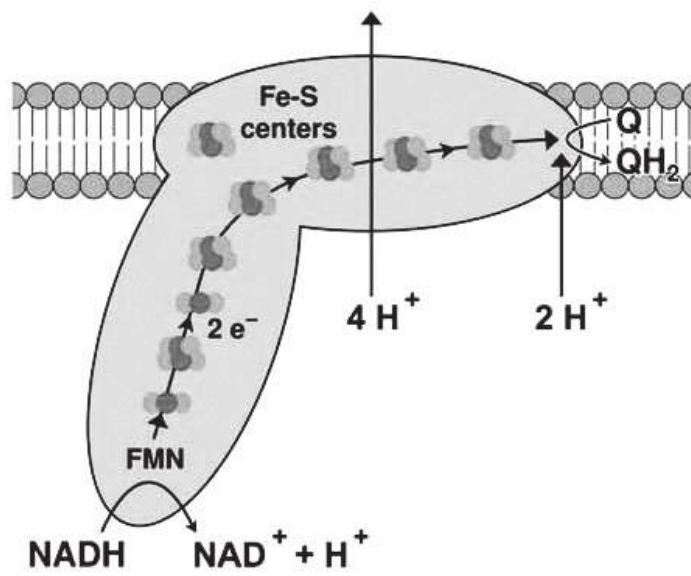




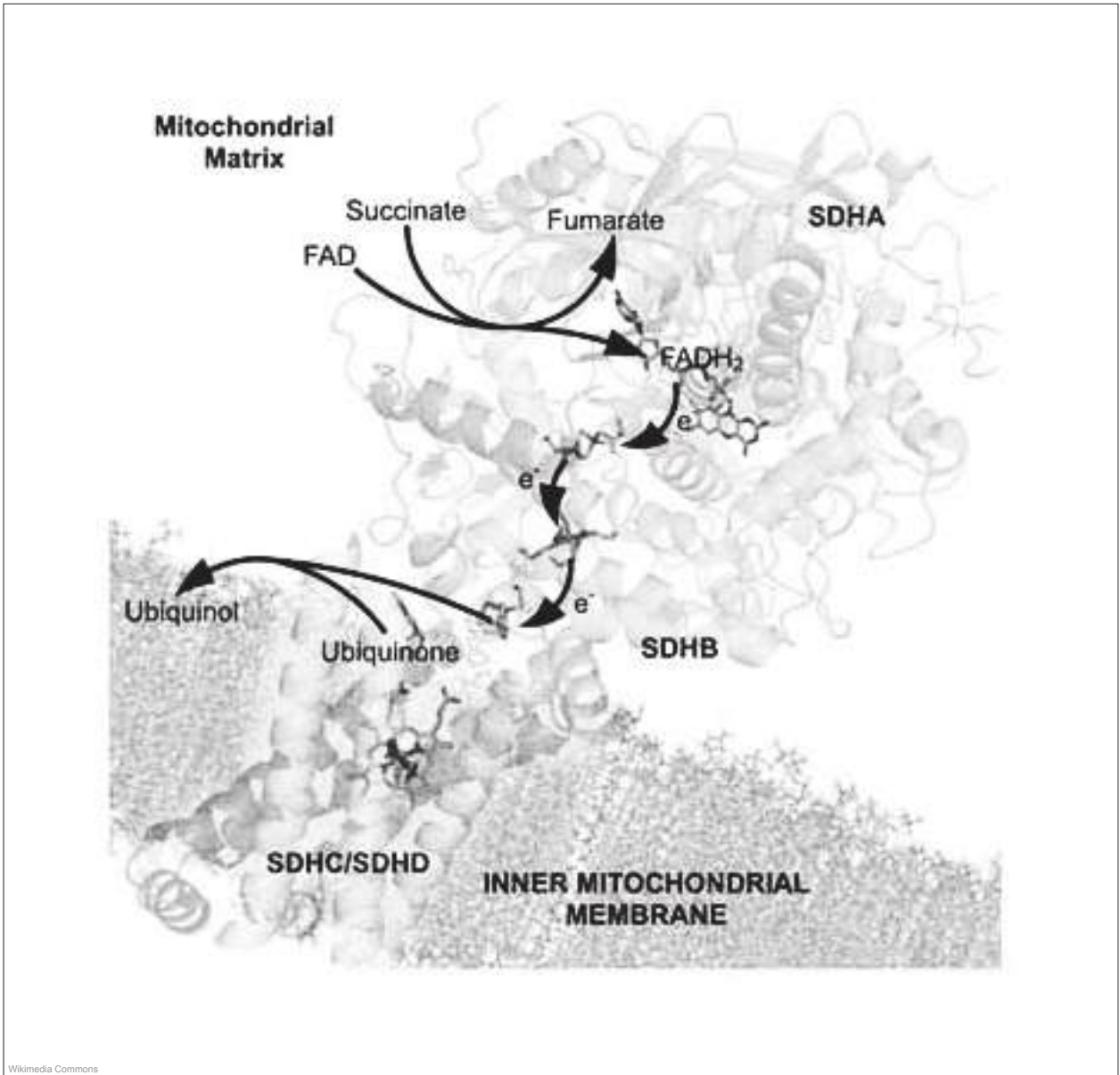
Oxidative Phosphorylation



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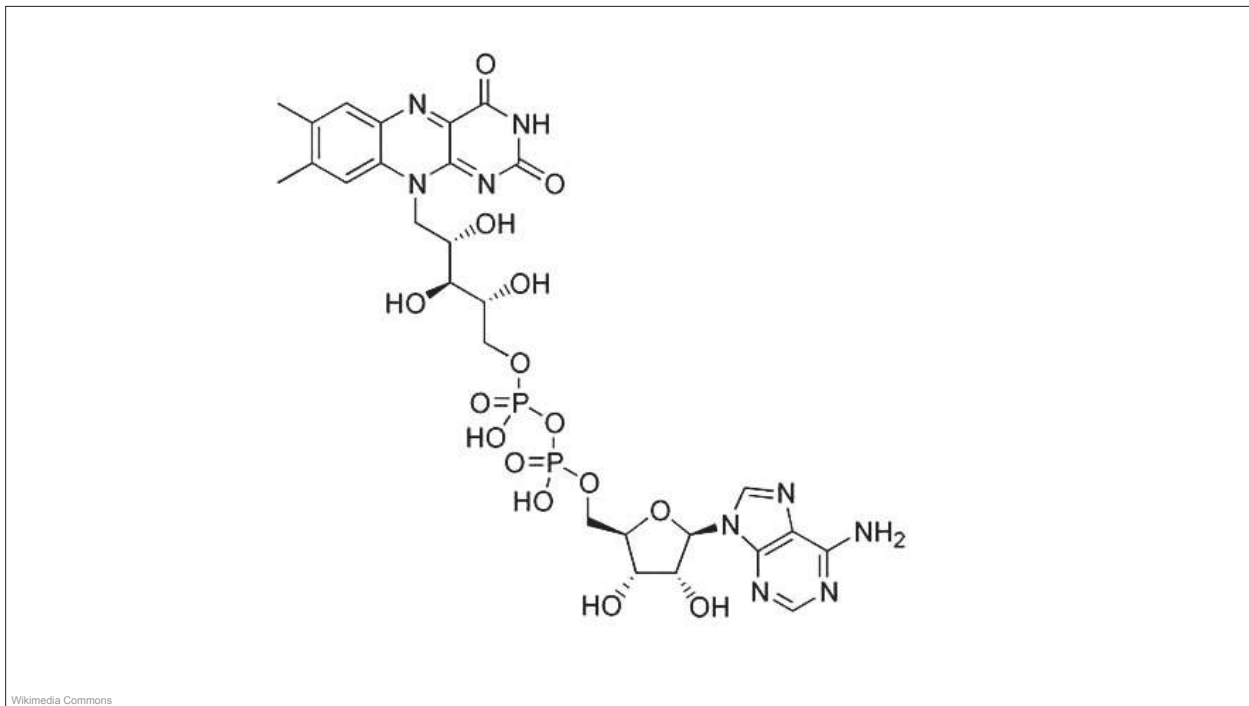
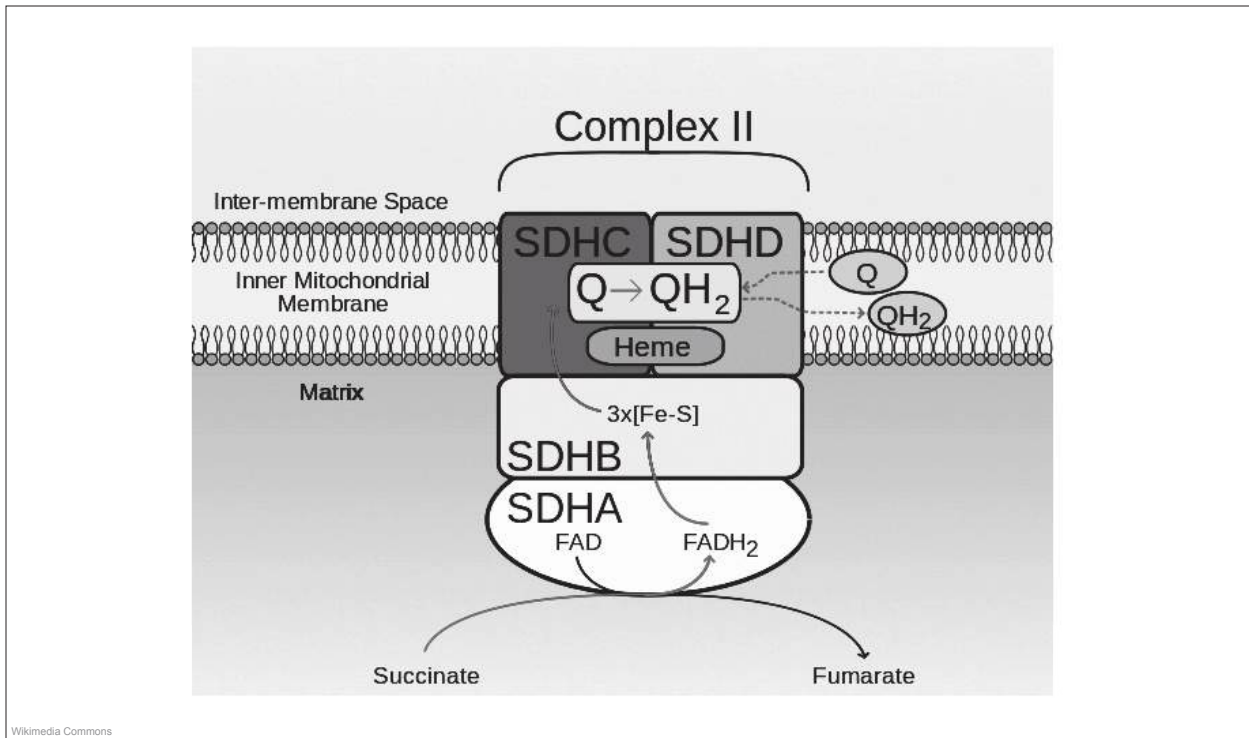


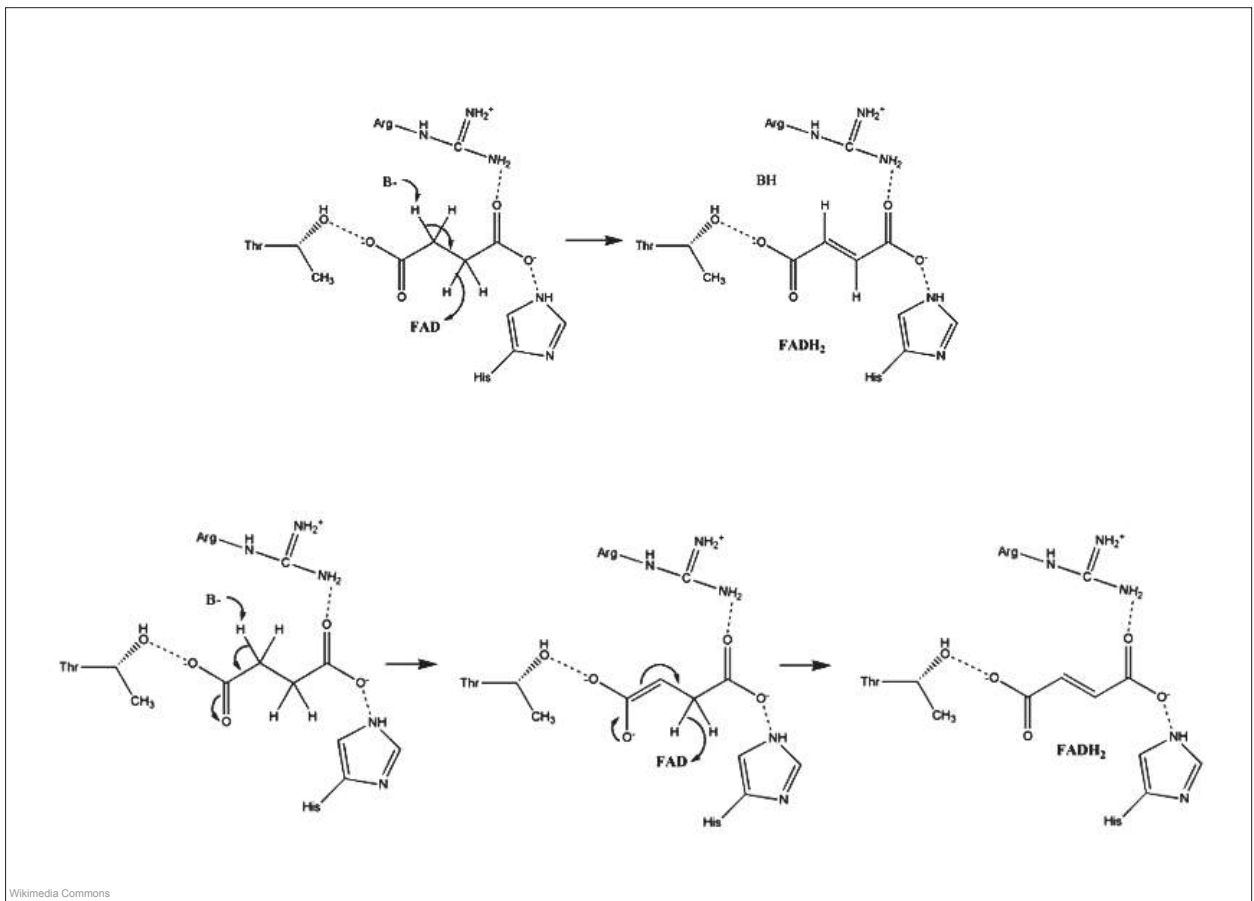
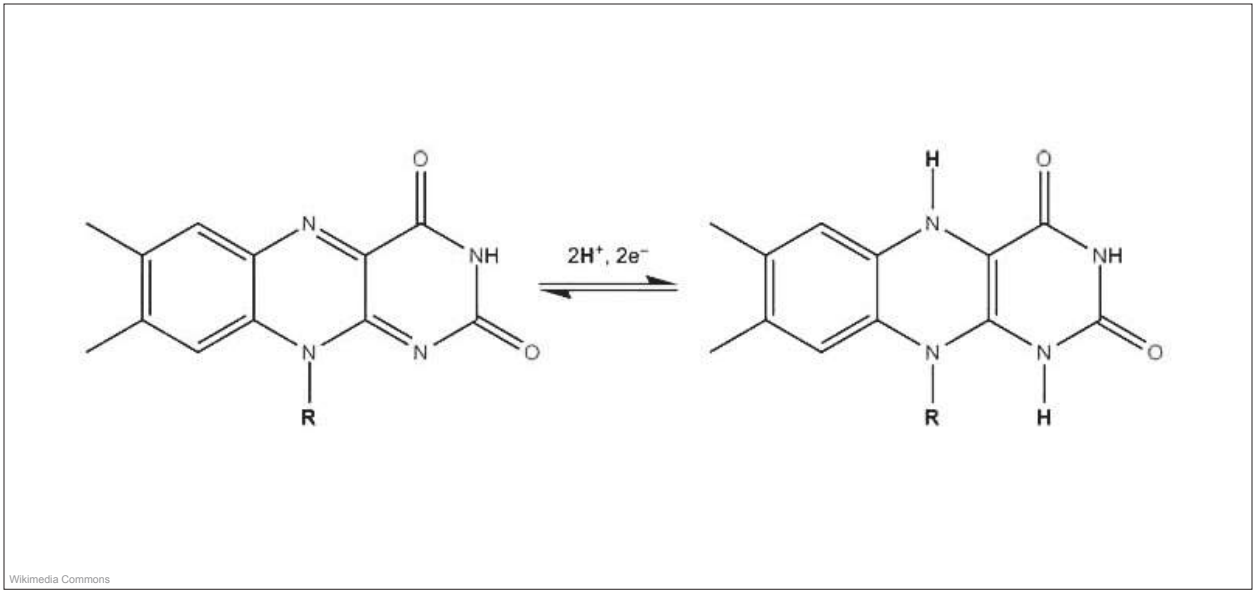
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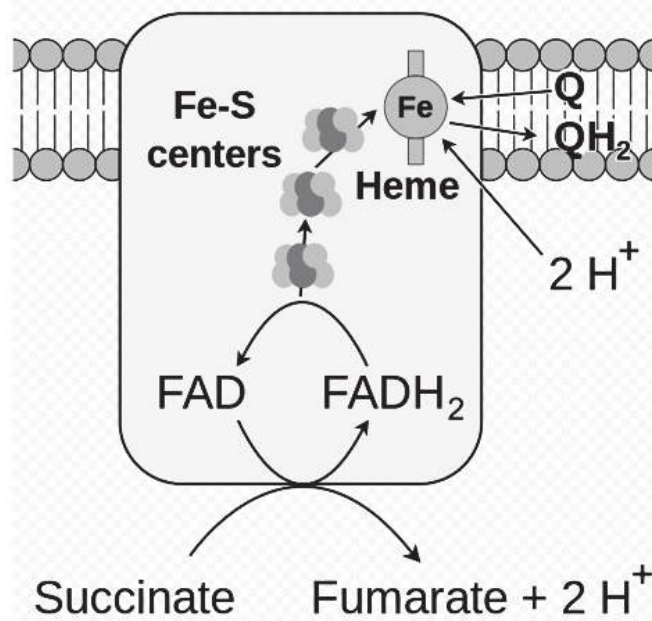
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Oxidative Phosphorylation





Oxidative Phosphorylation



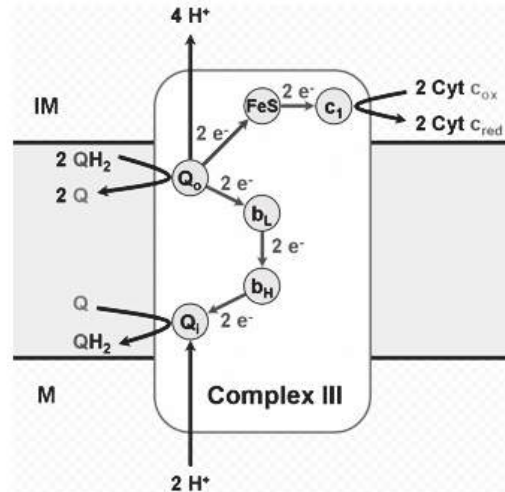
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Round 1:

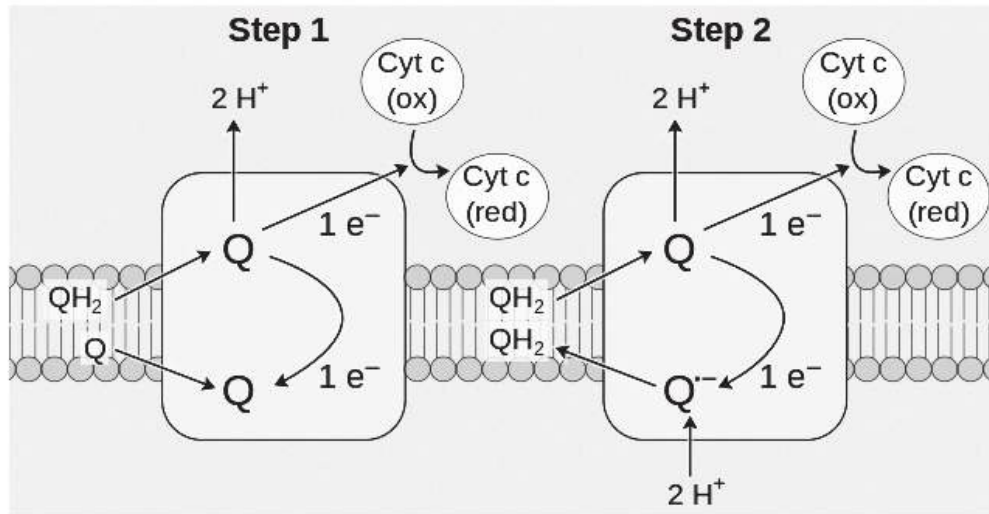
1. Cytochrome b binds a ubiquinol and a ubiquinone.
2. The 2Fe/2S center and B_L heme each pull an electron off the bound ubiquinol, releasing two hydrogens into the intermembrane space.
3. One electron is transferred to cytochrome c₁ from the 2Fe/2S centre, while another is transferred from the B_L heme to the B_H heme.
4. Cytochrome c₁ transfers its electron to cytochrome c (not to be confused with cytochrome c₁), and the B_H heme transfers its electron to a nearby ubiquinone, resulting in the formation of a ubisemiquinone.
5. Cytochrome c diffuses. The first ubiquinol (now oxidized to ubiquinone) is released, whilst the semiquinone remains bound.

Round 2:

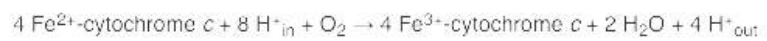
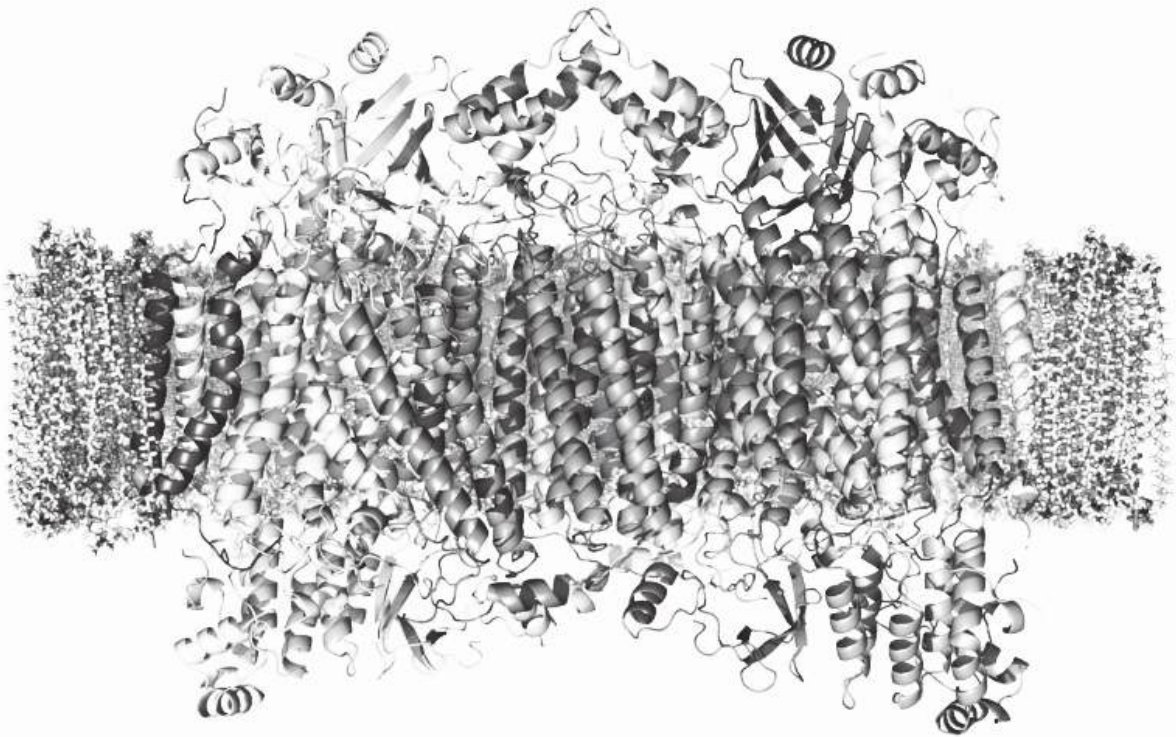
1. A second ubiquinol is bound by cytochrome b.
2. The 2Fe/2S center and B_L heme each pull an electron off the bound ubiquinol, releasing two hydrogens into the intermembrane space.
3. One electron is transferred to cytochrome c₁ from the 2Fe/2S centre, whilst another is transferred from the B_L heme to the B_H heme.
4. Cytochrome c₁ then transfers its electron to cytochrome c, while the nearby semiquinone picks up a second electron from the B_H heme, along with two protons from the matrix.
5. The second ubiquinol (now oxidised to ubiquinone), along with the newly formed ubiquinol are released.



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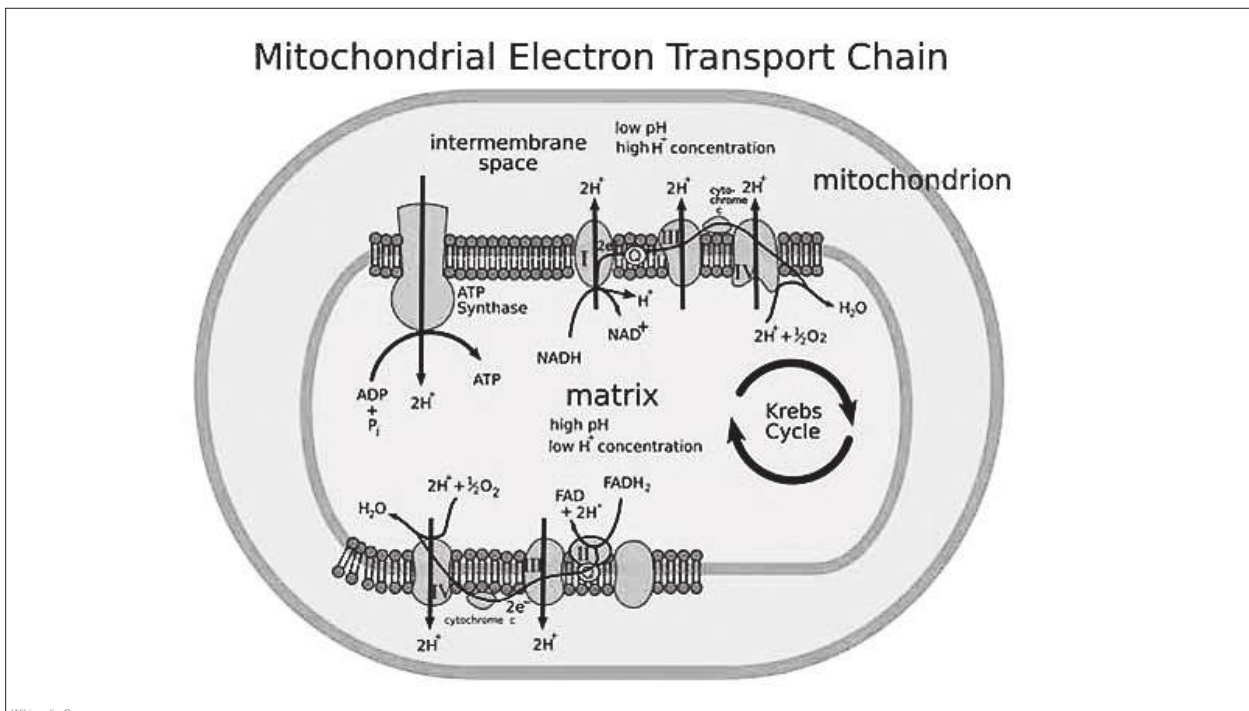
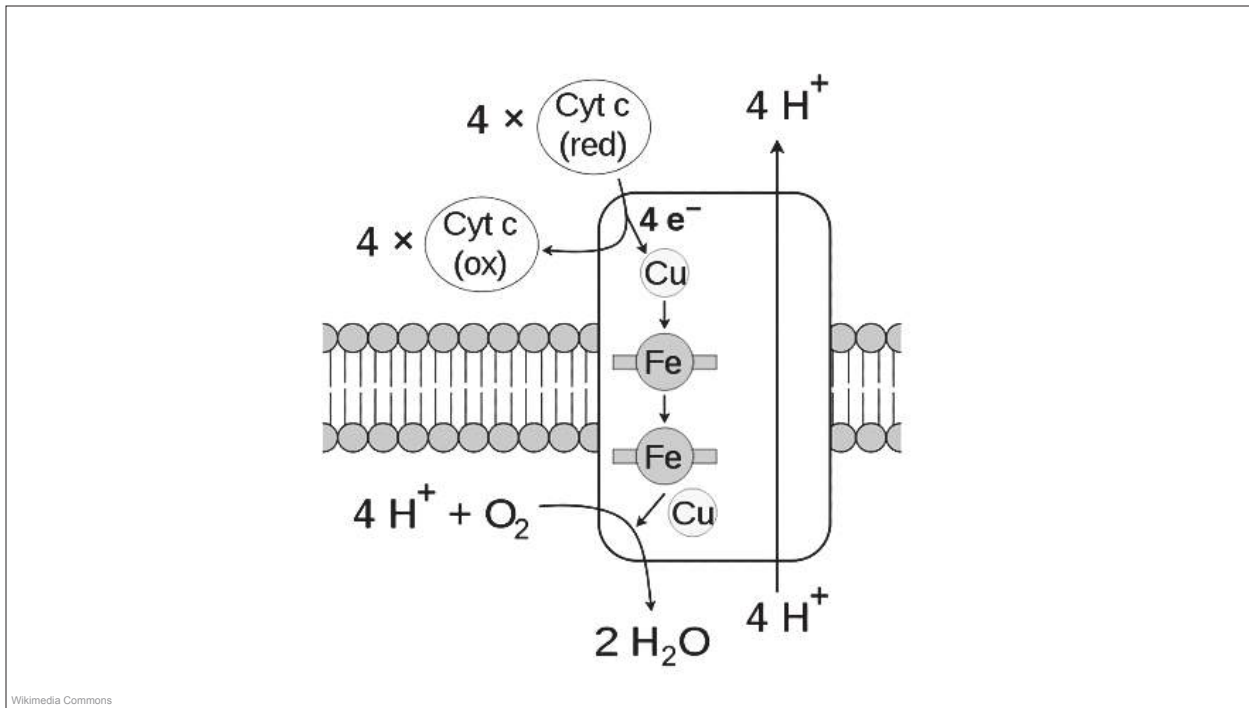


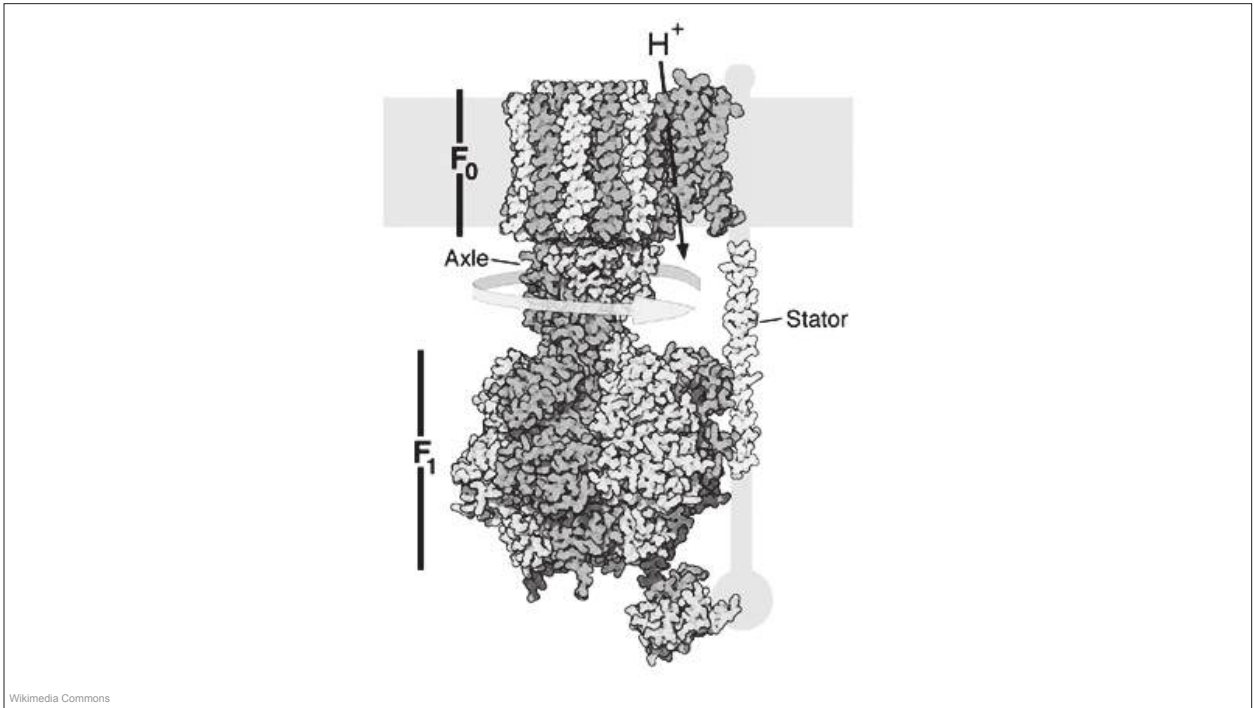
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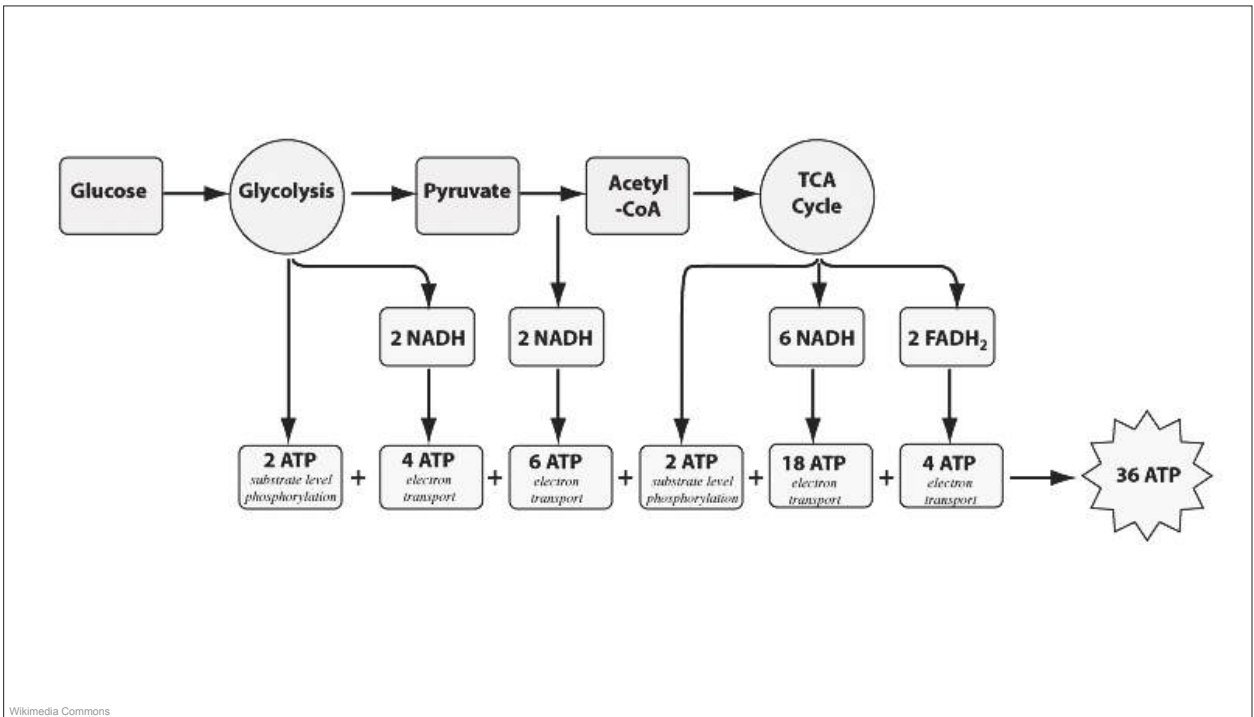
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Oxidative Phosphorylation



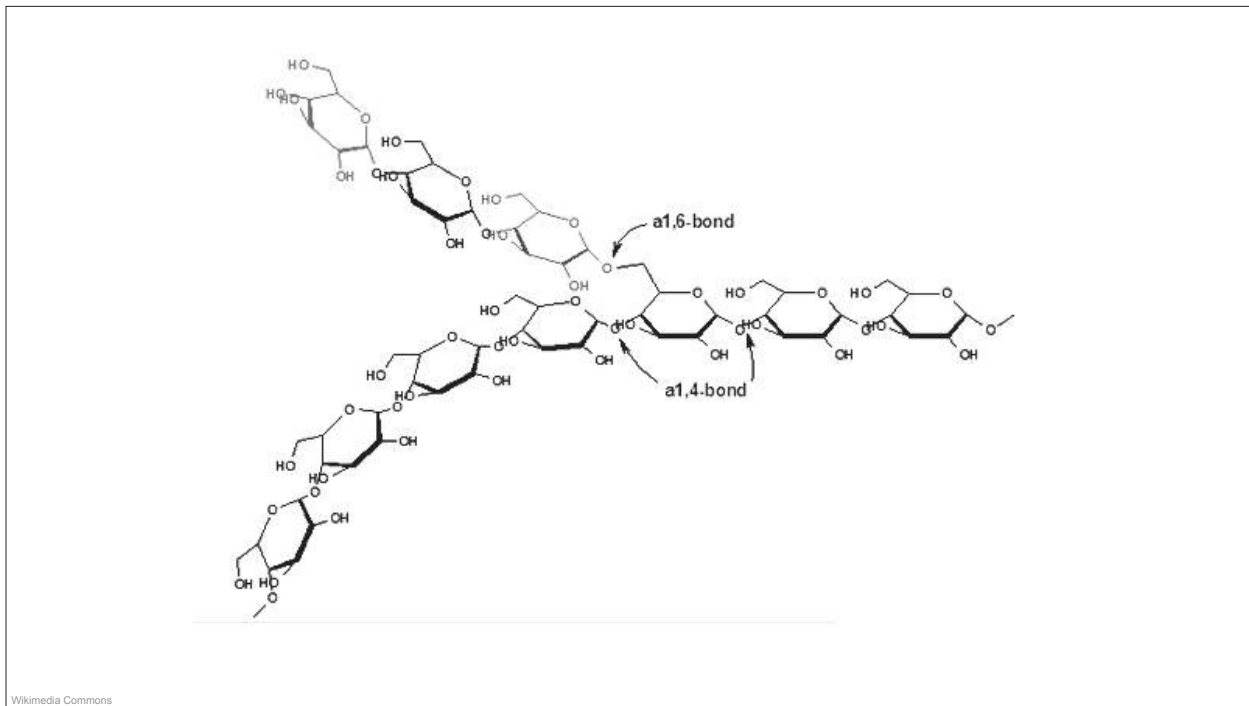
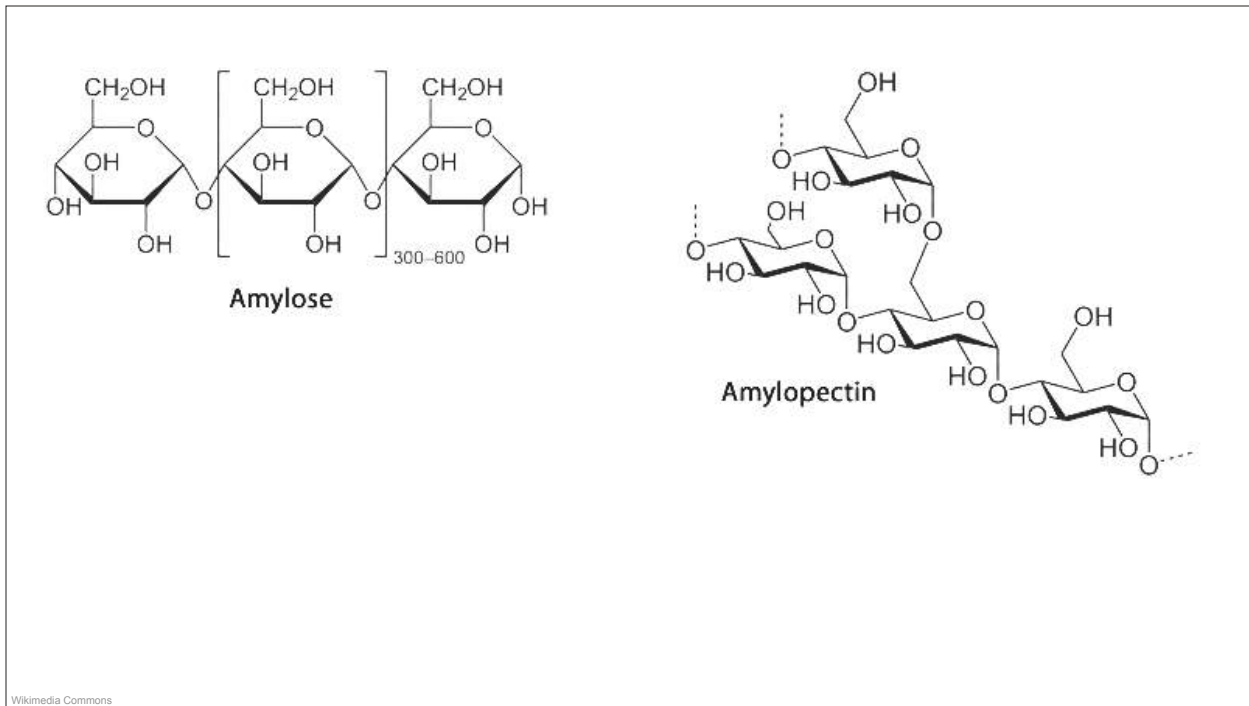


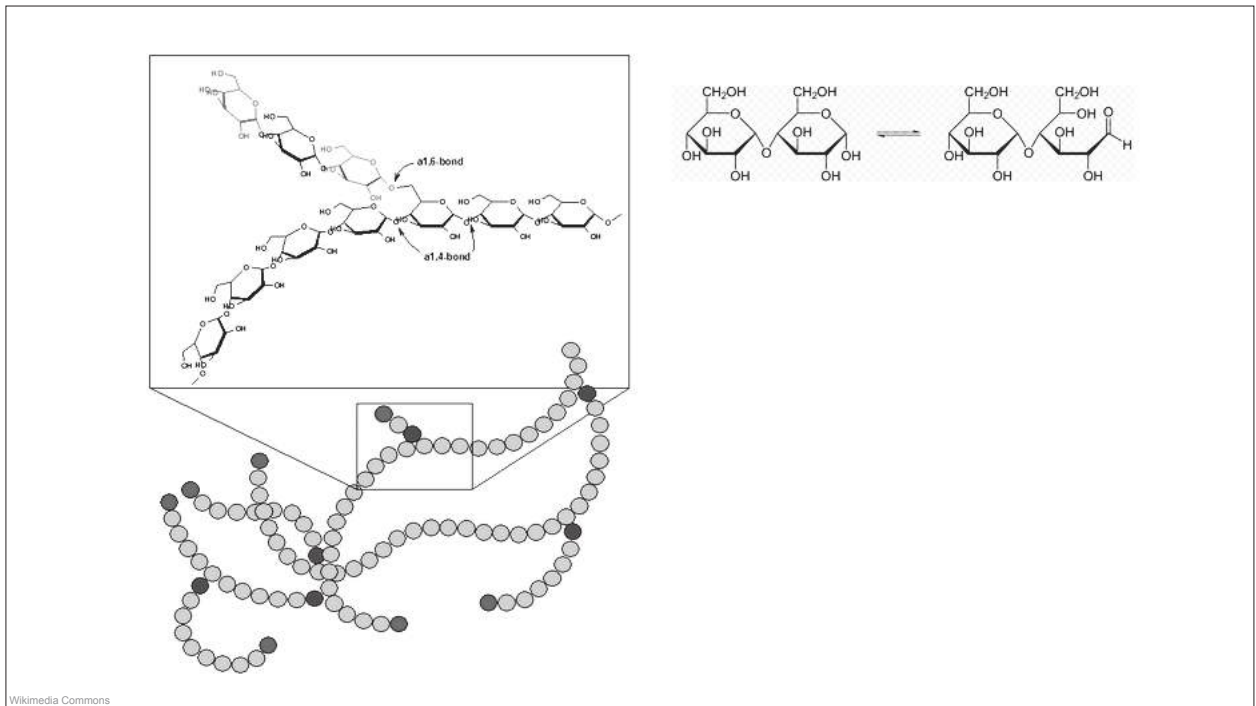
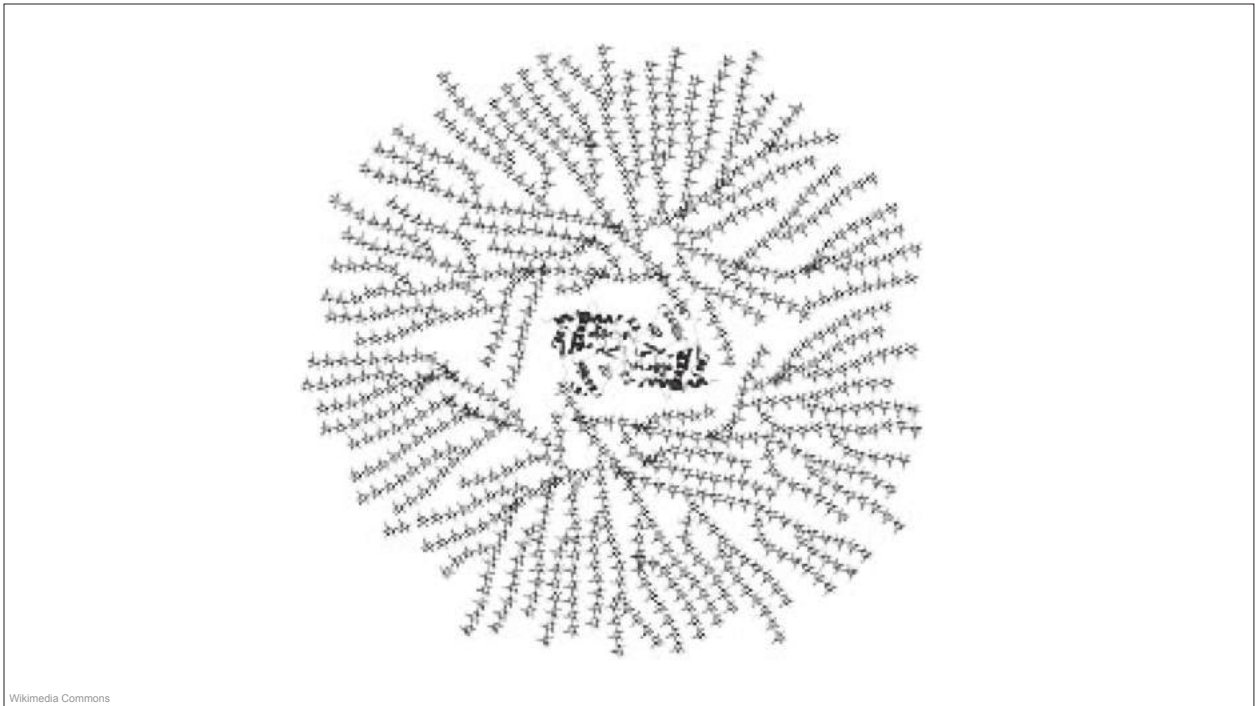
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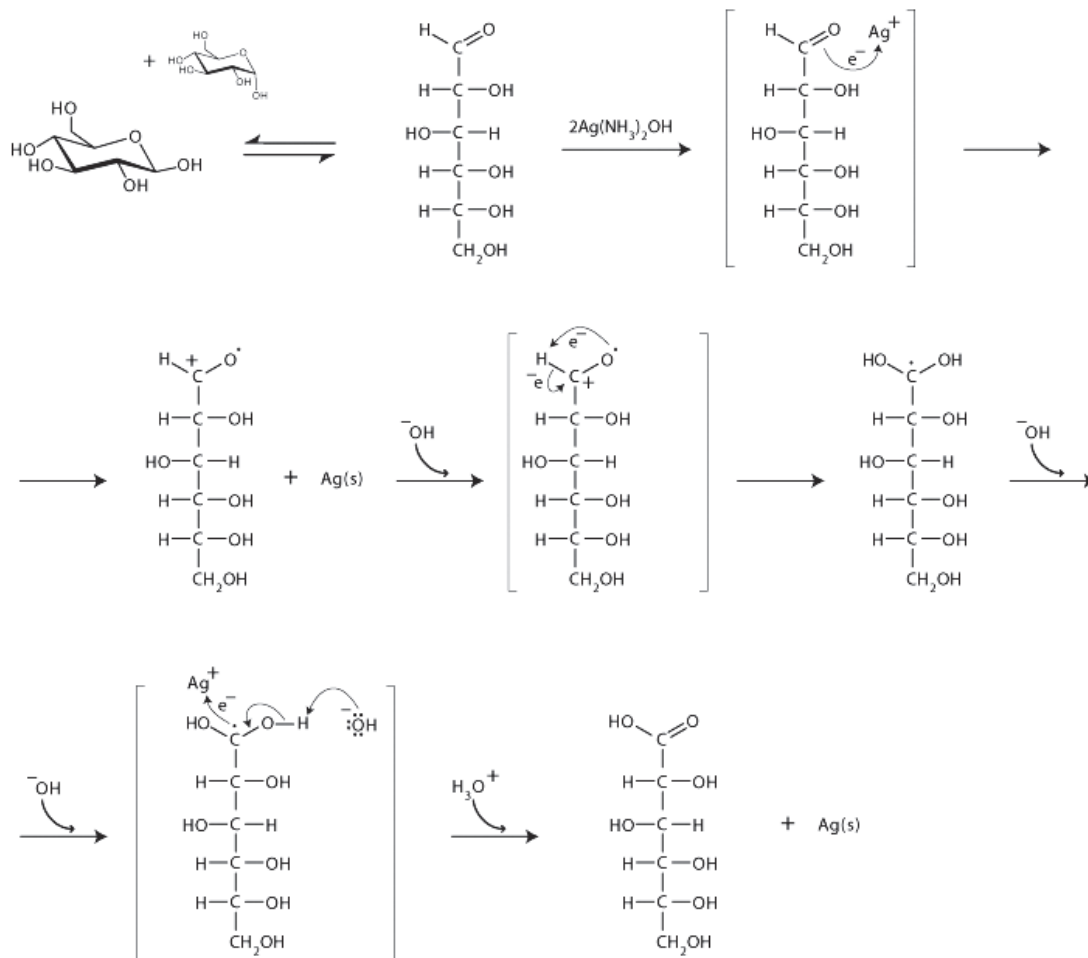
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Glycogen Metabolism

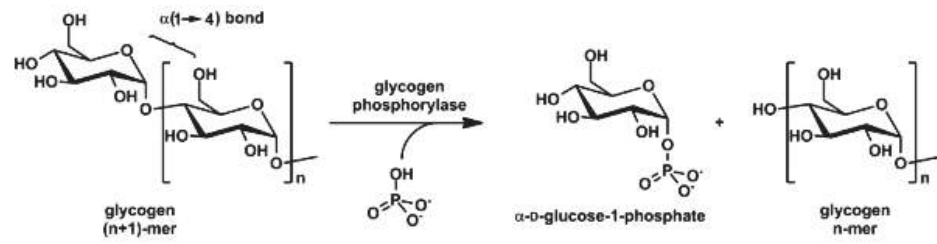




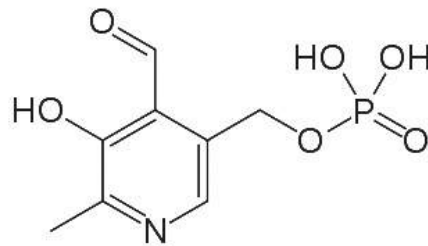
Tollens' Test



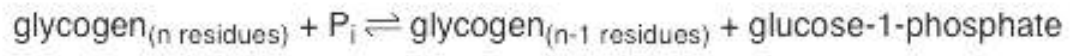
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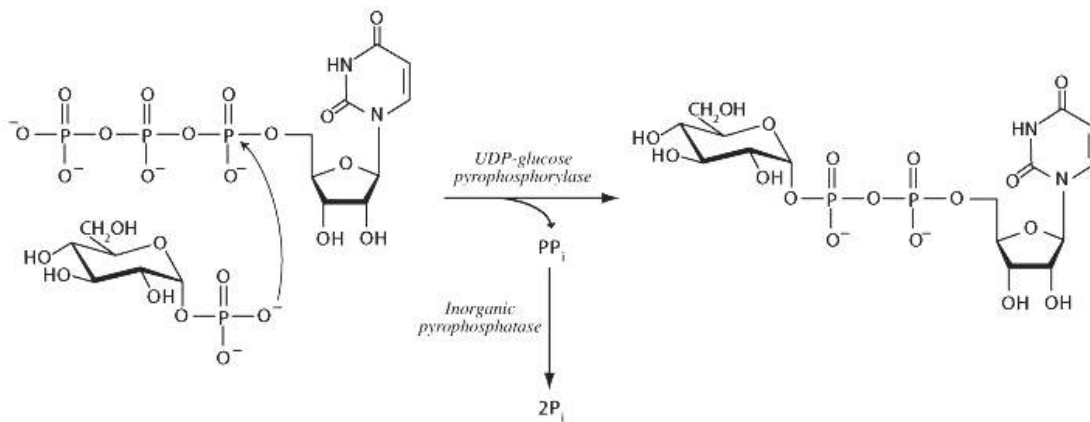
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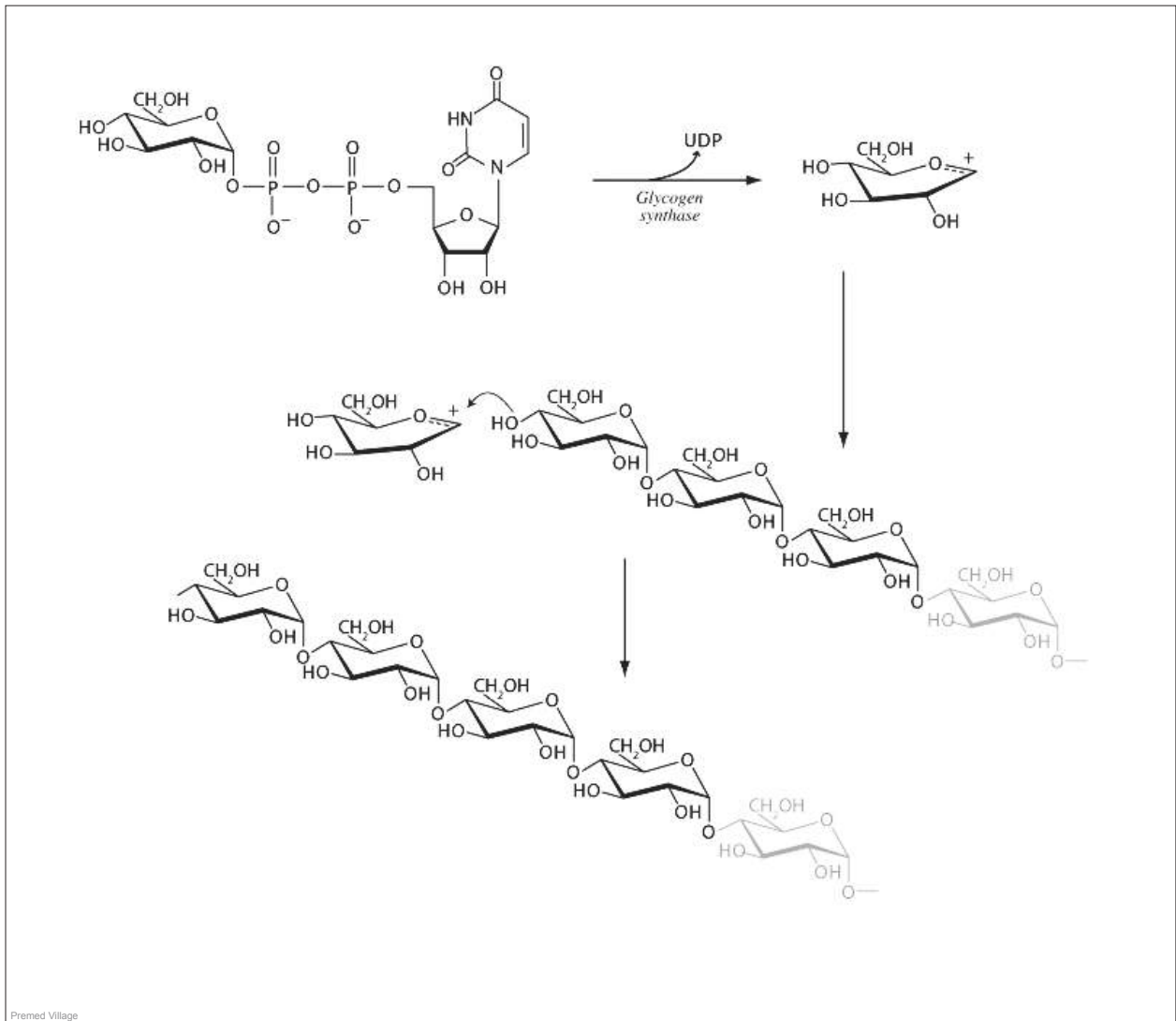
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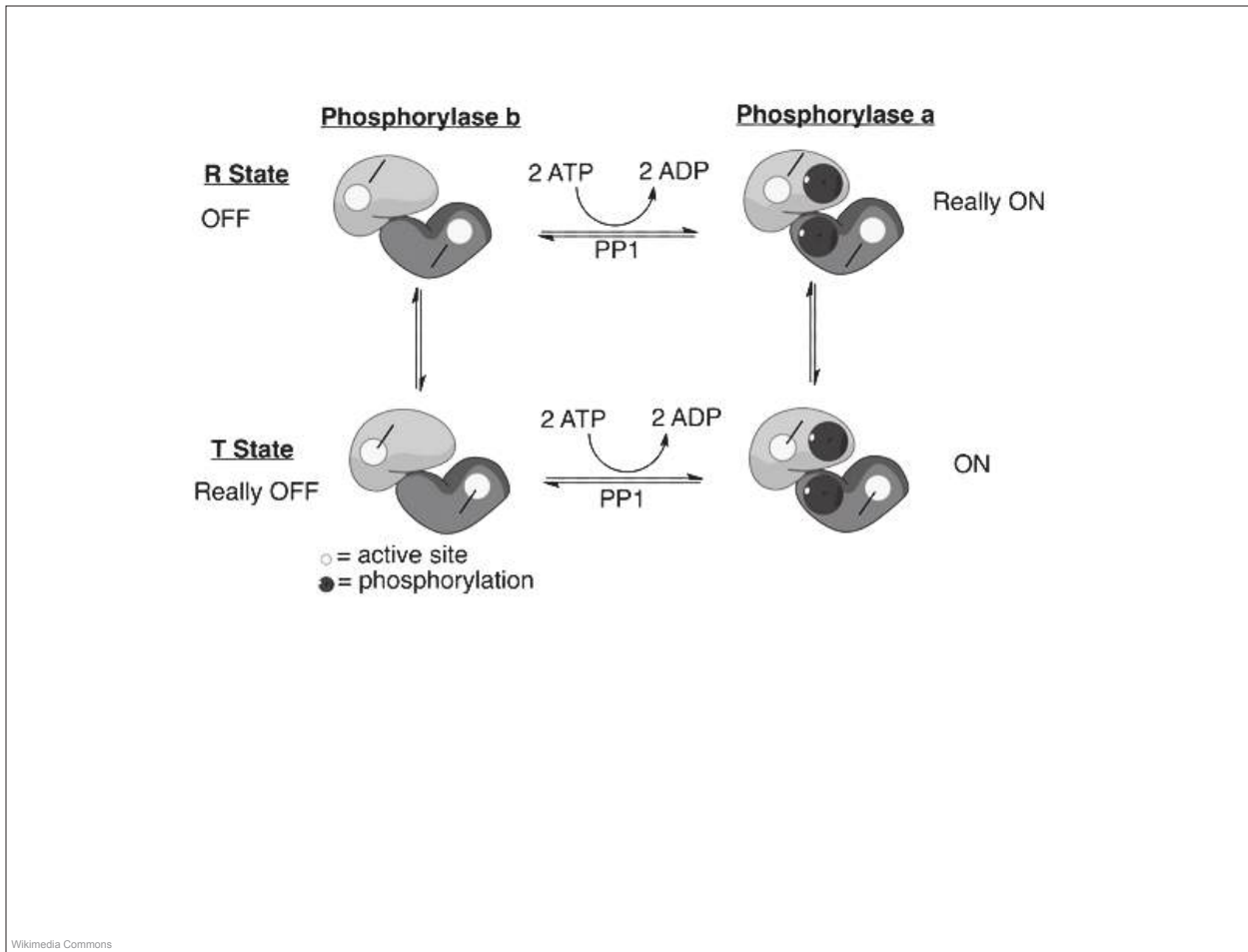


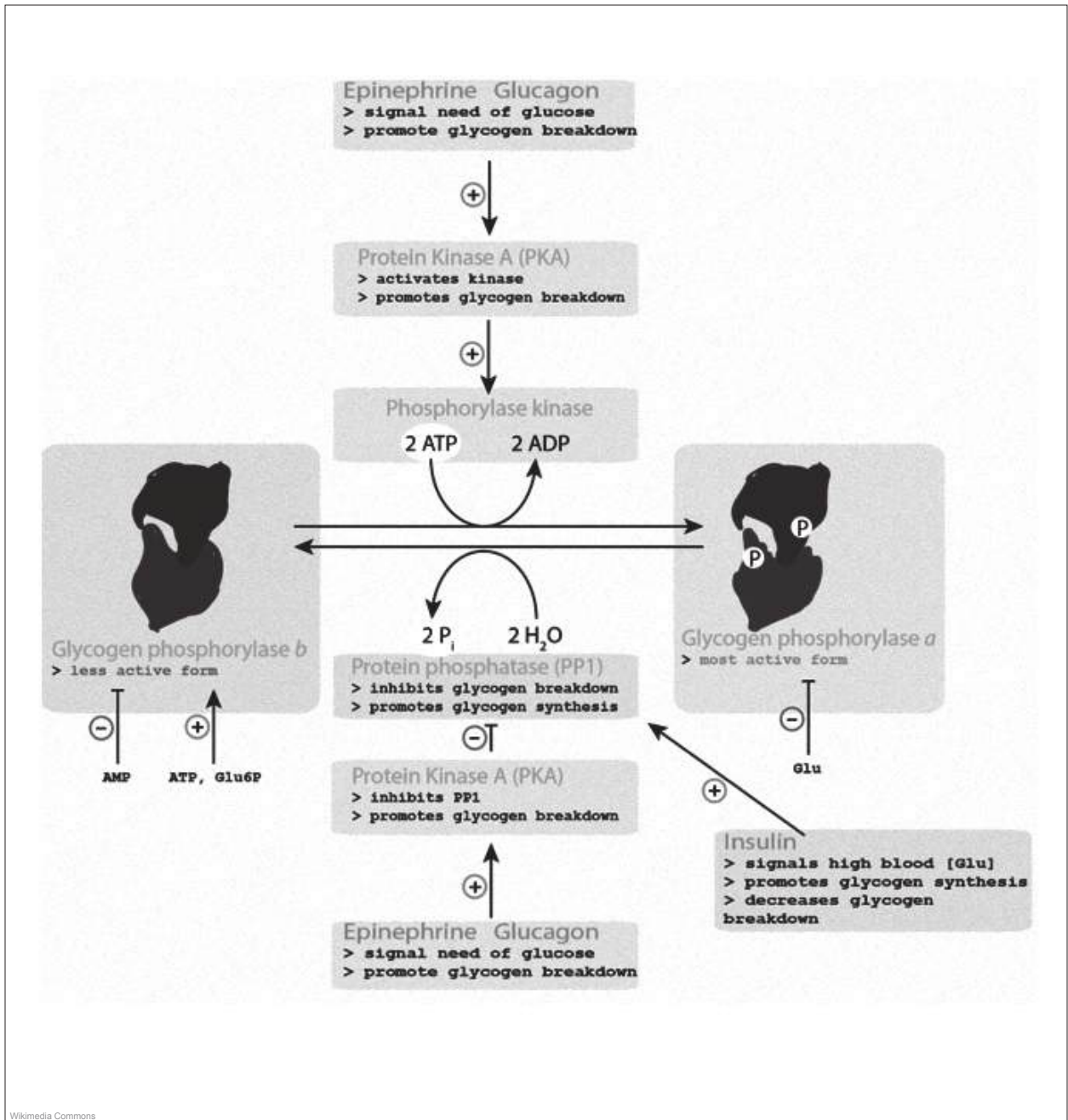
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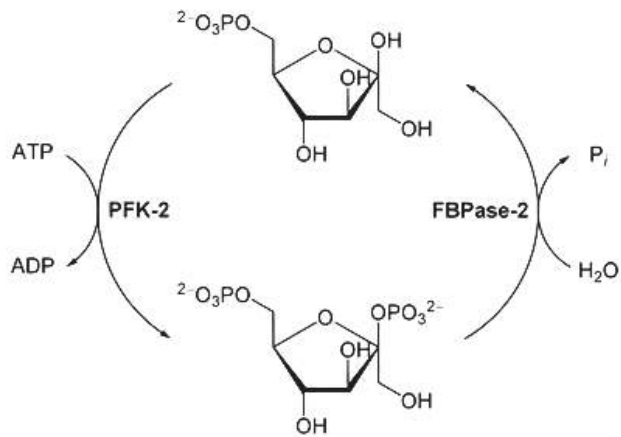




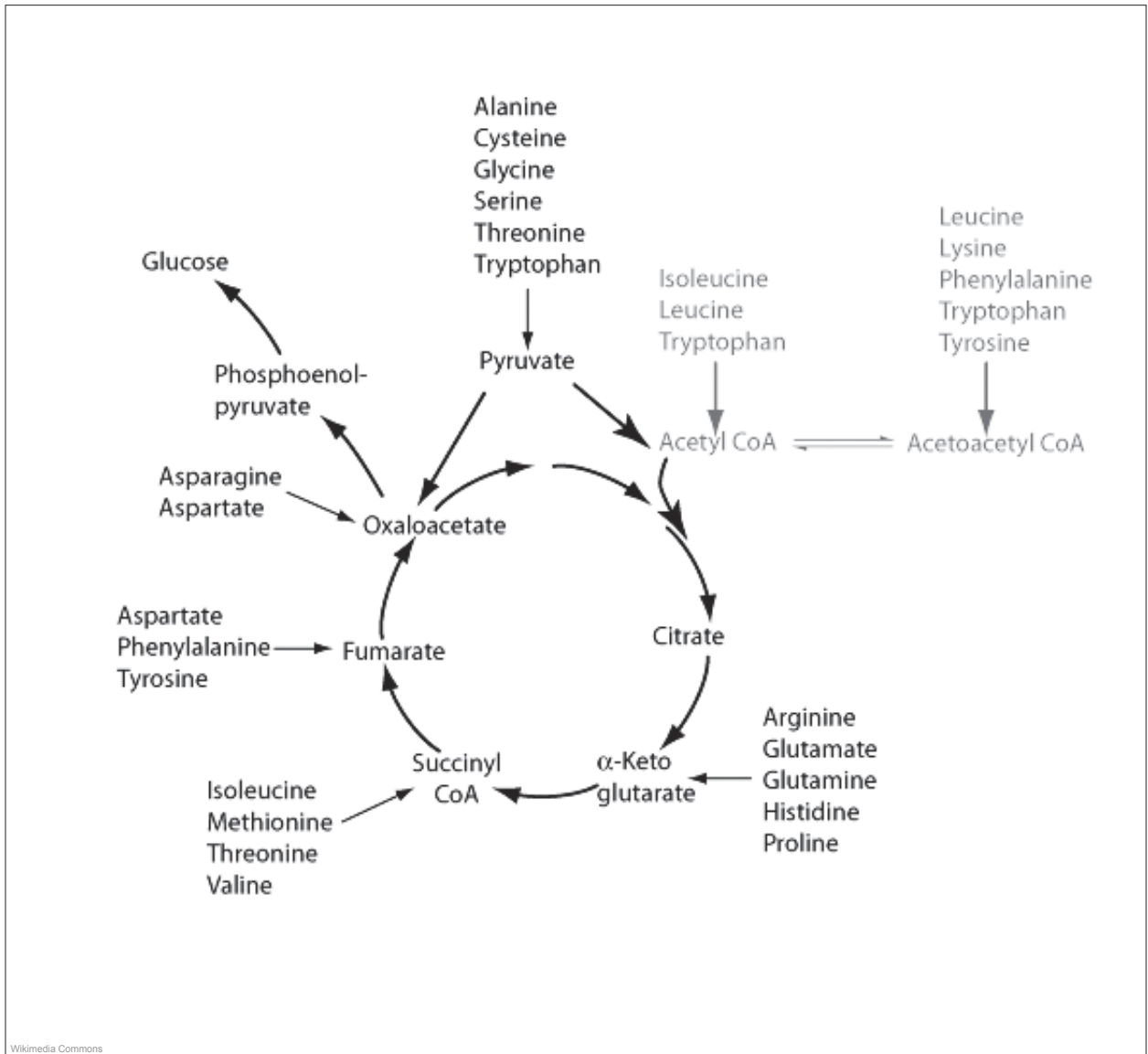




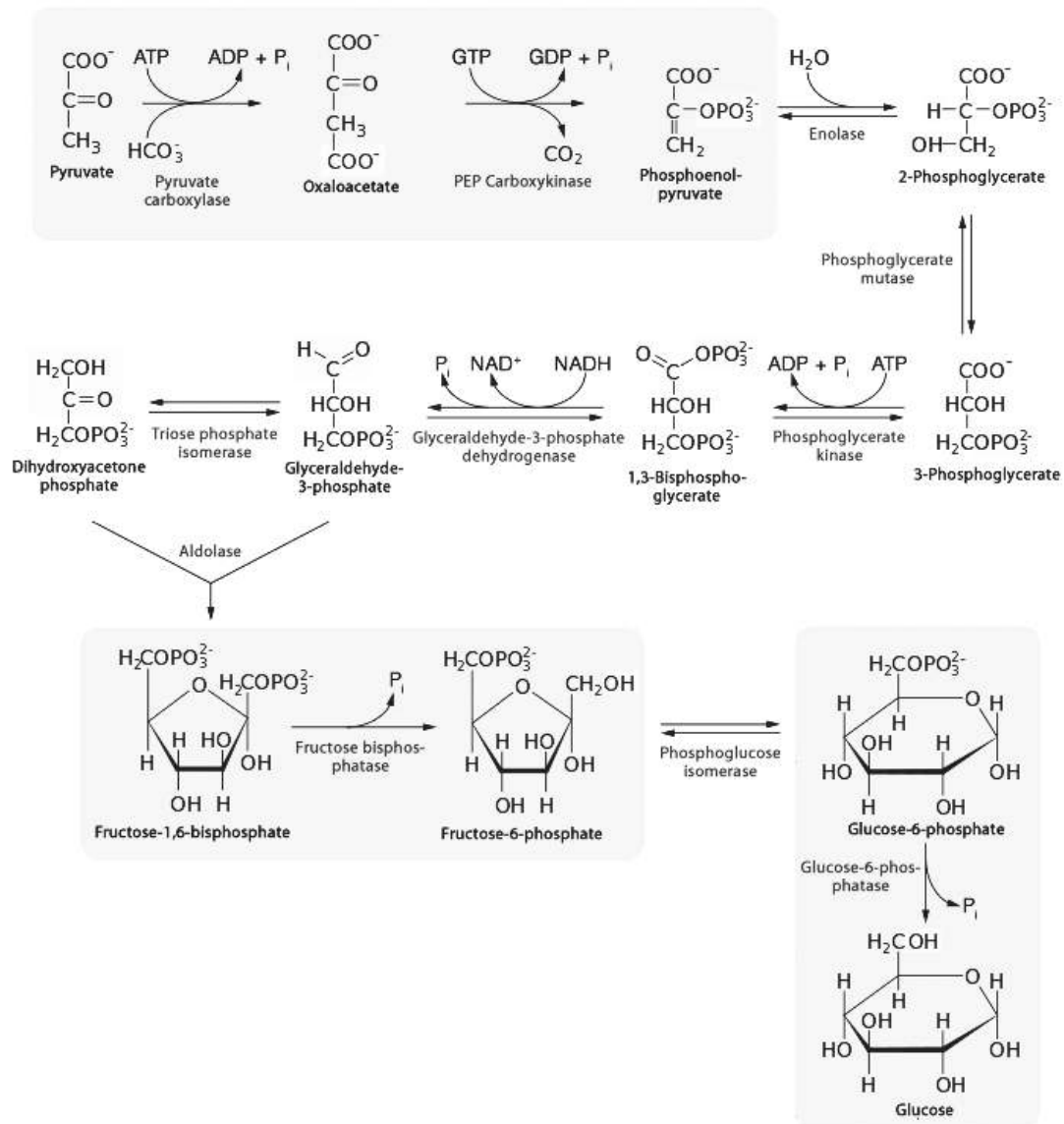
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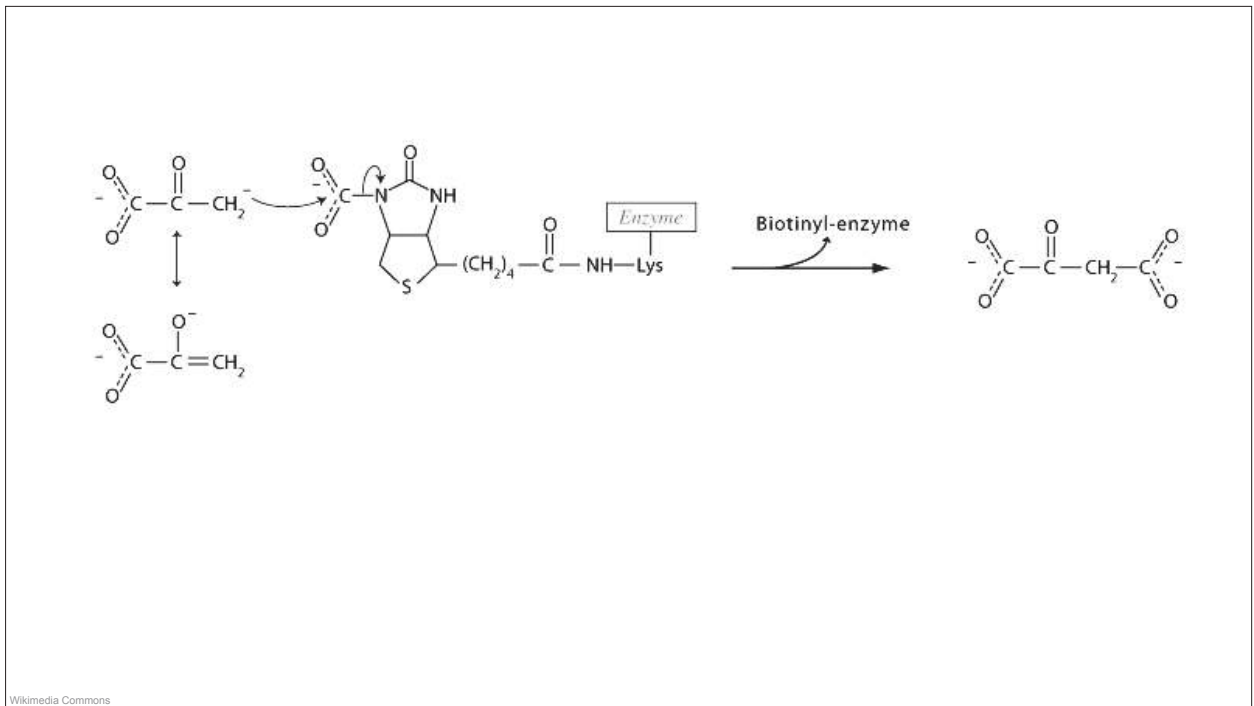
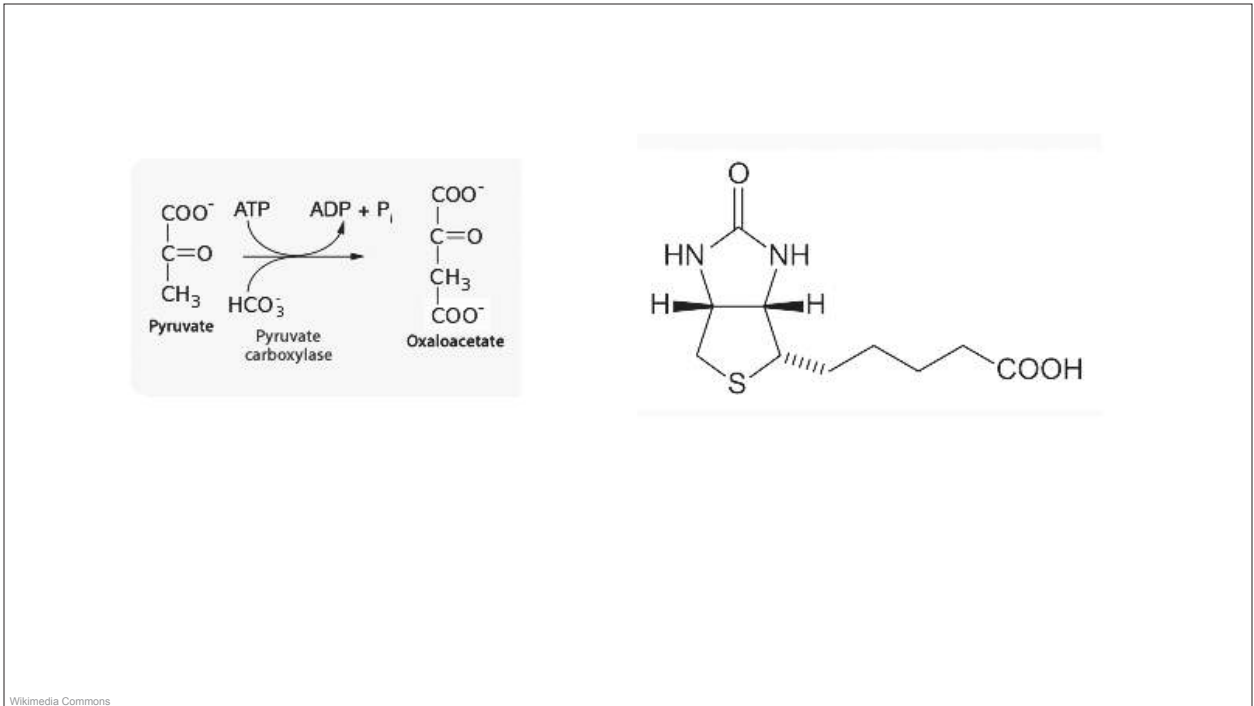
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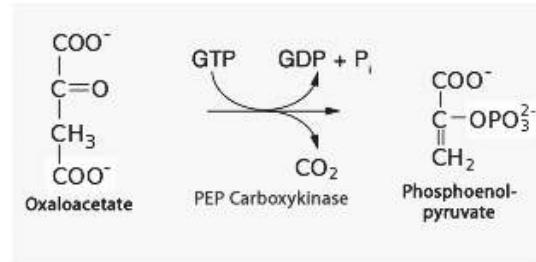


Gluconeogenesis

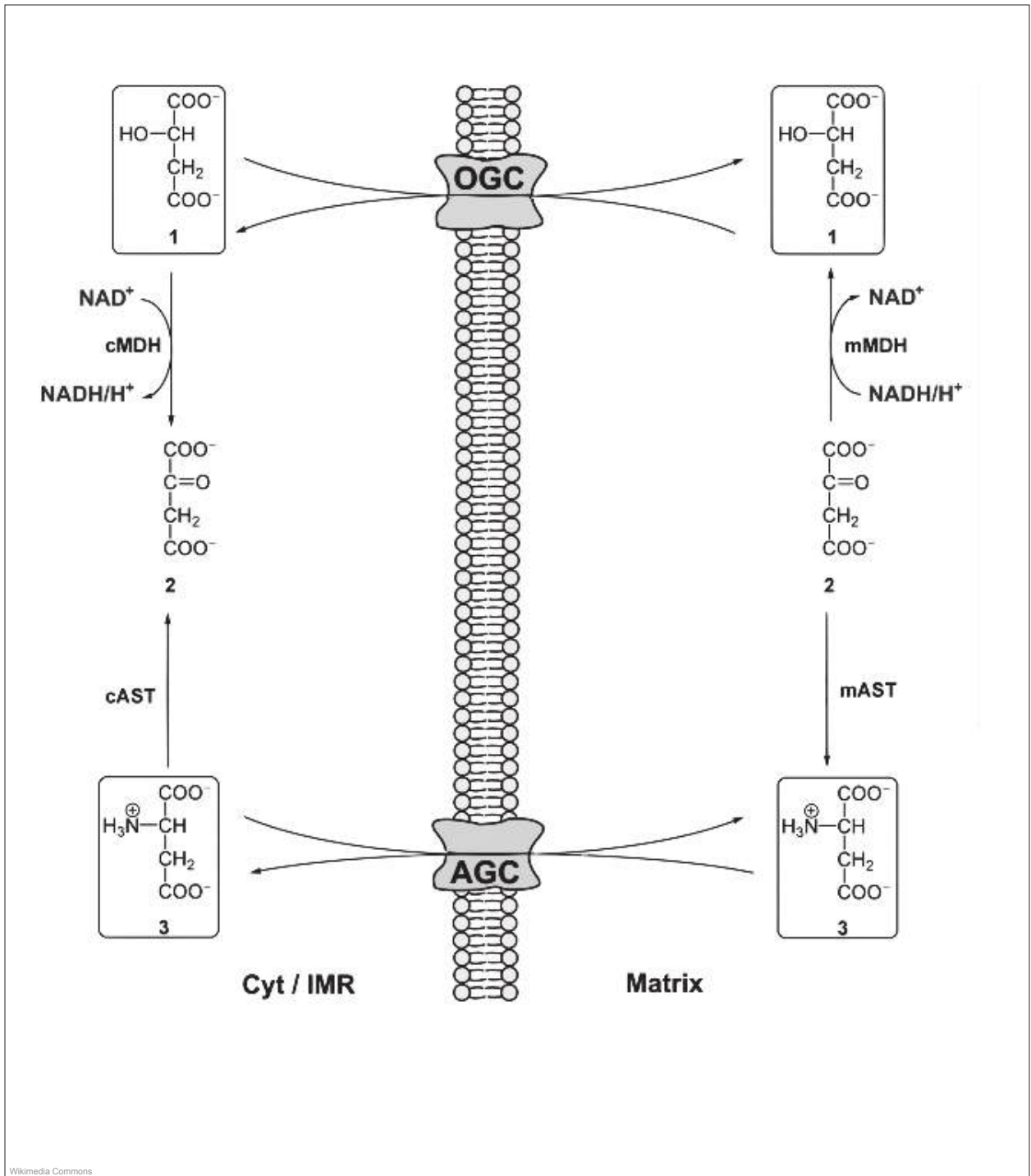


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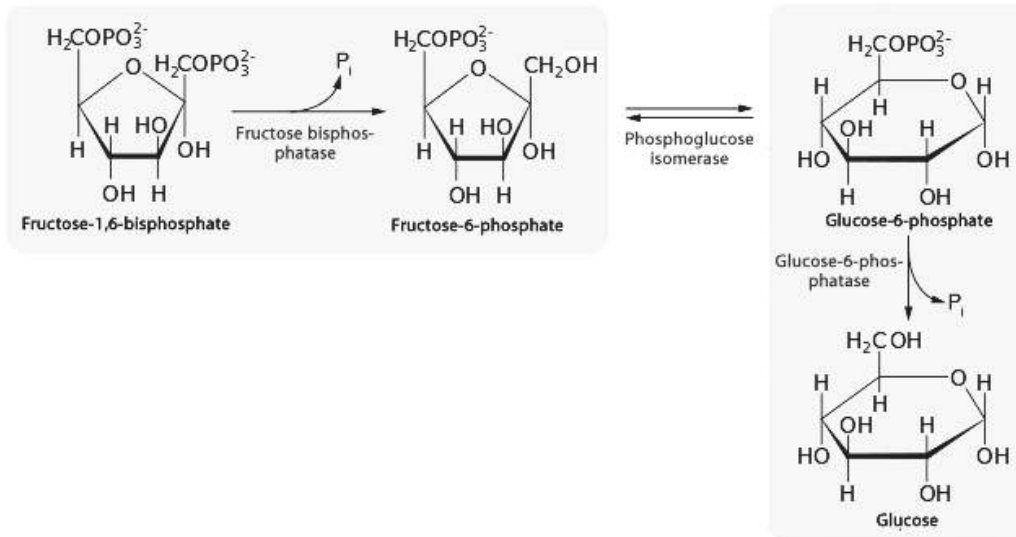




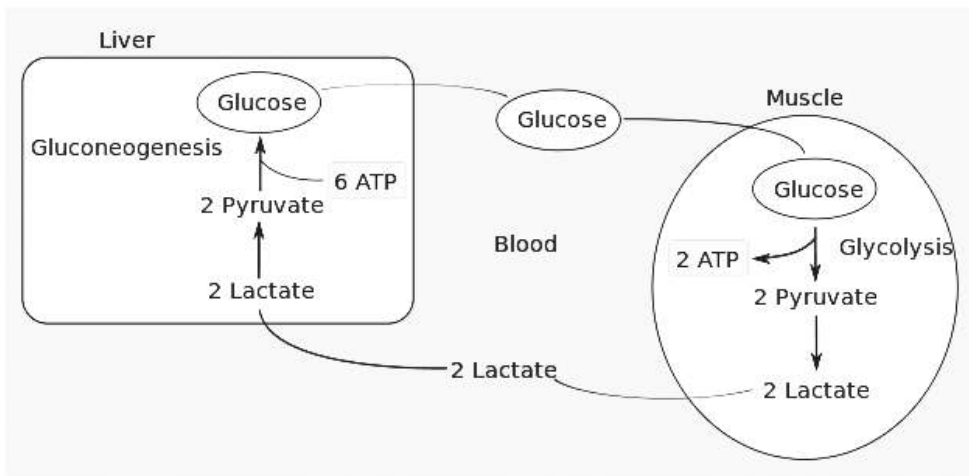
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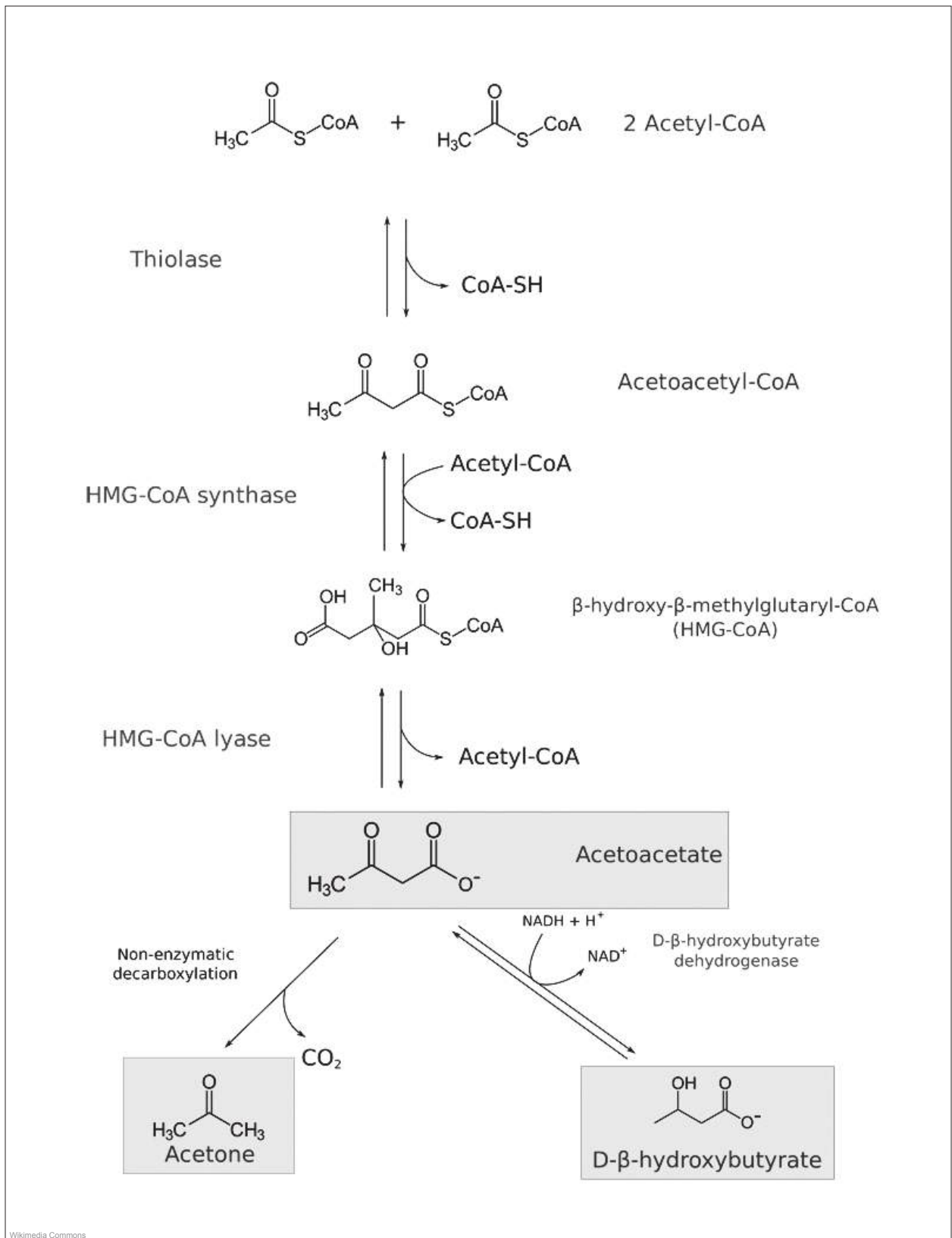
Gluconeogenesis



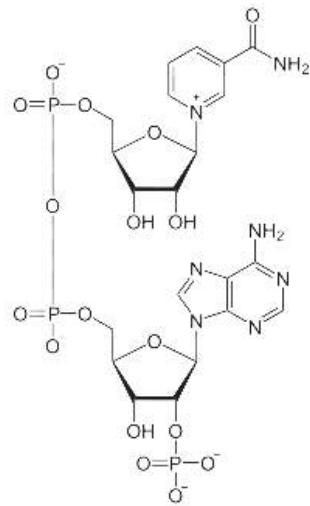
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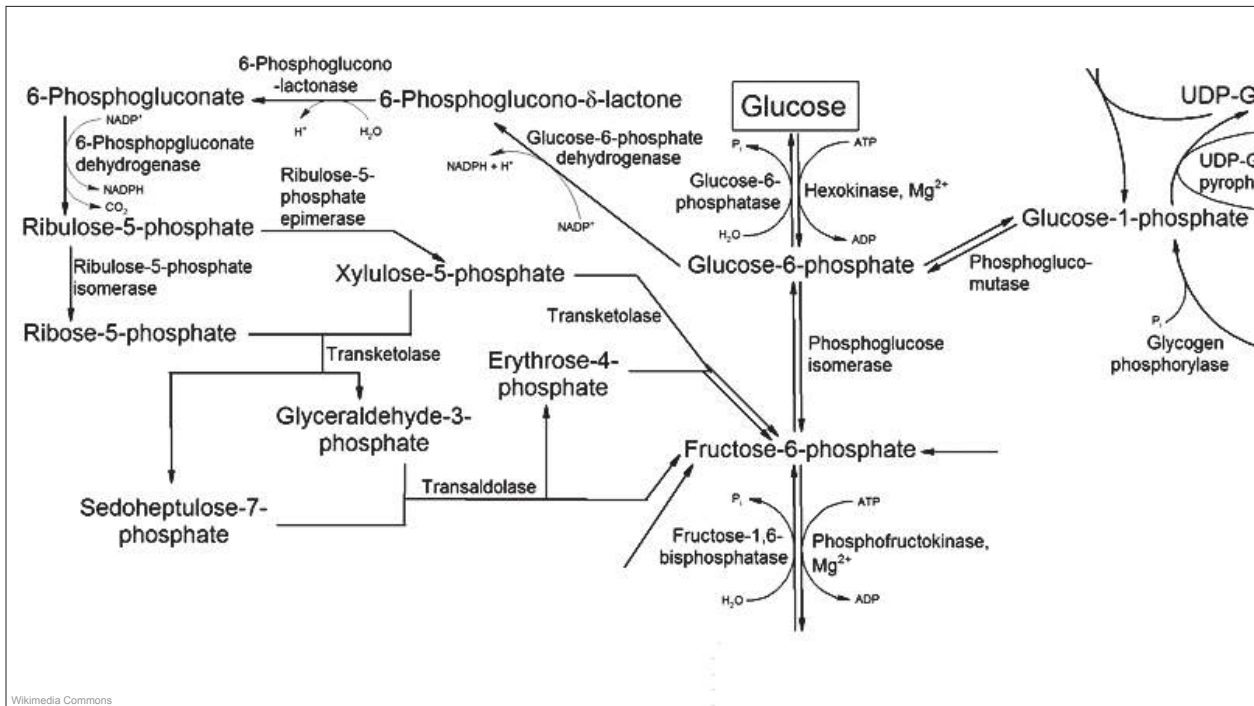
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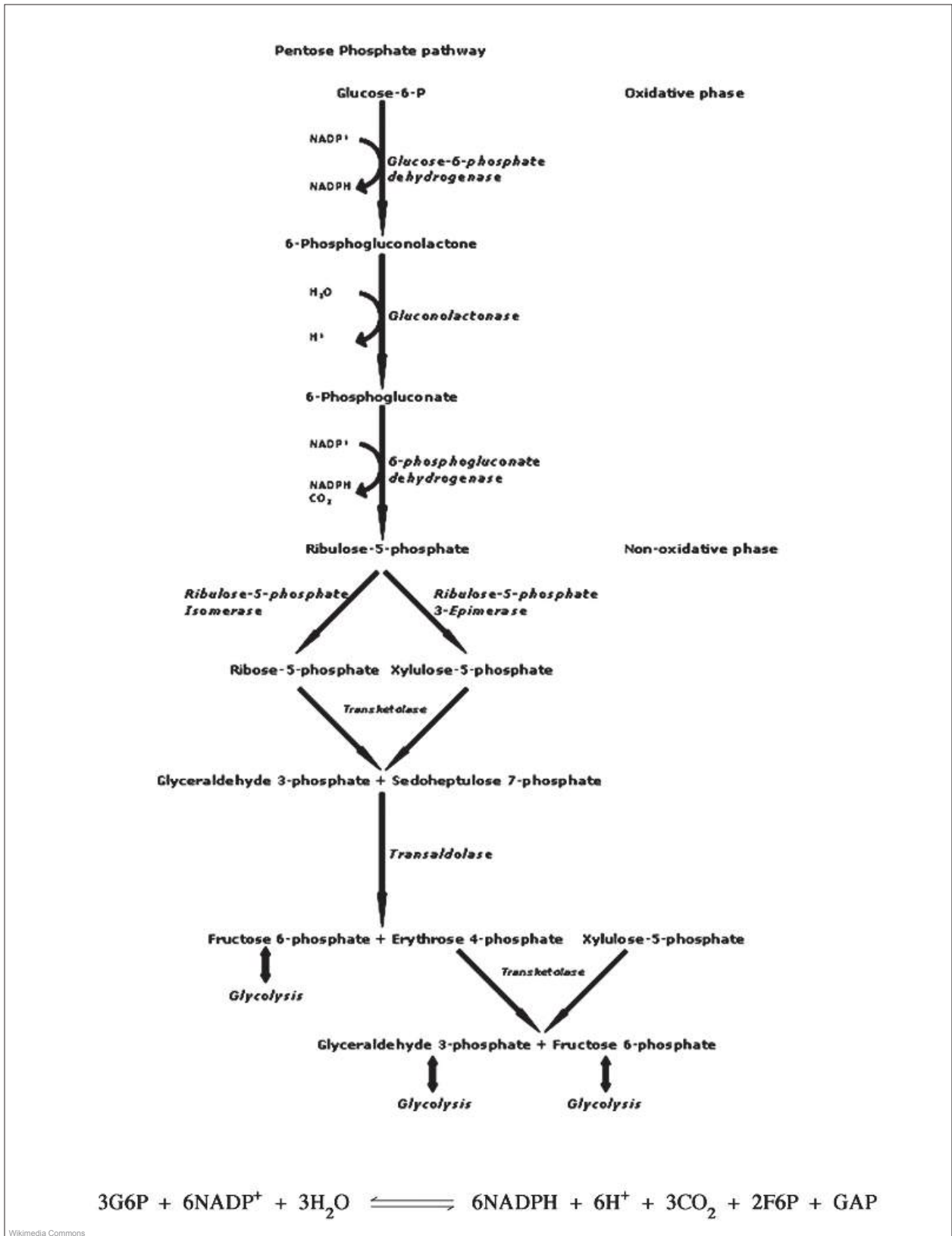
Pentose Phosphate Pathway



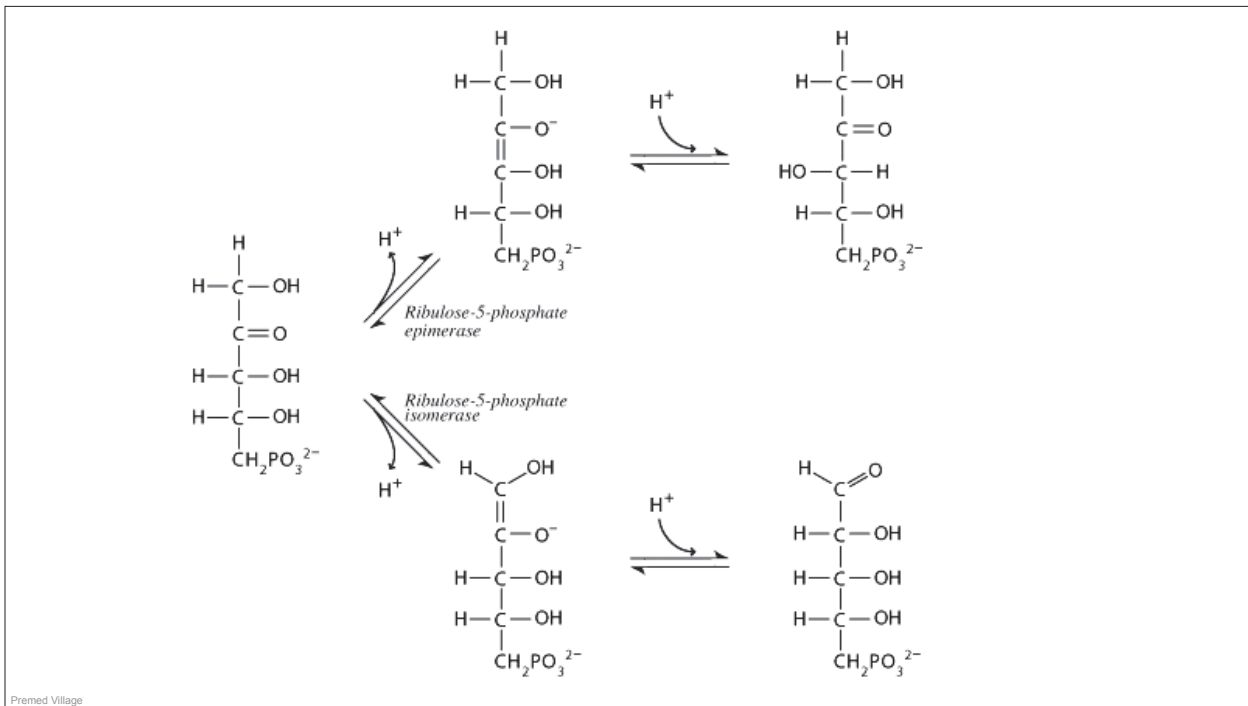
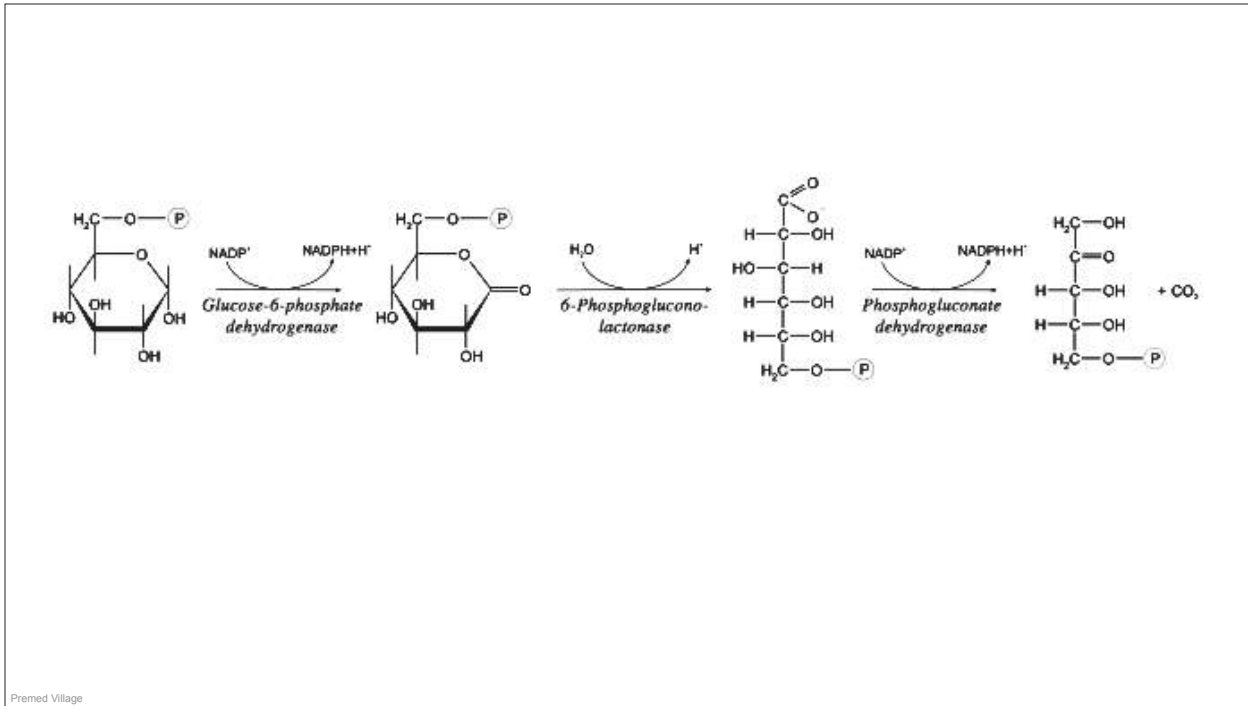
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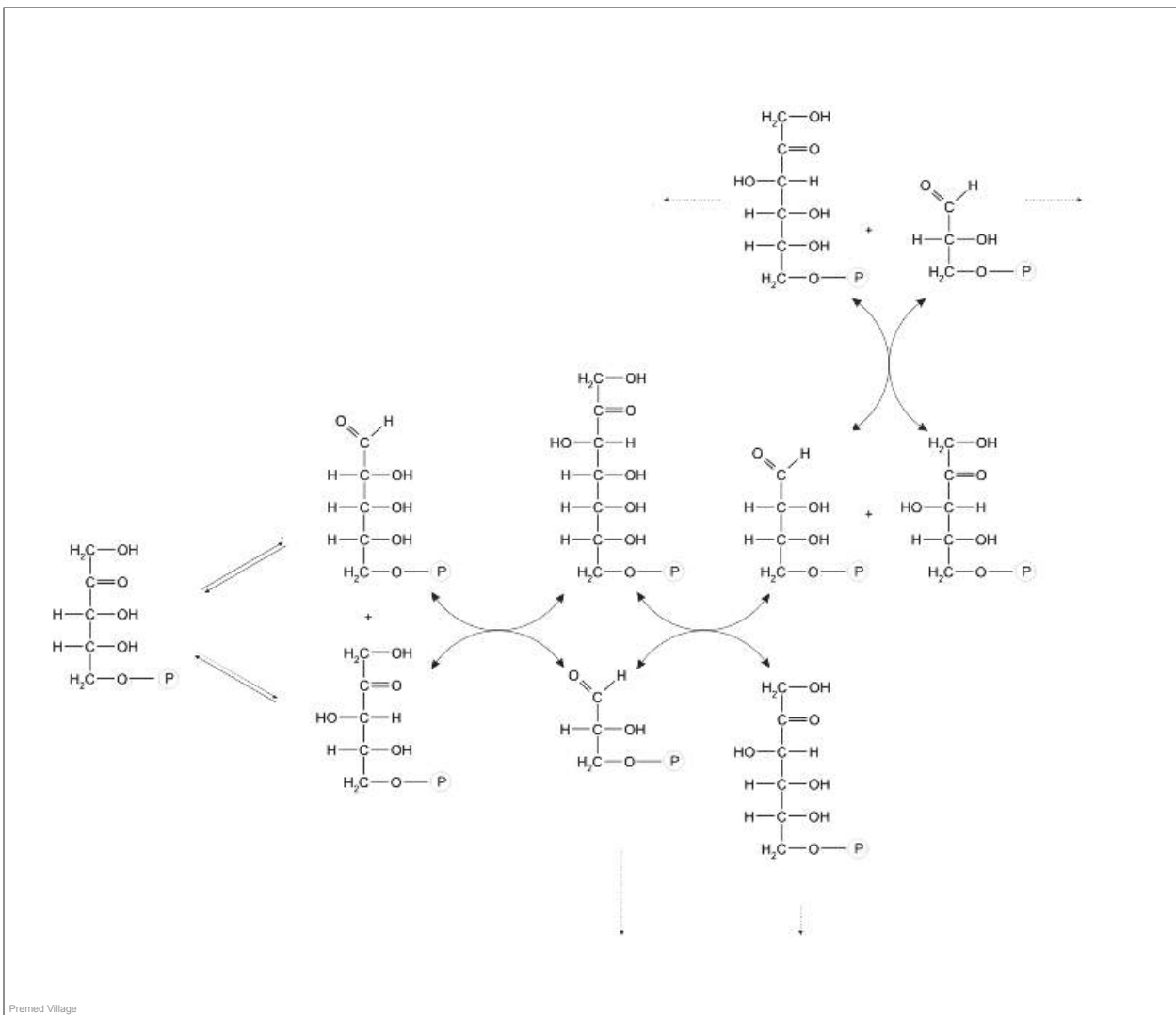


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Pentose Phosphate Pathway

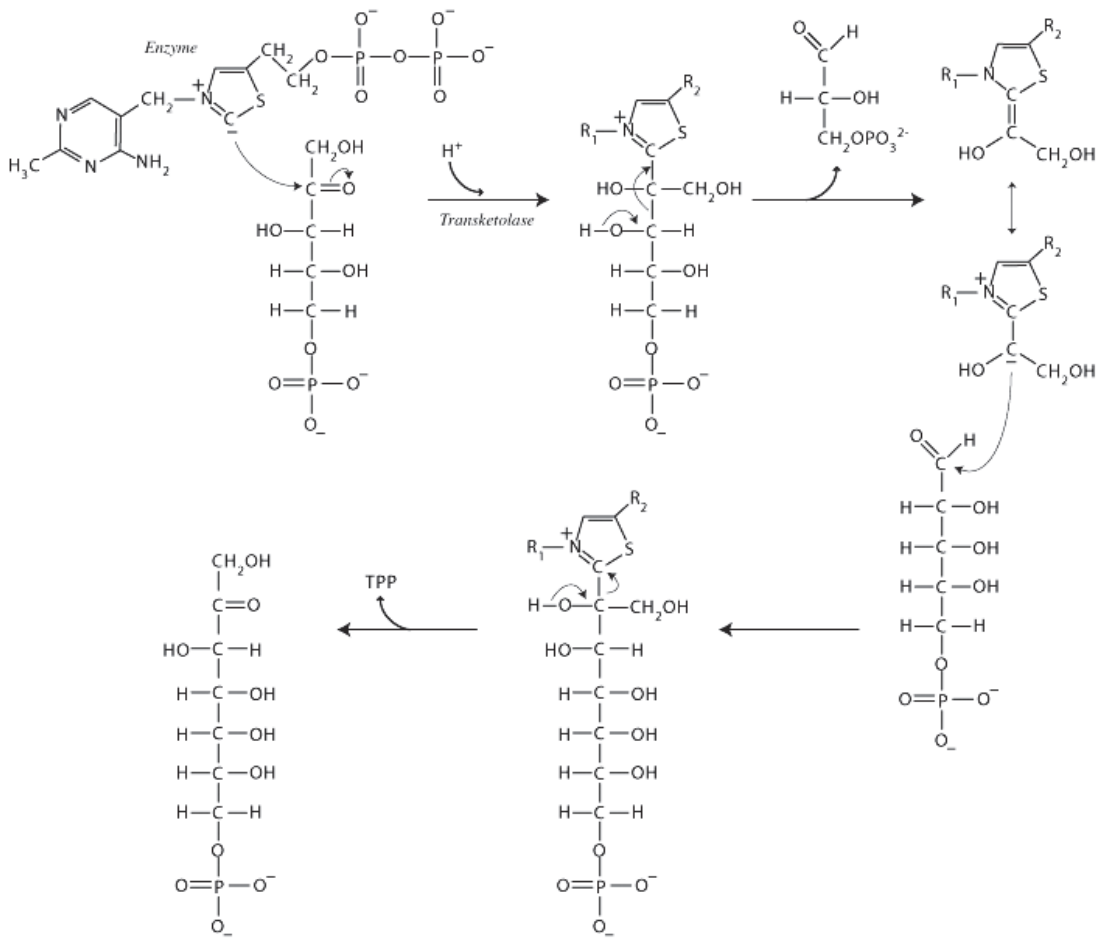




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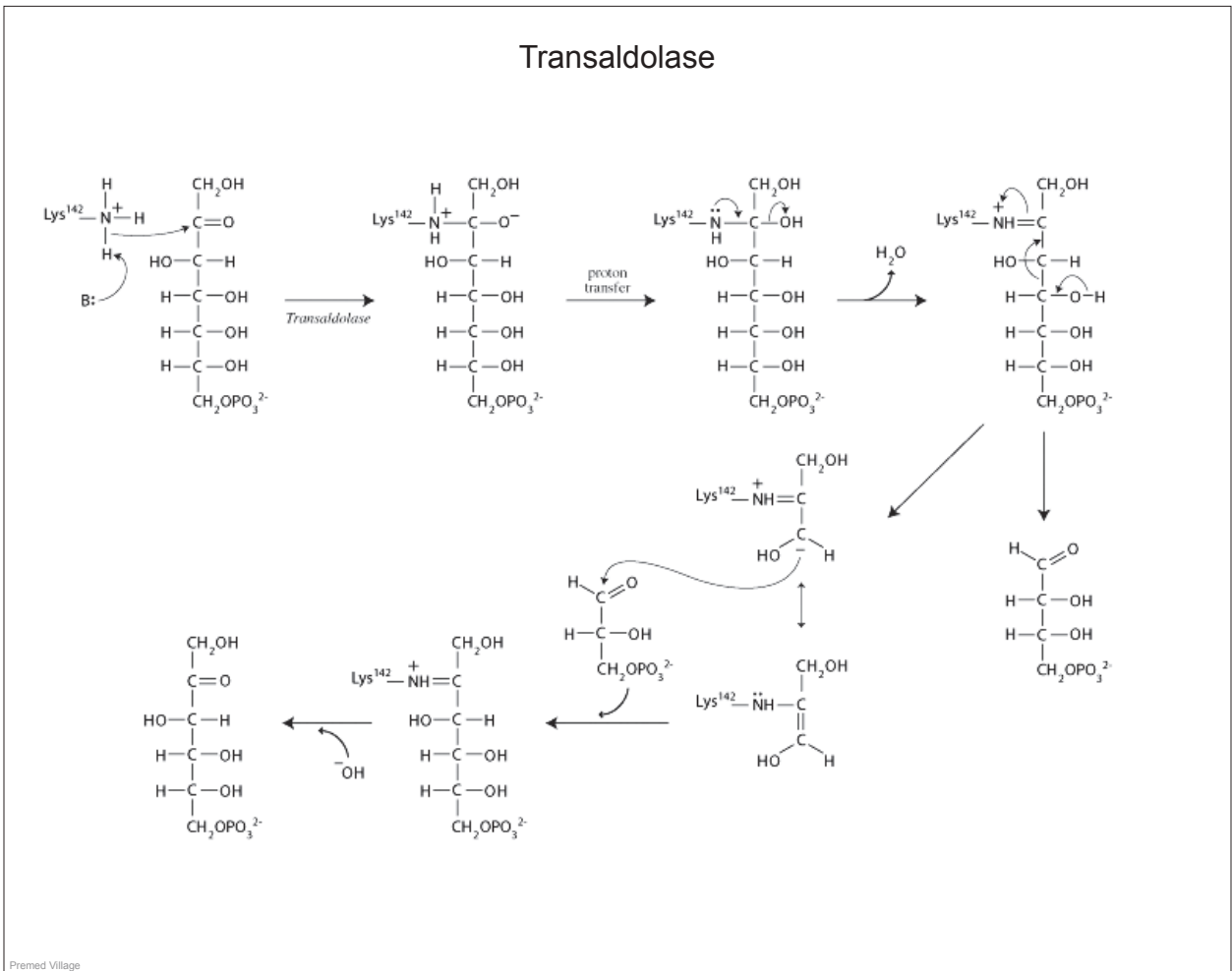
Pentose Phosphate Pathway

Transketolase

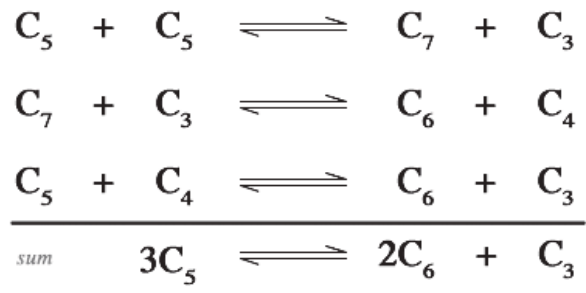


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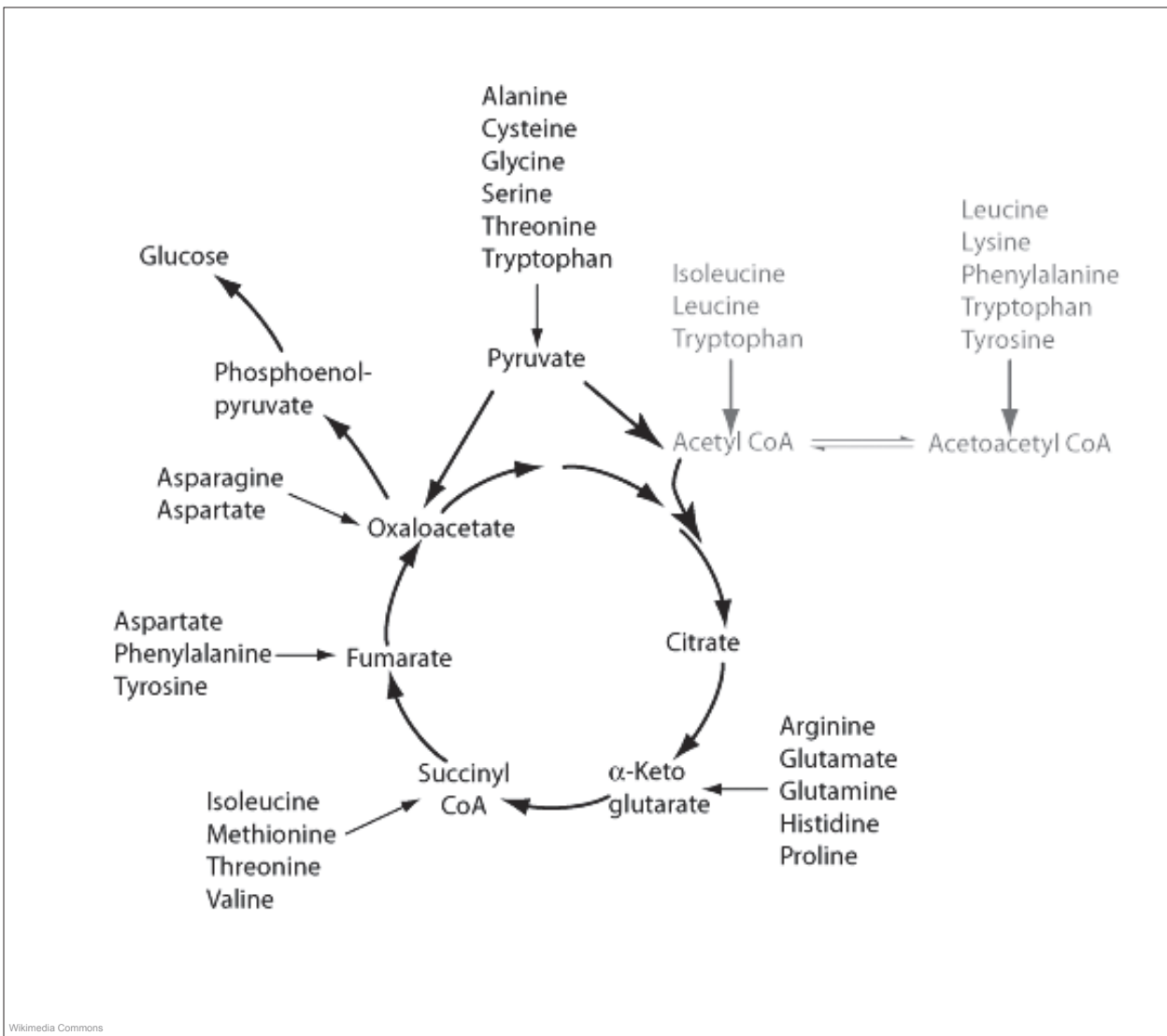
Transaldolase



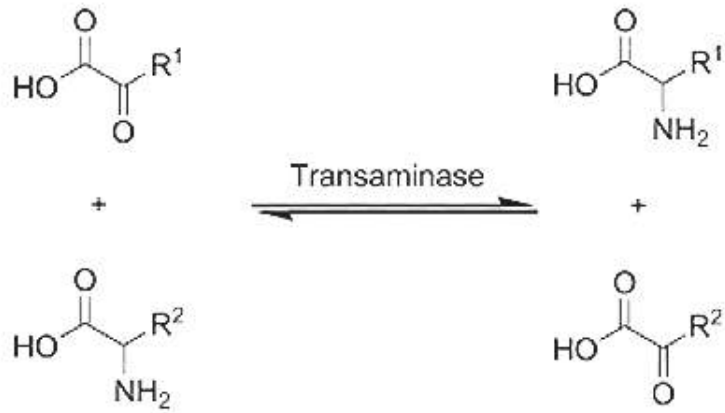
Pentose Phosphate Pathway



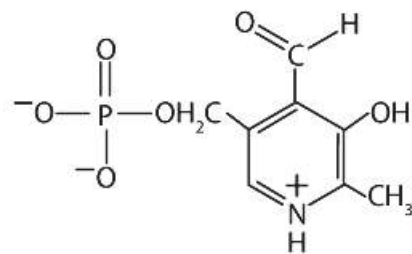
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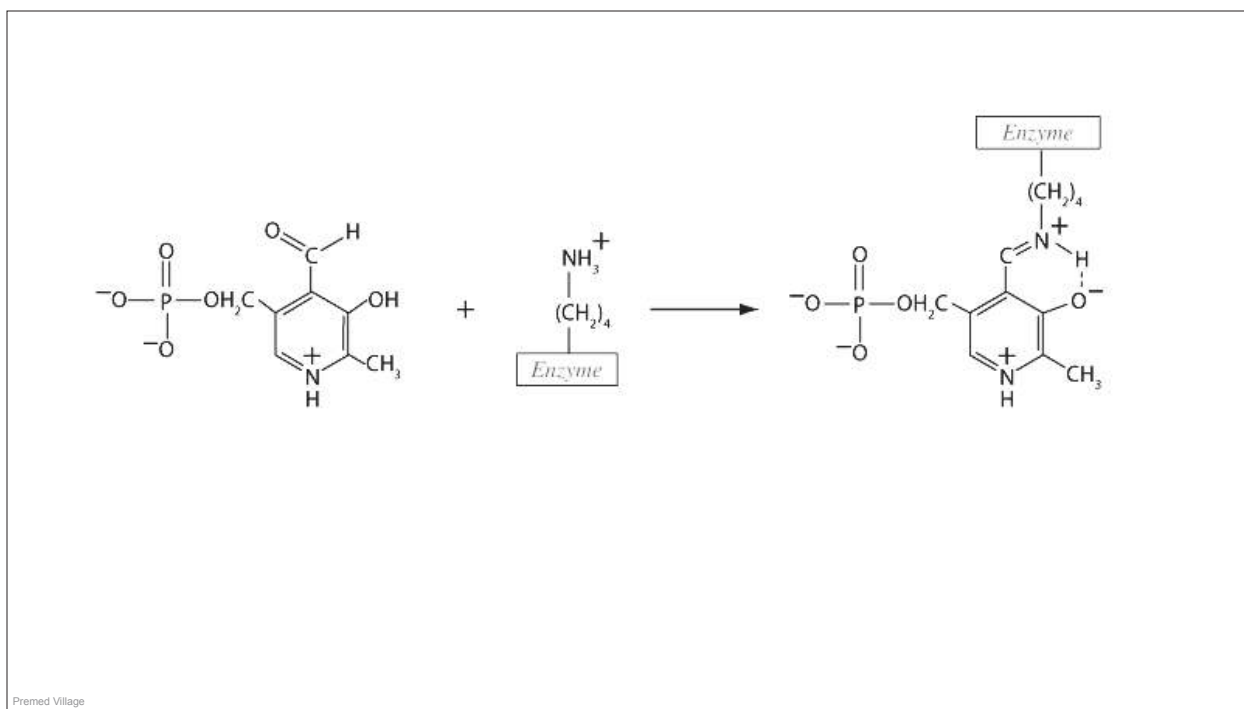
Urea Cycle



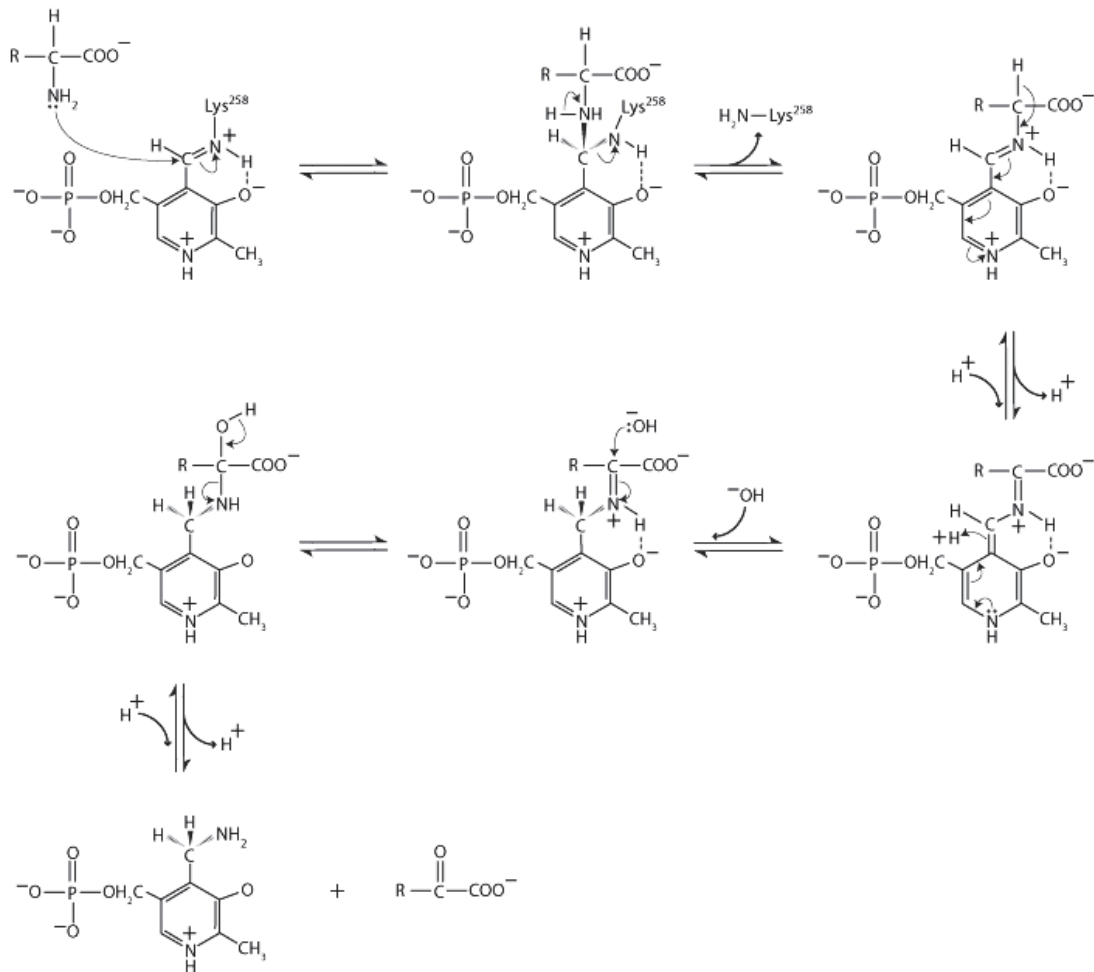
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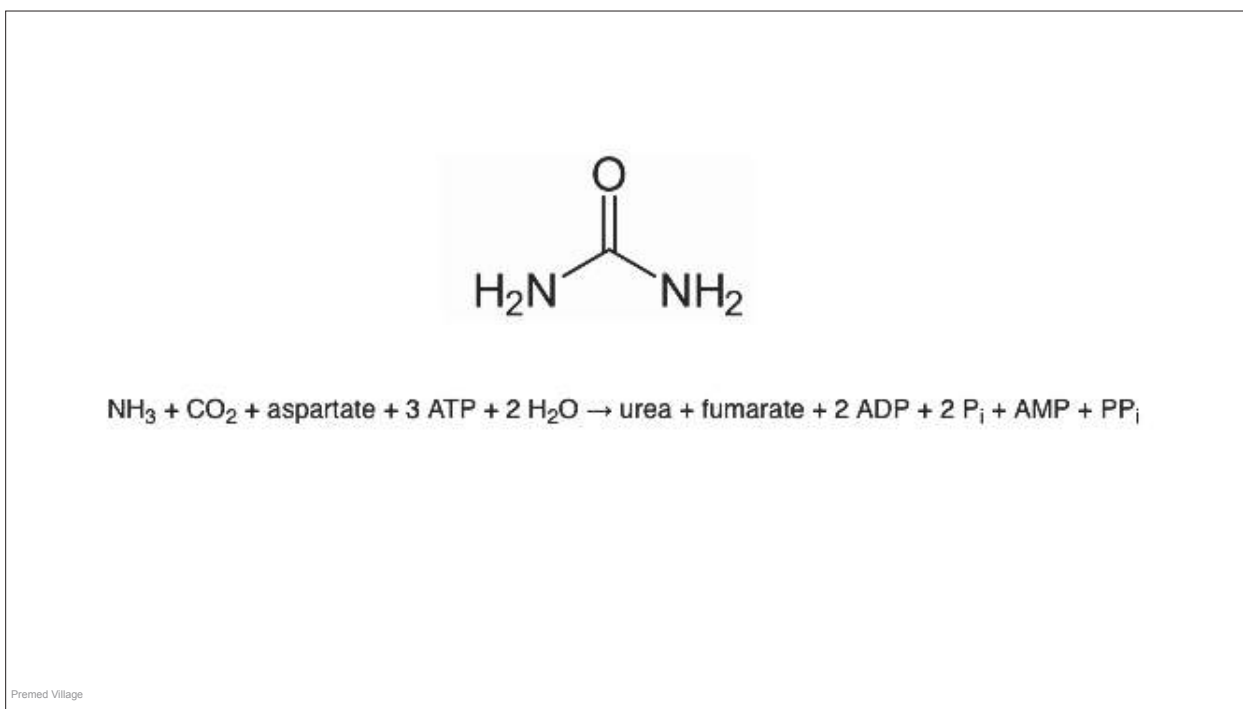
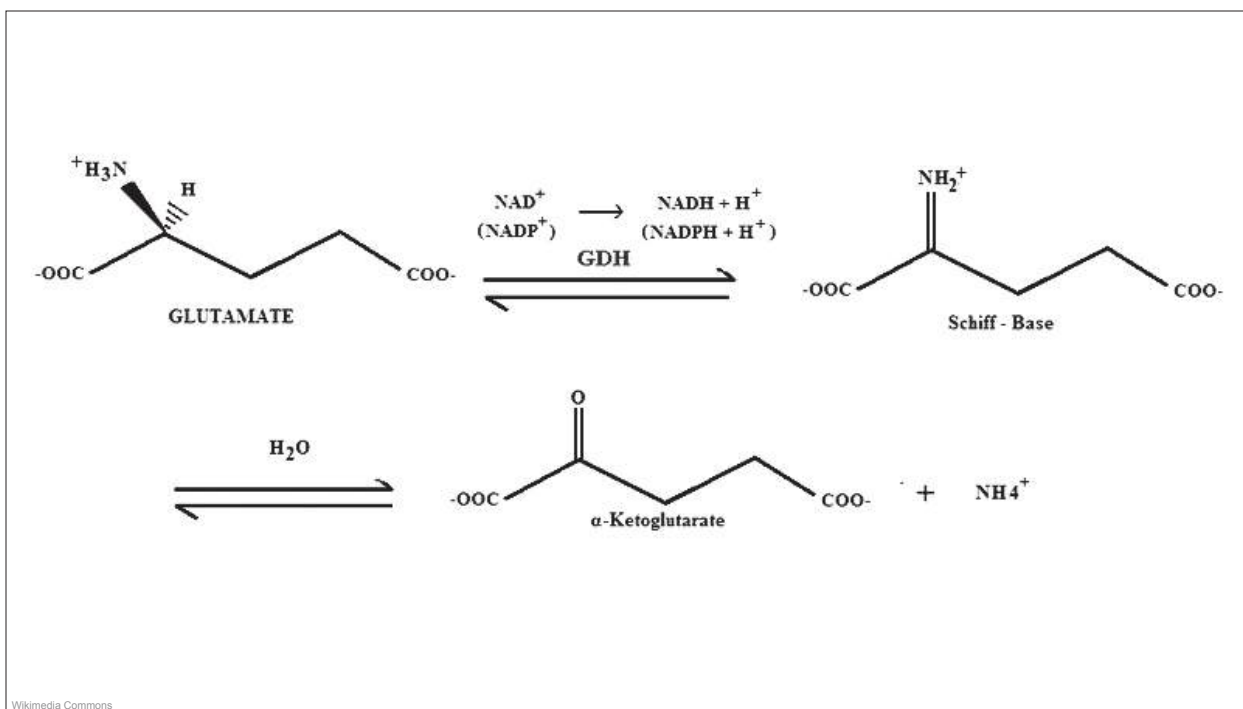
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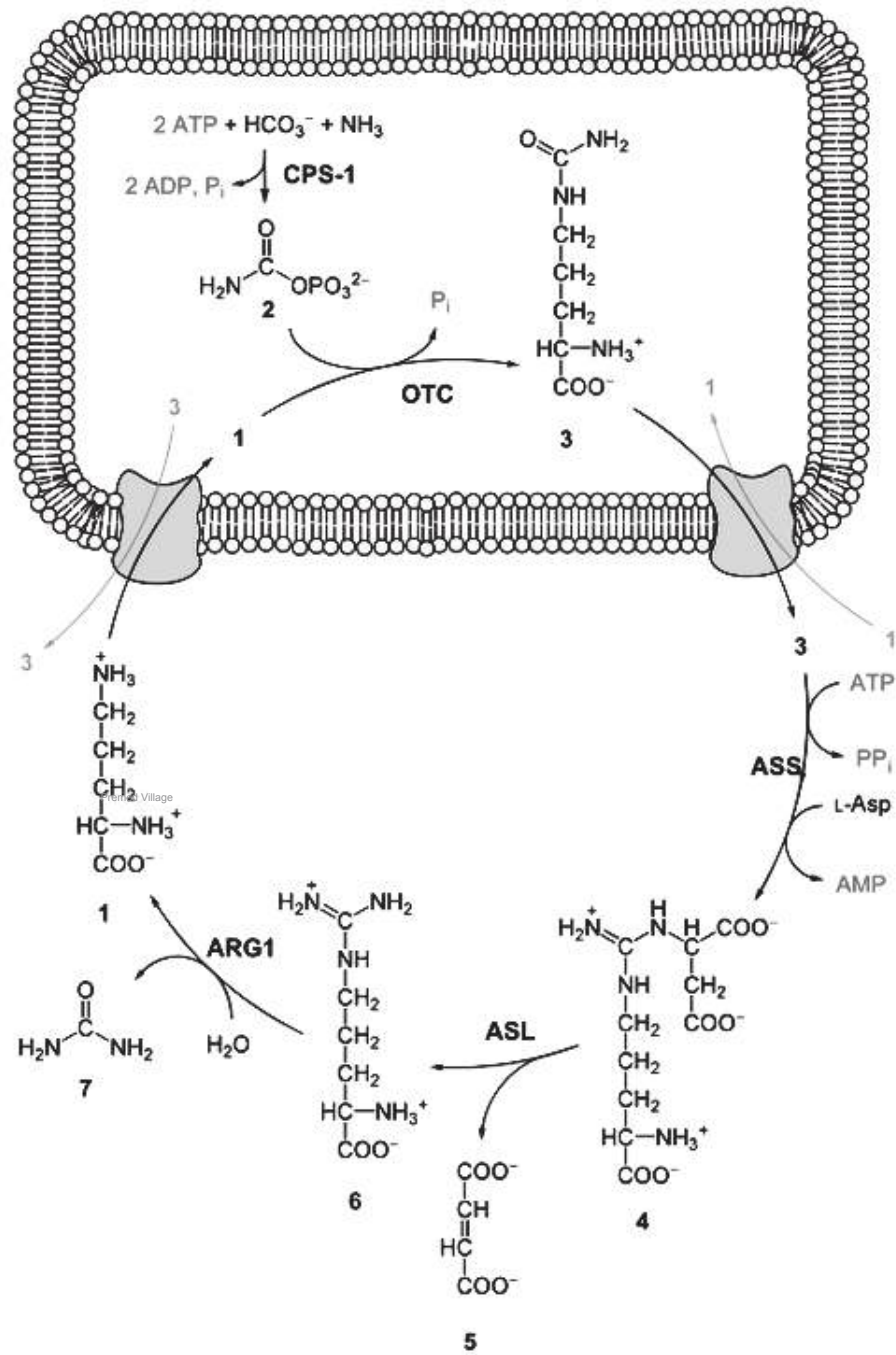
Transaminase



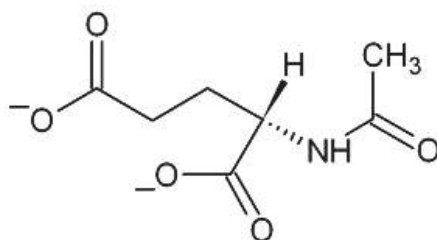
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Urea Cycle

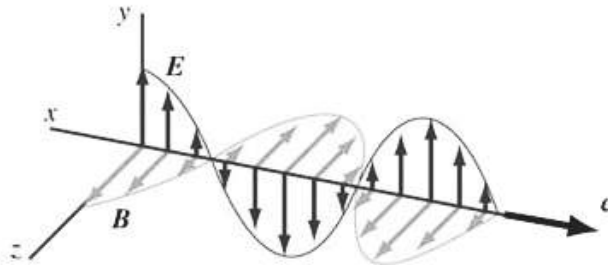


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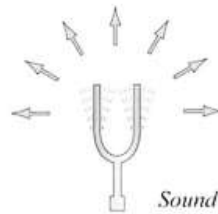
Electromagnetic Wave Propagation



Premed Village

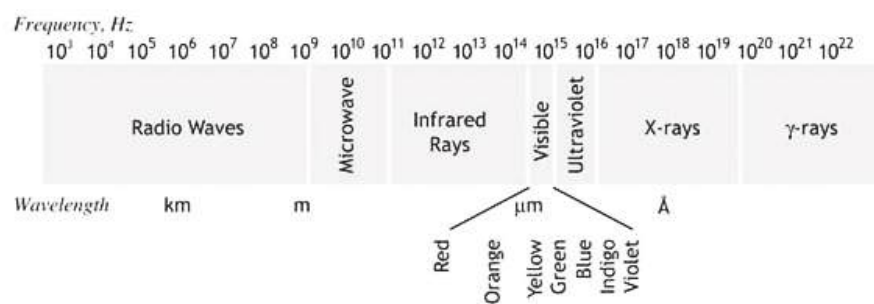
Which of the following distinguishes electromagnetic waves from sound waves?

- a. Electromagnetic waves are longitudinal. Sound waves are transverse.
- b. Electromagnetic waves do not require a medium.
- c. Electromagnetic waves carry energy.
- d. Electromagnetic waves can't be polarized.



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The Electromagnetic Spectrum



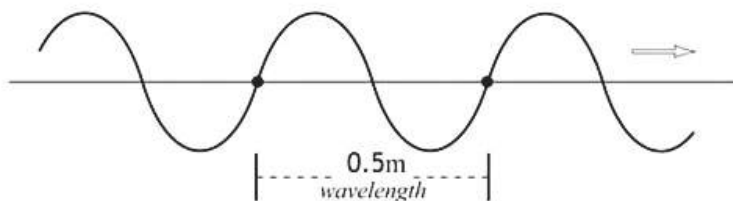
$$c = f\lambda$$

$$= 3 \times 10^8 \frac{\text{m}}{\text{s}}$$

c = speed of light
 f = frequency
 λ = wavelength

Properties of Light

A radio wave travelling through space has a wavelength of 0.5m. What is the frequency of the wave?

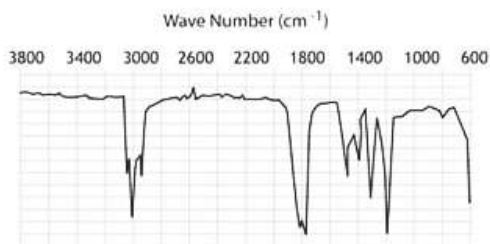


- a. 150 MHz
- b. 250 MHz
- c. 300 MHz
- d. 600 MHz

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Infrared spectroscopy is a technique to identify an unknown compound by assaying the absorption of frequencies of infrared radiation matching the vibrational frequencies associated with the chemical bonds within the substance.

Infrared spectrographs usually represent absorption frequencies as *wave numbers* (cm^{-1}). Wave numbers are reciprocal values of the wavelengths of absorbed radiation.



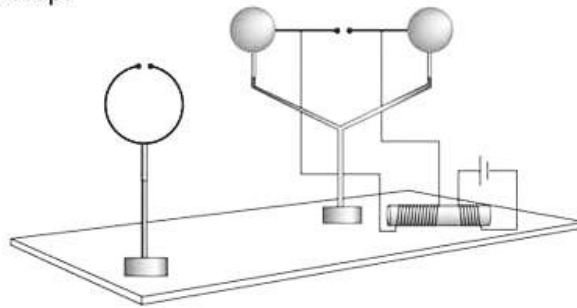
The unknown substance depicted by the spectrograph above has a strong absorbance at 3000 cm^{-1} . What is the frequency in Hz of this peak?

- a. 1×10^{-5} Hz
- b. 1×10^7 Hz
- c. 9×10^{11} Hz
- a. 9×10^{13} Hz

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When sufficient voltage is supplied to the induction coil in the apparatus below, an oscillatory discharge occurs across the spark gap between the two electrode spheres. The oscillatory discharge occurs at the resonance frequency of the induction coil/electrode combination, an LC circuit, at approximately 1×10^8 Hz. When the resonance frequency of a nearby conducting loop with its own spark gap is adjusted to match this frequency, sparks are observed across the gap in the nearby loop, even though the loop is not touching the induction coil/electrode apparatus. What are being transmitted by the coil/electrode apparatus to the loop to cause sparking in the loop?

- a. cathode rays
- b. radio waves
- c. alpha particles
- d. x-rays



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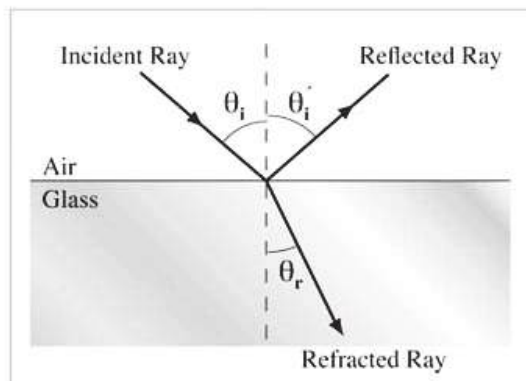
Reflection and Refraction

Law of Reflection

$$\theta_i = \theta_i'$$

θ_i = angle of incidence

θ_i' = angle of reflection



Snell's Law Governing Refraction

$$n_1 \sin \theta_i = n_2 \sin \theta_r$$

n_1 = index of refraction in first medium

θ_i = angle of incidence

n_2 = index of refraction in second medium

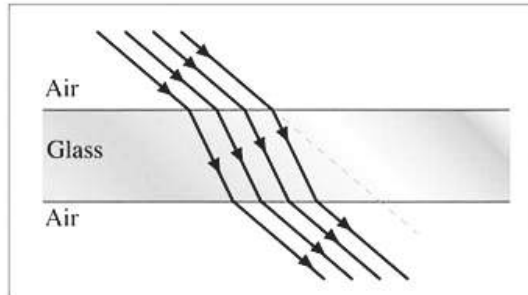
θ_r = angle of refraction

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Index of Refraction

$$n = \frac{c}{v}$$

n = index of refraction of medium
 c = speed of light in a vacuum
 v = speed of light in the medium



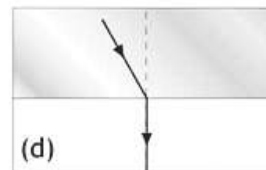
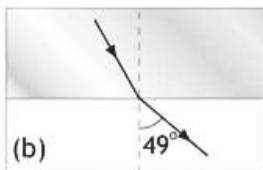
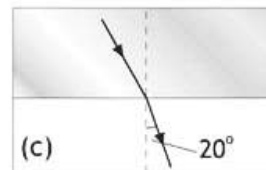
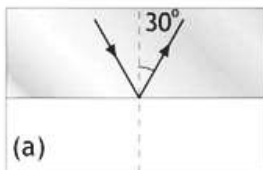
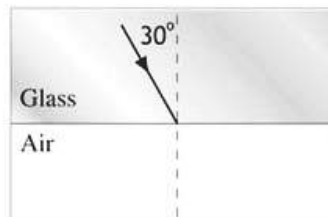
$$\frac{v_2}{v_1} = \frac{n_1}{n_2}$$

$$\frac{\lambda_2}{\lambda_1} = \frac{v_2}{v_1}$$

$$\frac{\lambda_2}{\lambda_1} = \frac{n_1}{n_2}$$

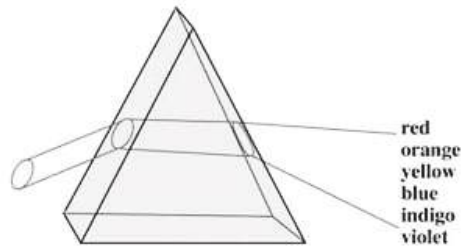
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A light ray travelling through glass ($n = 1.5$) is incident on the smooth, flat interface between the glass and outside air ($n = 1.0$). The light is travelling at an angle of 30° to the normal as pictured at right. Which results from refraction at the boundary?



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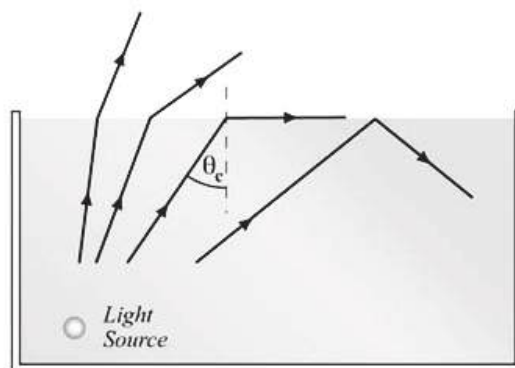
A prism disperses white light into its spectrum, revealing the colored components of white light. Which of the following accounts for this behavior?



- a. Red rays are refracted the most by the prism, violet rays the least.
- b. The product of wavelength and frequency is the same for all colors in the glass but not in empty space.
- c. Visible light of longer wavelength moves with greater speed in glass than visible light of shorter wavelength.
- d. Moving from a slower to a faster media increases the wavelength of a particular light ray.

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The Critical Angle and Internal Reflection



$$\sin \theta_c = \frac{n_2}{n_1}$$

$$(n_1 > n_2)$$

- θ_c = critical angle
- n_1 = index of refraction in first medium
- n_2 = index of refraction in second medium

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A typical fiber optic cable consists of two concentric layers: the outer cladding and the inner core. The index of refraction of the core is higher than that of the cladding. With a straight or slightly bending fiber, the signal always strikes the core-cladding interface at an angle (from the normal) higher than the critical angle. Therefore, the light is reflected back into the fiber which allows transmission over great distance.

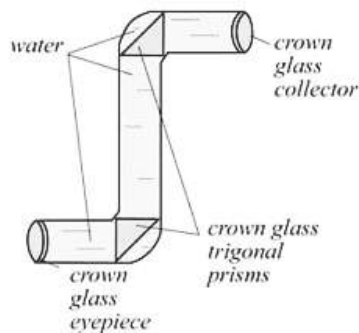


What is the minimum time required for the cable above to transmit a signal over a distance of 90 km?

- a. 3.0×10^{-7} s
- b. 2.0×10^{-4} s
- c. 3.0×10^{-4} s
- d. 4.5×10^{-4} s

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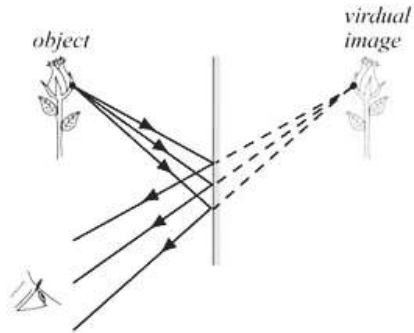
To develop a device for viewing objects under ocean water, an inventor chooses a traditional periscope design as a starting point. Attempting to improve image quality, she experiments with filling the interior chambers of the periscope with pure water. However, she sees no image at all through the modified device. Which of the following is a root cause of the problem?



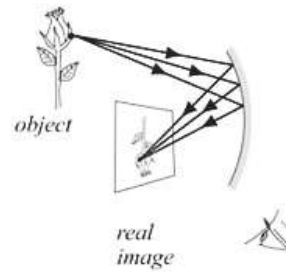
- a. The device was filled with pure water instead of salt water.
- b. Internal reflection at the eyepiece.
- c. Water and crown glass are too close in refractive index.
- d. The transmittance of water is too low (absorbance too great).

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Virtual and Real Images



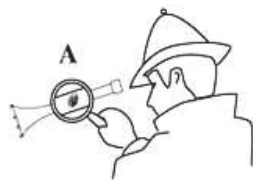
A plane mirror creates a virtual image, located behind the mirror.



A real image is created by a concave mirror (at this object distance) which can be visualized on a screen.

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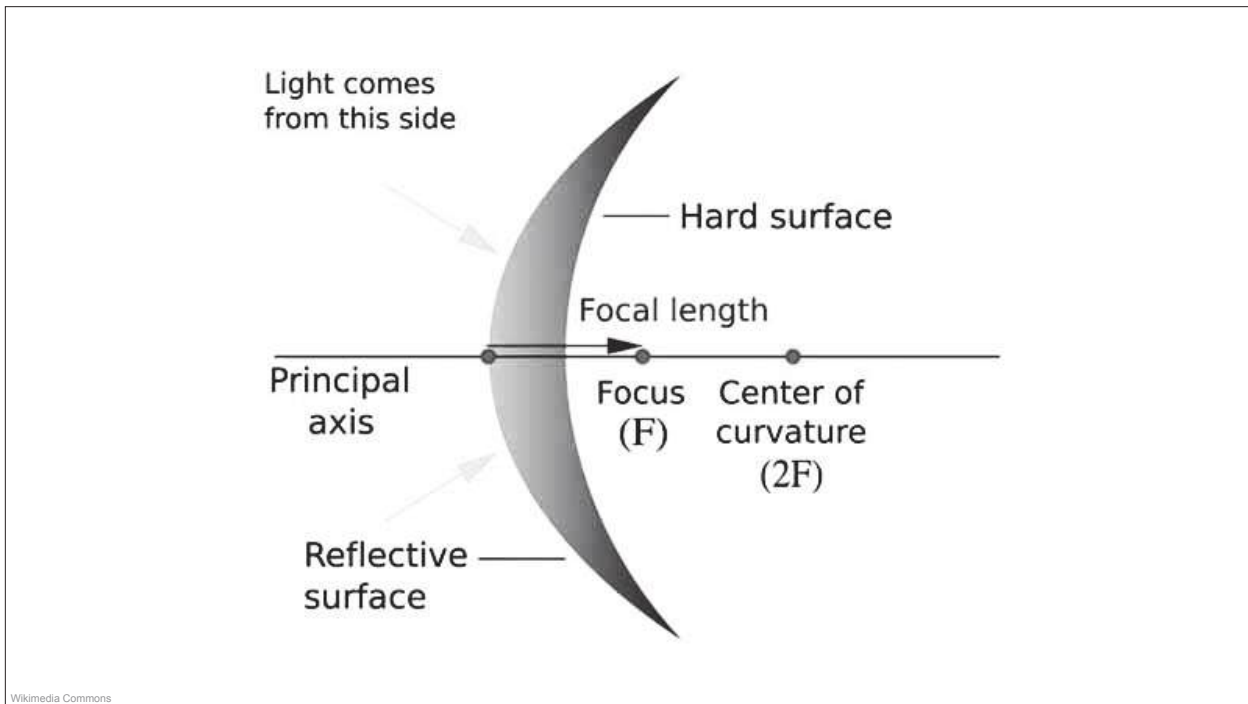
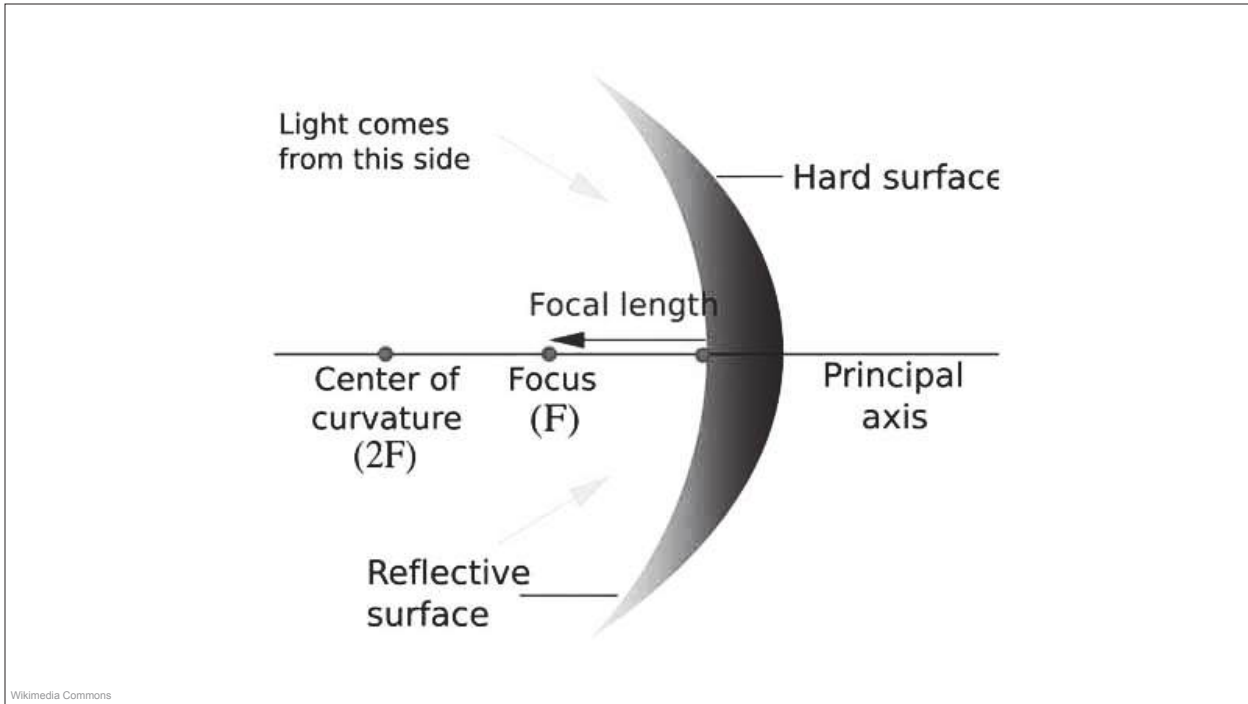
A detective's magnifying glass and a concave make-up mirror are two simple optical devices that can produce enlarged images.



Which of the following statements is true about the images produced above?

- Image **A** is real and image **B** is virtual.
- Image **A** is virtual and image **B** is real.
- Both images are real.
- Both images are virtual.

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Concave and Convex Mirrors

concave

$O > C$

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O}$$

$$M = -\frac{I}{O}$$

C = center of curvature
 F = focal length ($1/2 C$)
 I = image distance
 O = object distance
 M = lateral magnification

convex

DEV (*diminished, erect, virtual*)
with a single convex mirror.

$O = C$

$O = F$

$O < F$

$C > O > F$

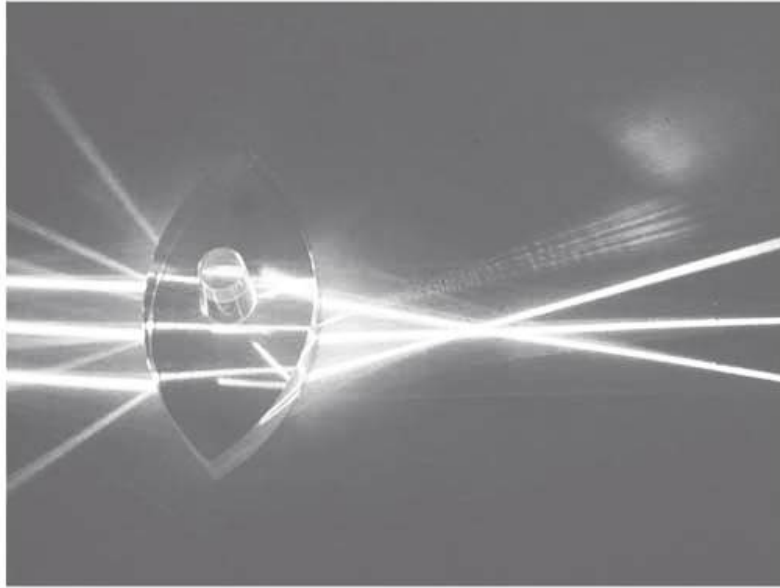
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A concave mirror has a focal length of 20cm. What type of image will the mirror form of a light bulb placed 80cm in front of the mirror?

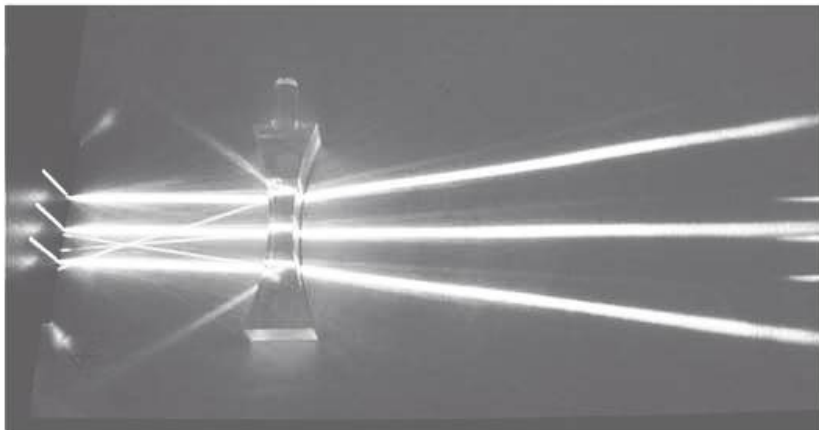


- | | |
|-------------------------------|--------------------------------|
| a. virtual, erect, diminished | c. real, inverted, diminished |
| b. real, erect, enlarged | d. virtual, inverted, enlarged |

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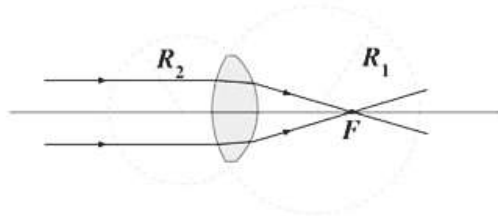


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Lens-Maker's Equation

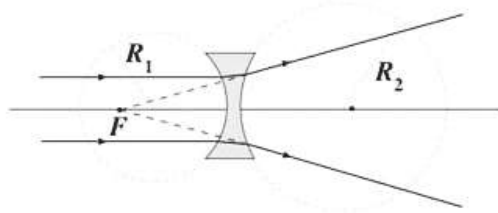
$$\frac{1}{F} = (n - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

F = focal length ($1/2 C$)
 n = refractive index
 R = radius of curvature



Positive (Converging) Lens

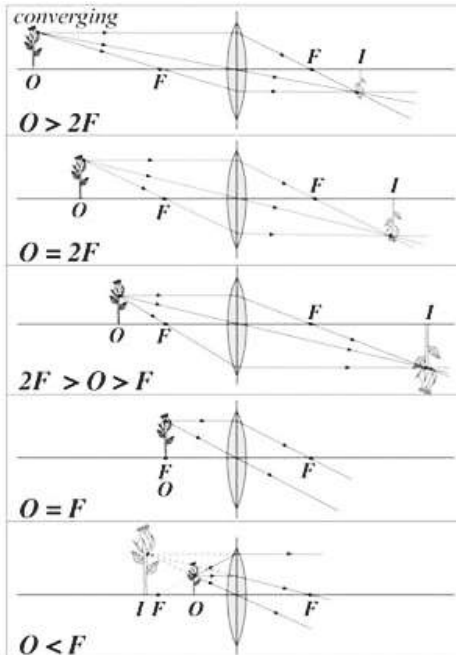
- R_1 - positive
- R_2 - negative
- F - positive



Negative (Diverging) Lens

- R_1 - negative
- R_2 - positive
- F - negative

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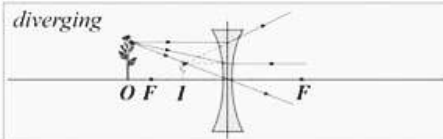


Converging and Diverging Lenses

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O}$$

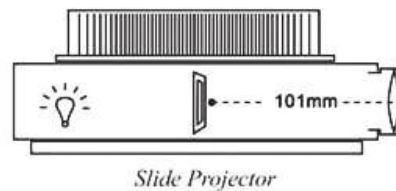
$$M = -\frac{I}{O}$$

- F = focal length
- I = image distance
- O = object distance
- M = lateral magnification



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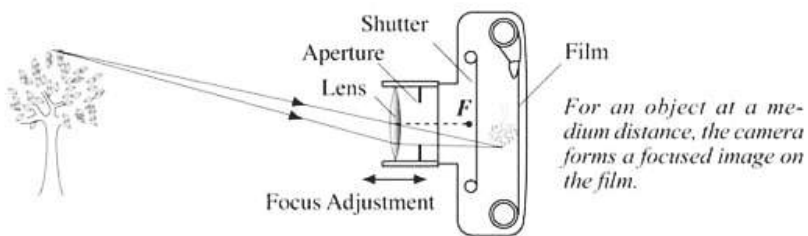
A slide projector has a 100mm projection lens. When the focus knob is adjusted so that the distance between the slide and the lens is 101mm, the projector creates a focused image on a screen 10m in front of the projector. What is the magnification of the image?



- | | |
|--------|--------|
| a. -99 | c. 100 |
| b. 99 | d. 990 |

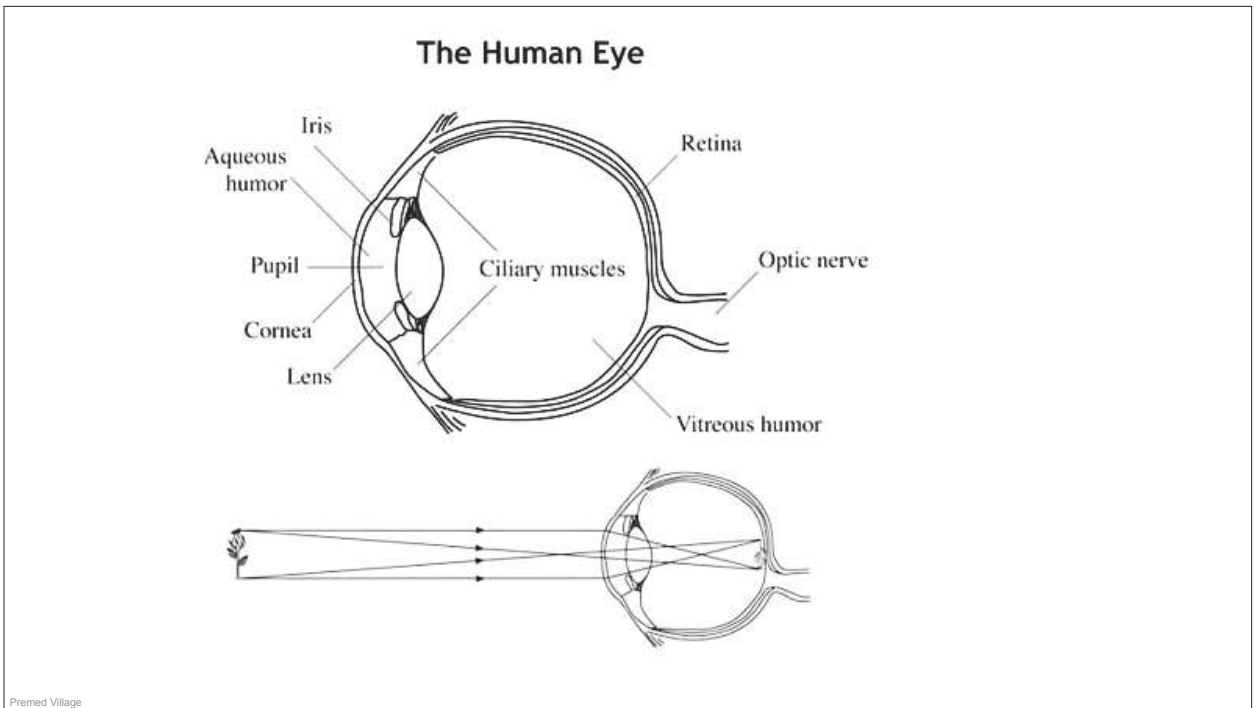
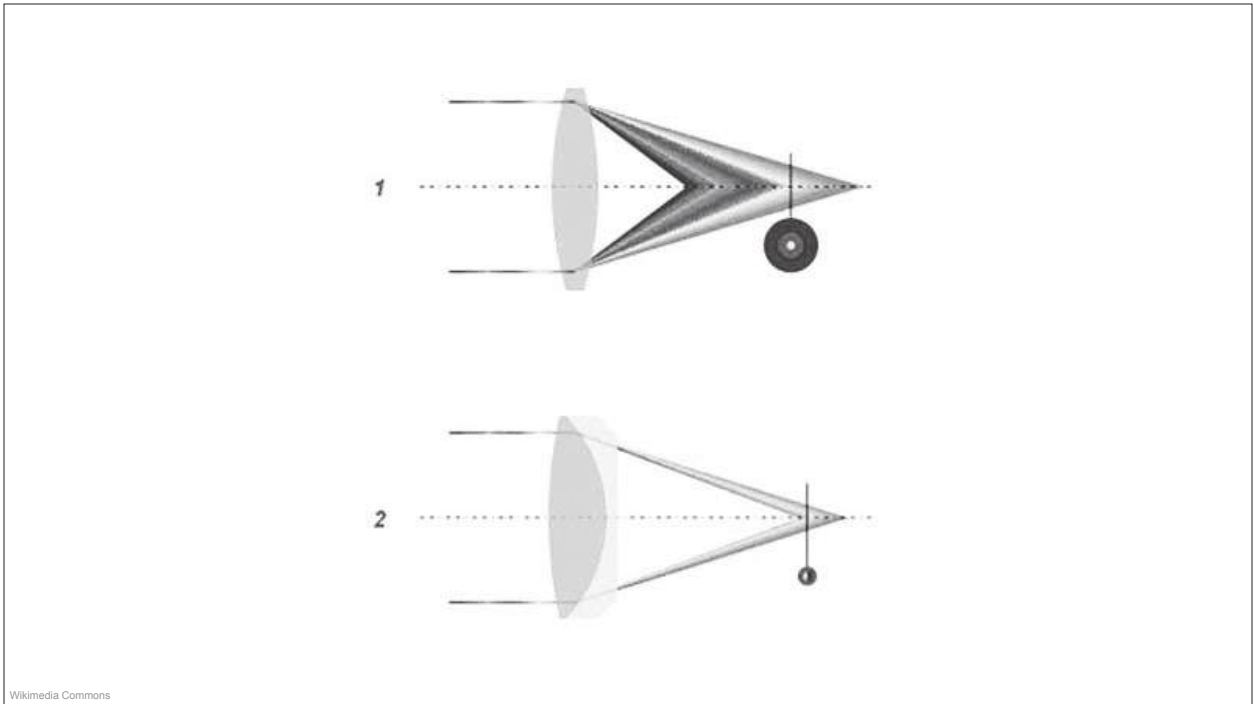
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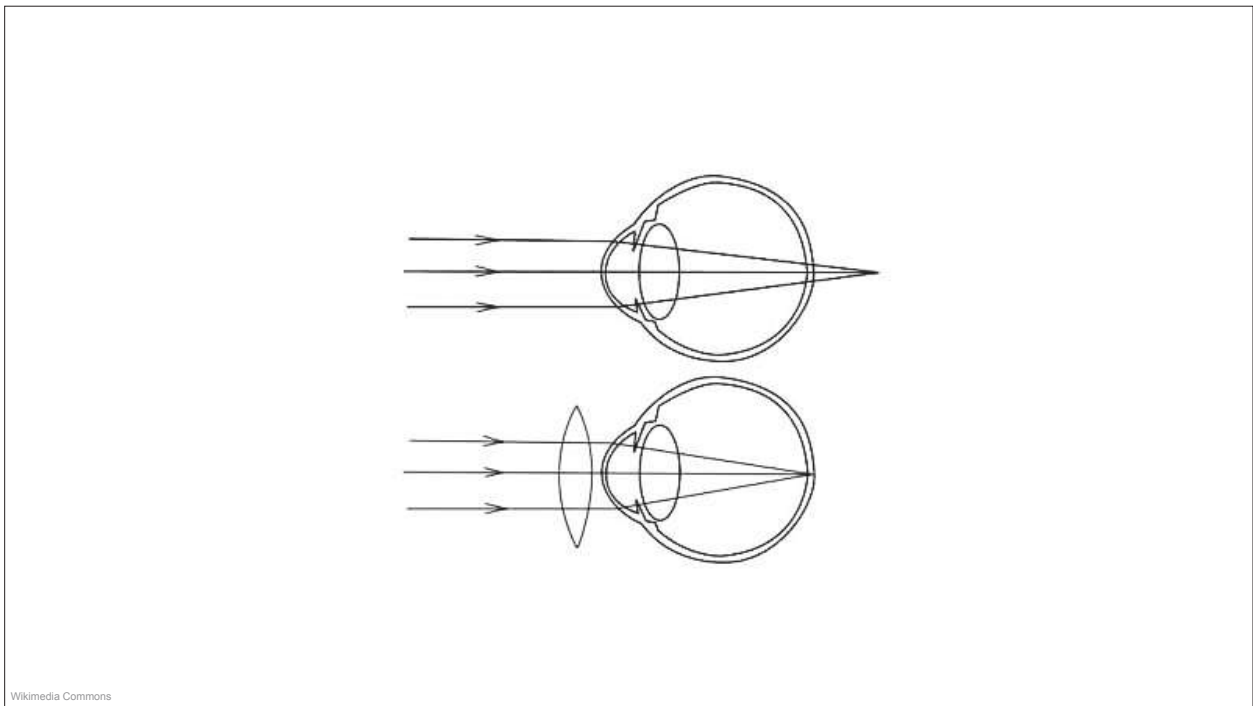
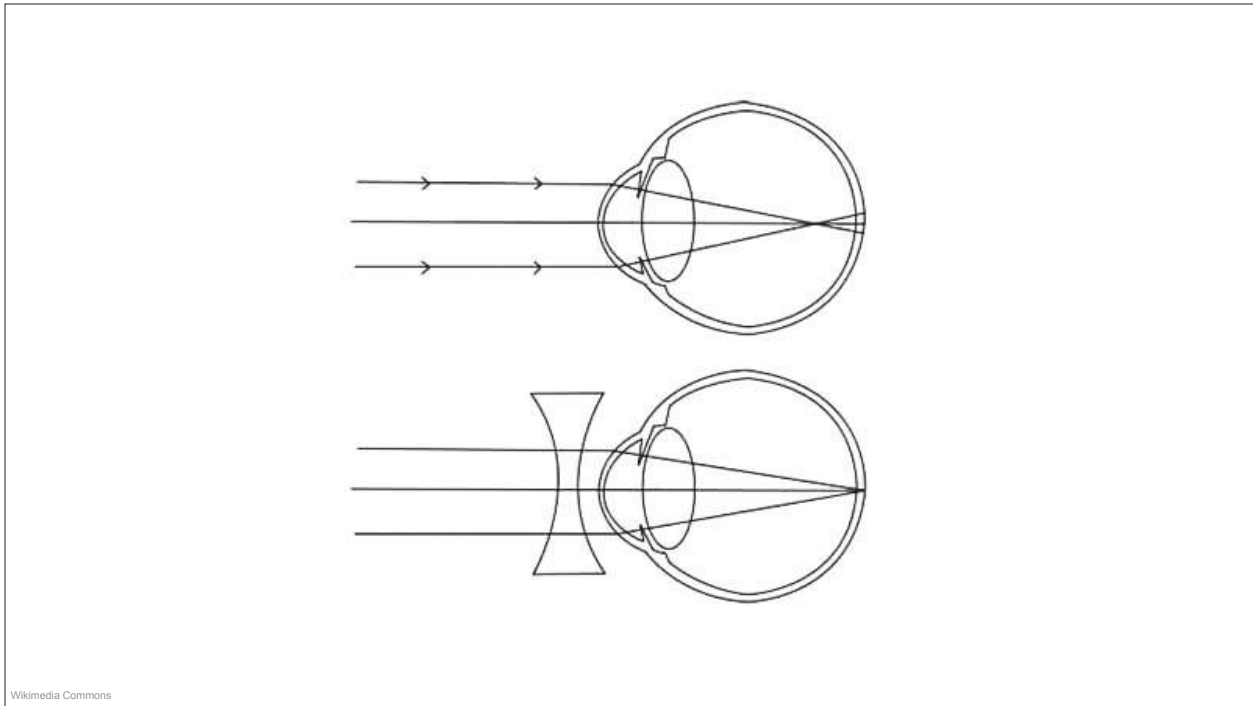
The first prototype of a new camera design can't produce a focused image of an object near the camera. Which of the following might improve the focusing on near objects?



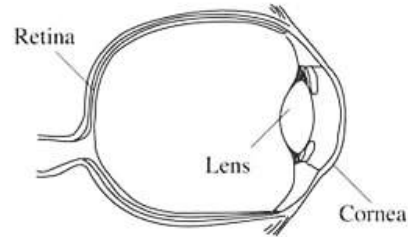
- decrease the maximum distance between lens and film
- substitute a lens with increased index of refraction material
- increase the radii of curvature of the two lens surfaces
- decrease the aperture

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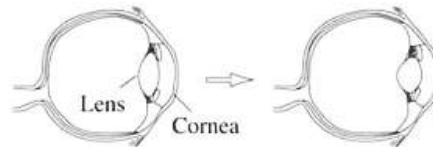
A common vision defect results if the eyeball is too long in relation to lens and corneal structure. Which of the following describes the underlying optical causes of poor vision in such cases?



- An inverted (upside-down) image forms on the retina.
- Distant objects are focused on the retina, but near objects are focused behind it.
- The images of far objects focus in front of the retina.
- The images of near objects focus in front of the retina.

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Although most of the diffraction of light entering the eye happens at the air-cornea boundary, adjustments of focal length to distance are made by changes in lens shape, a process called accommodation.

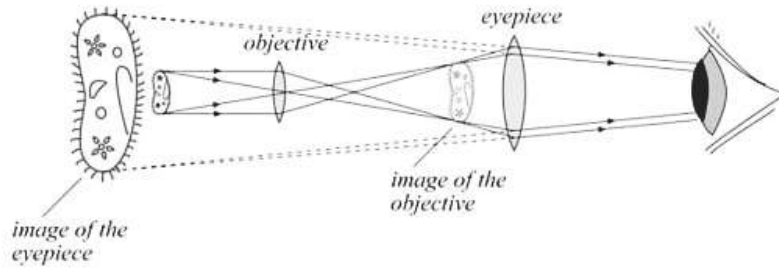


Which of the following happens when the lens becomes less elastic with age and less able to assume a rounded shape?

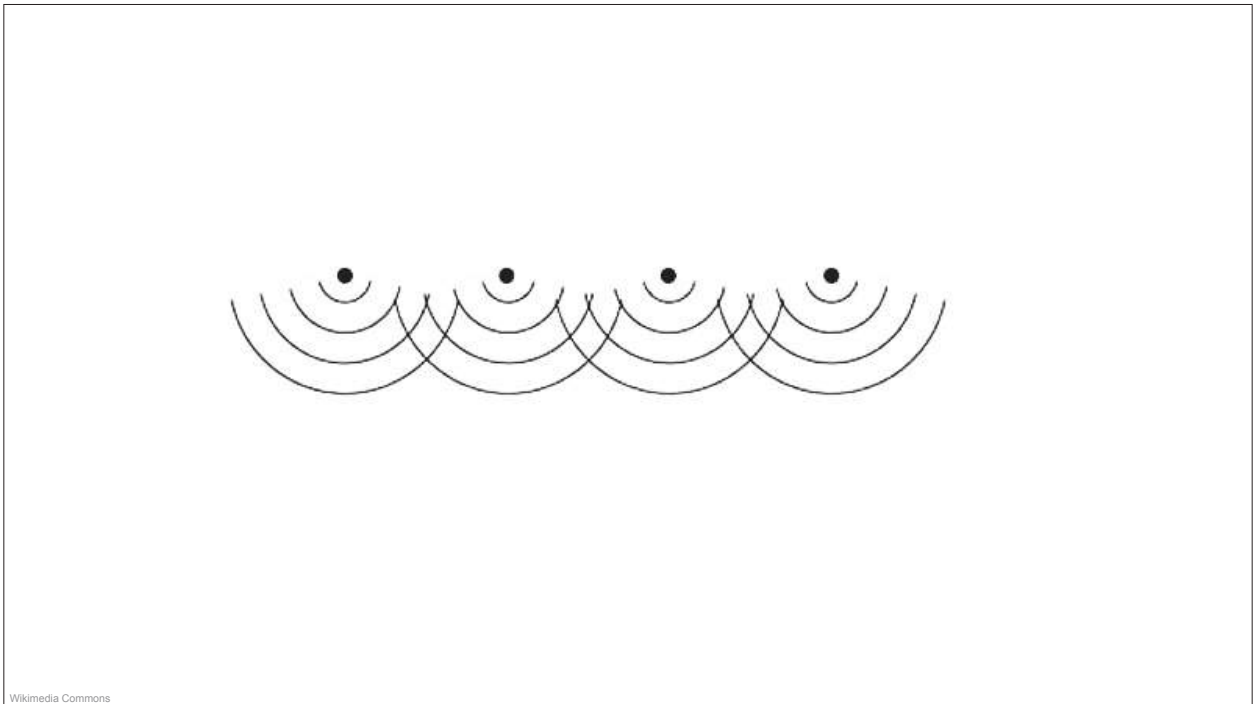
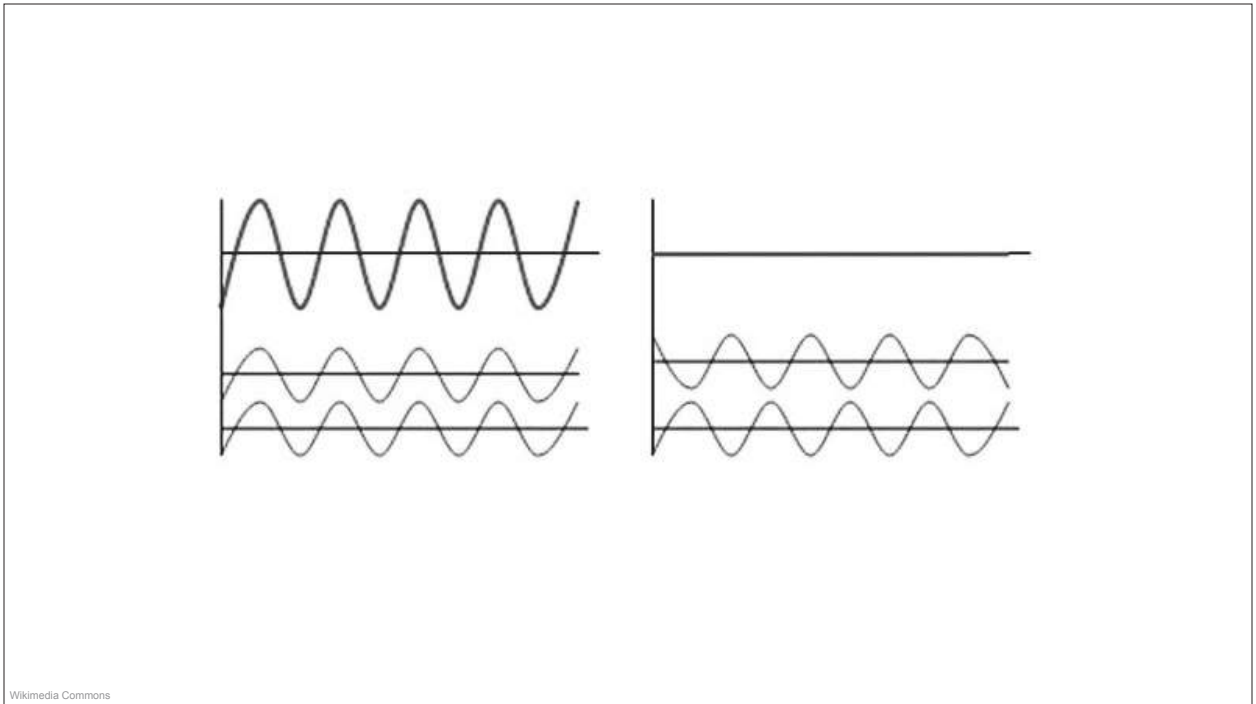
- The images of near objects focus on the retina.
- The images of near objects focus in front of the retina.
- The images of distant objects focus in front of the retina.
- The value of the near point increases.

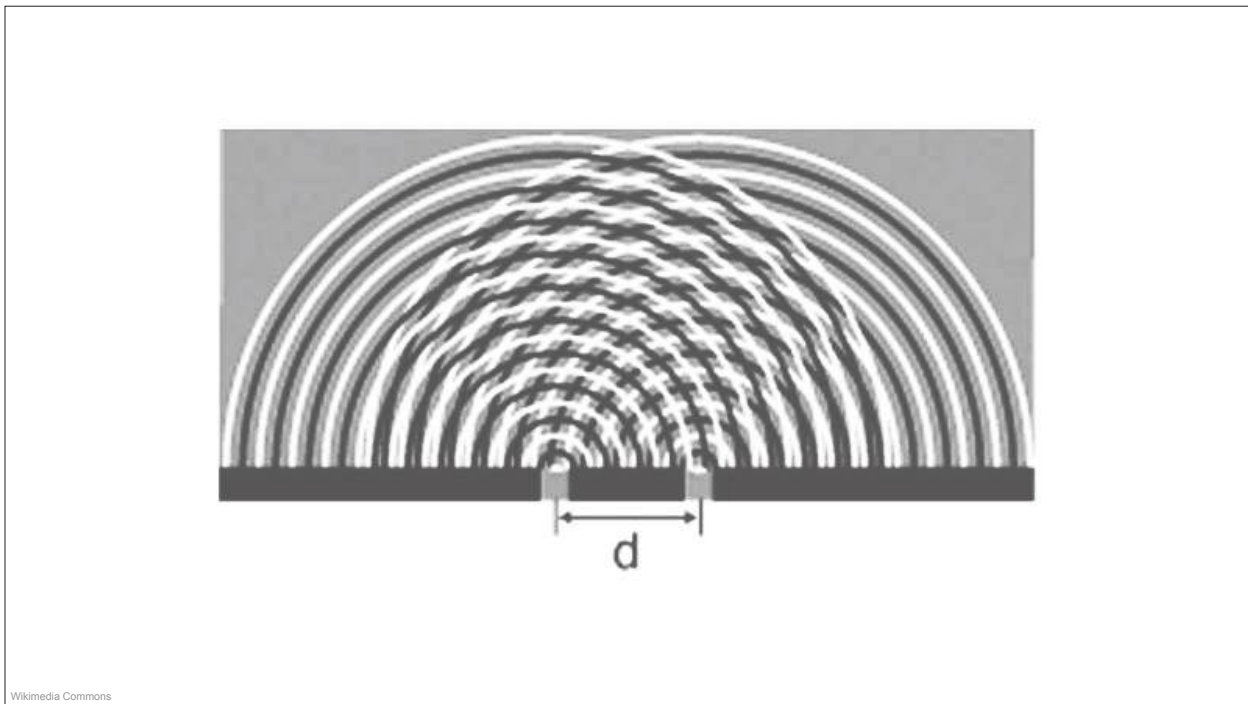
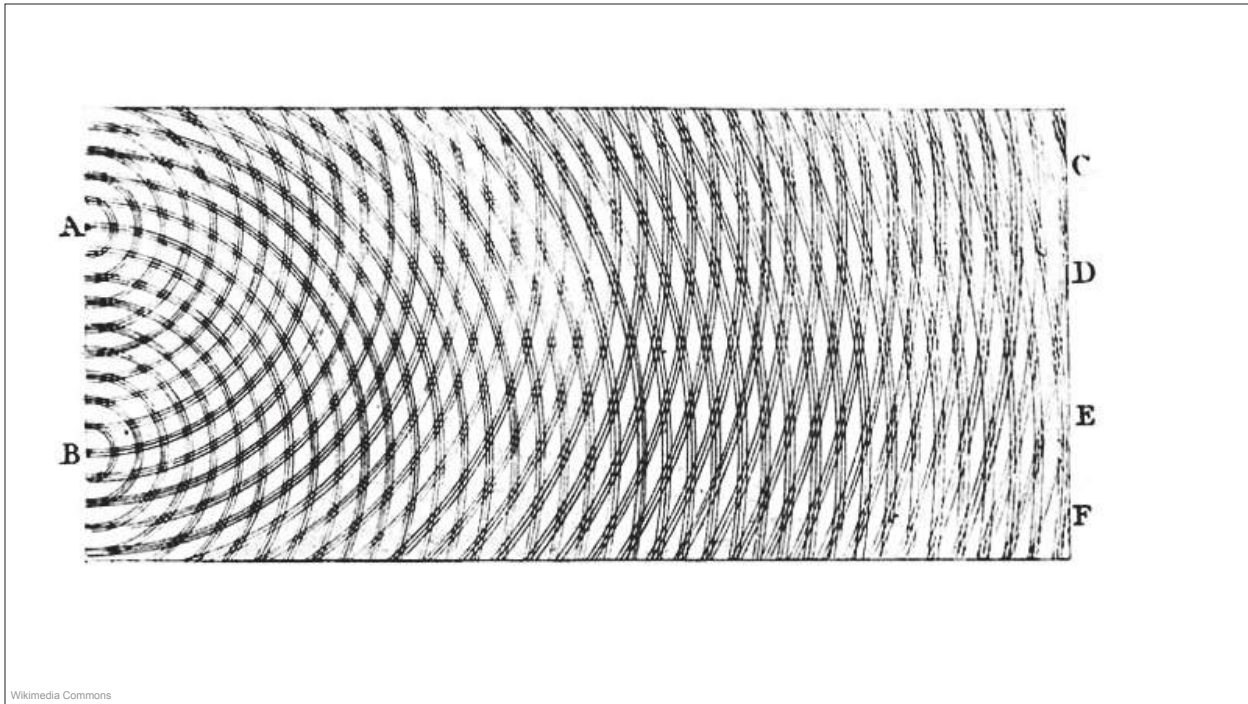
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Compound Microscope

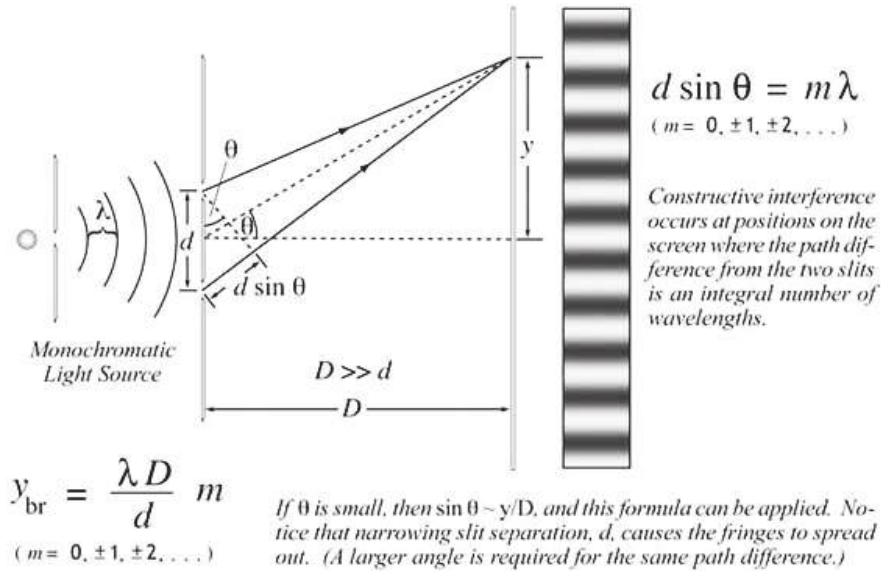


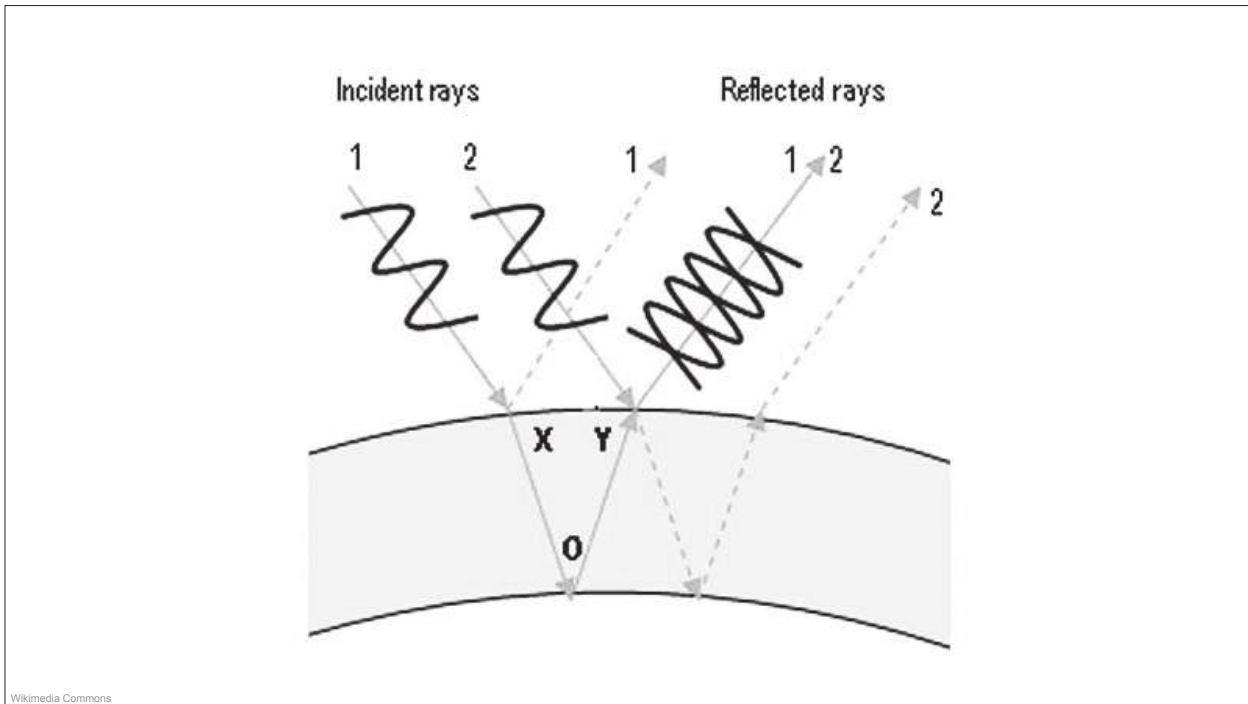
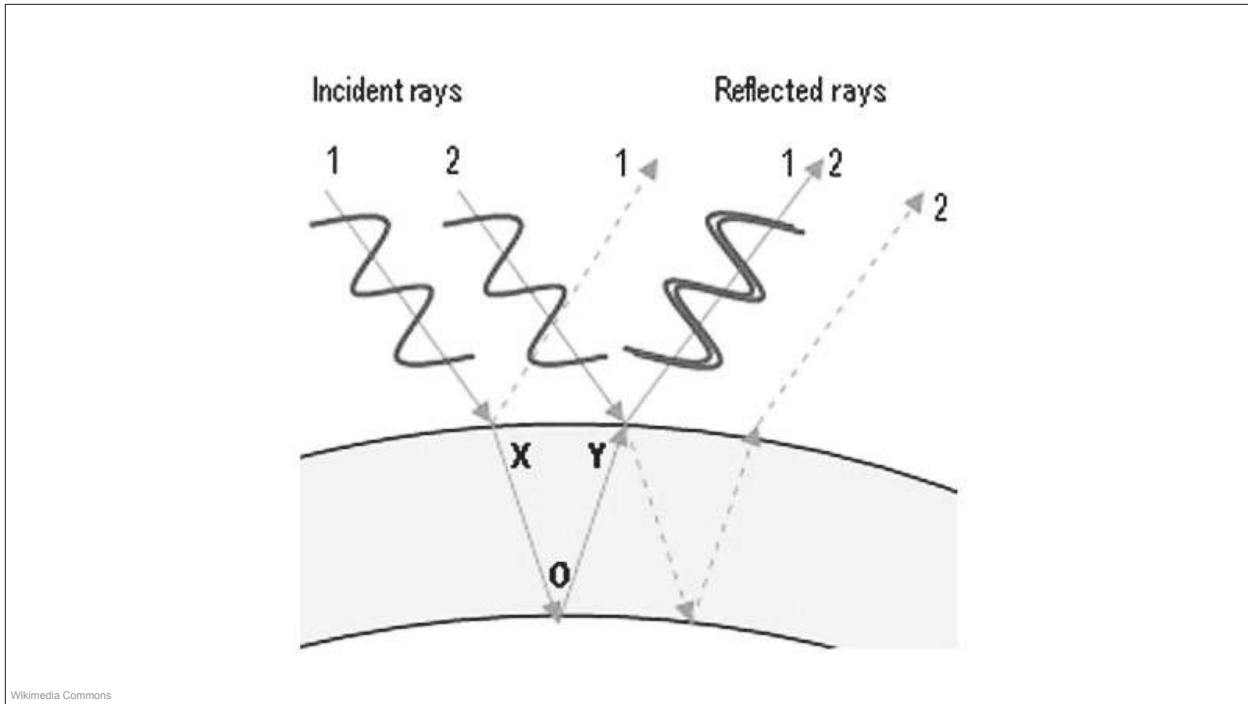
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Young's Double Slit Interference





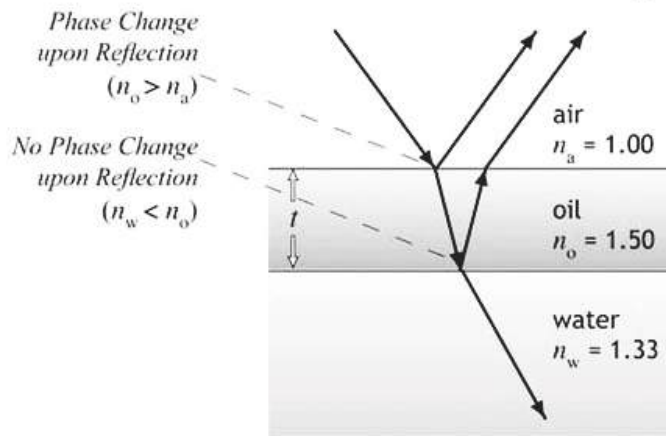
Thin Film Interference

Condition of Constructive Interference
(with one reflection having a phase change)

$$2t = \left(m + \frac{1}{2}\right) \lambda_n$$

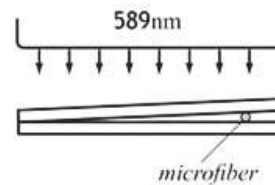
($m = 0, 1, 2, \dots$)

t = thin film thickness
 λ_n = wavelength of light within film medium



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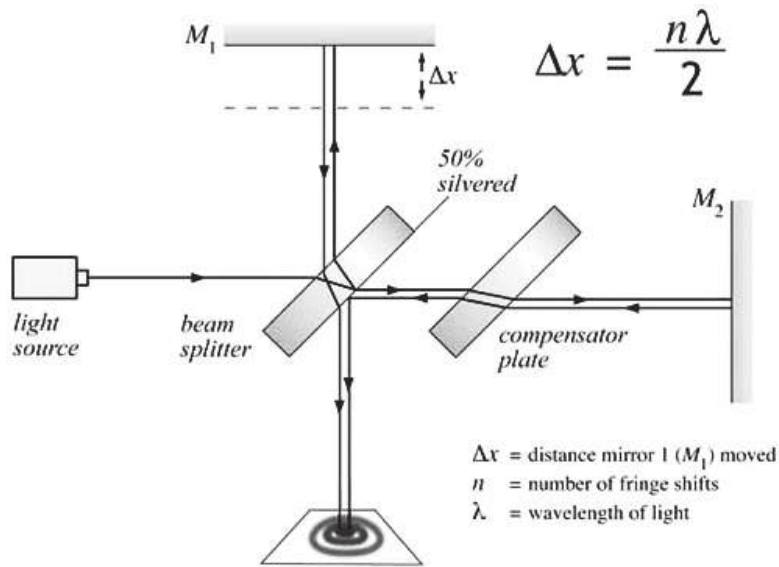
An engineer confirmed the thickness of a synthetic microfiber to be approximately 3 microns by placing the filament between two glass slides and illuminating it with a sodium light ($\lambda = 589\text{nm}$). Which view of the two slides from above shows the pattern of light and dark fringes observed?



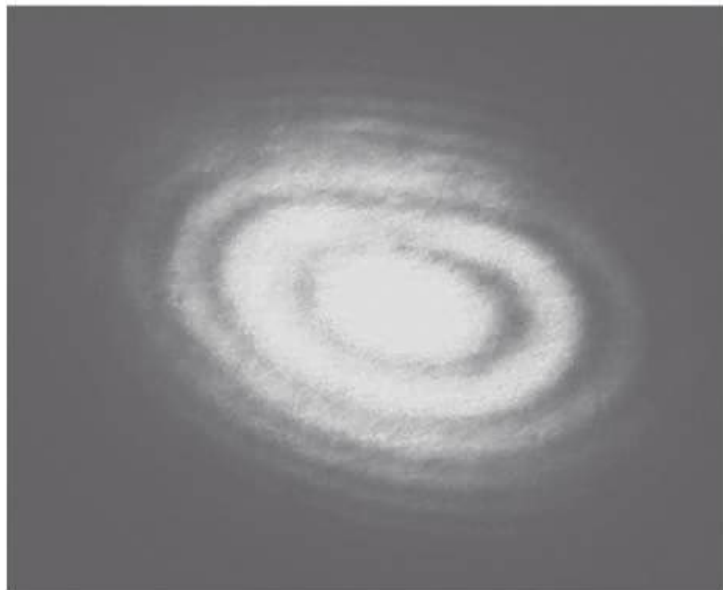
- a.
- b.
- c.
- d.

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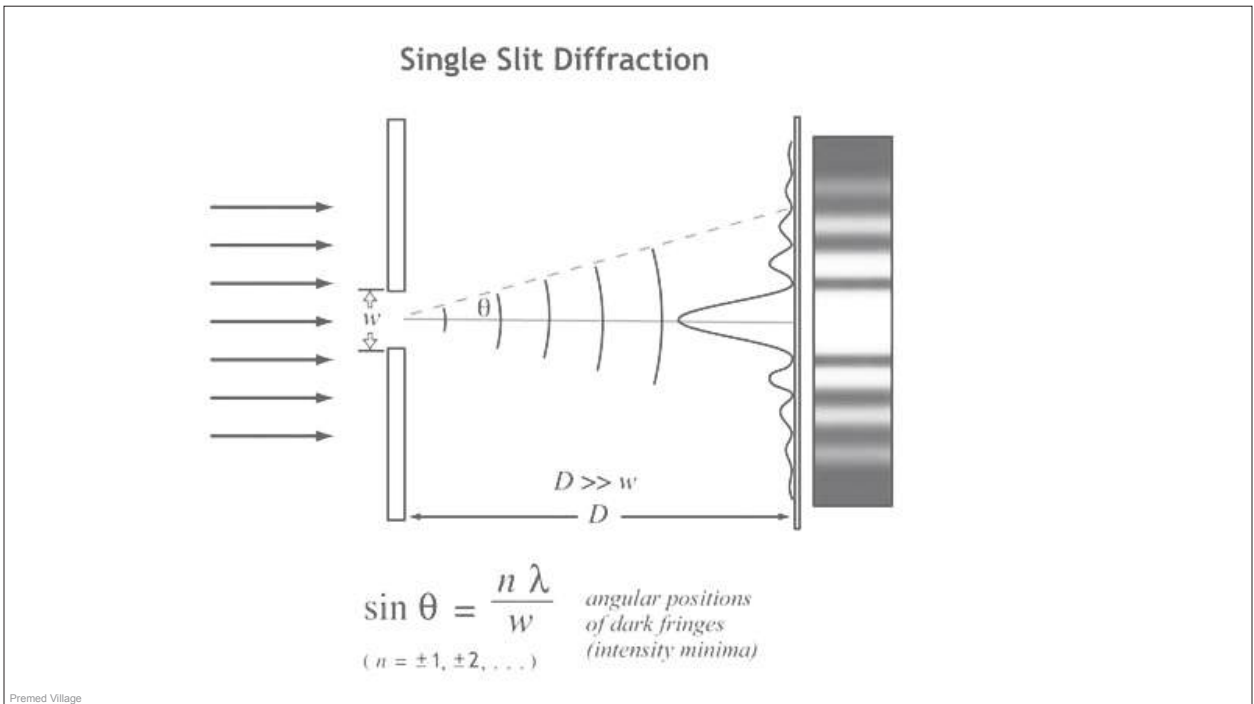
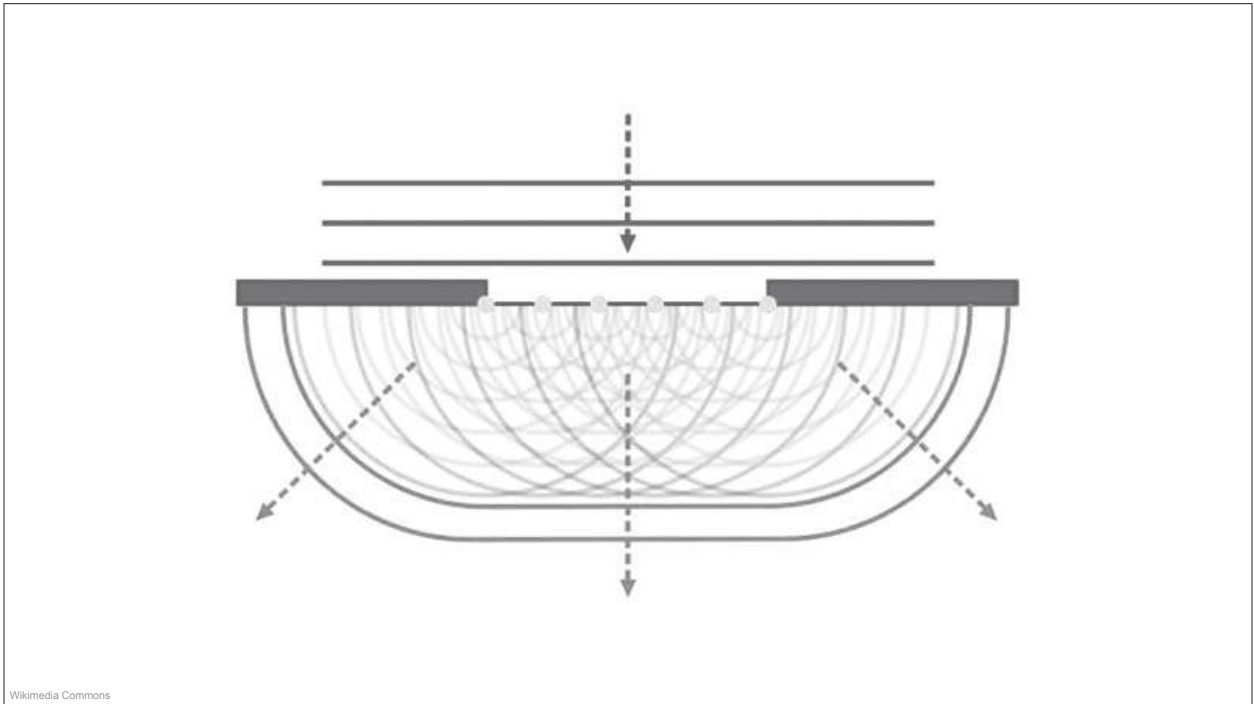
The Michelson Interferometer



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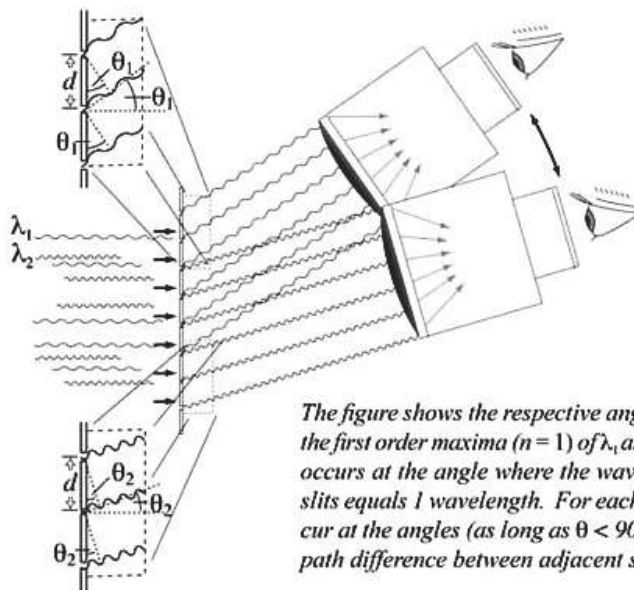
Monochromatic light is incident on a screen which is provided with a narrow 200μ wide slit. The light emerging from this slit casts the visible pattern seen at right onto a second screen 1.5m beyond the first slit. The width of the central bright fringe is 10mm . Which of the following actions would *increase* the width of this central fringe?



- Decreasing the wavelength of the light
- Narrowing the slit to 100μ in width
- Moving the second screen to 1.0m distance from the first screen
- Employing an incandescent light source

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The Diffraction Grating Spectrometer



Condition for Maxima for a Particular Wavelength:

$$d \sin \theta = m \lambda$$

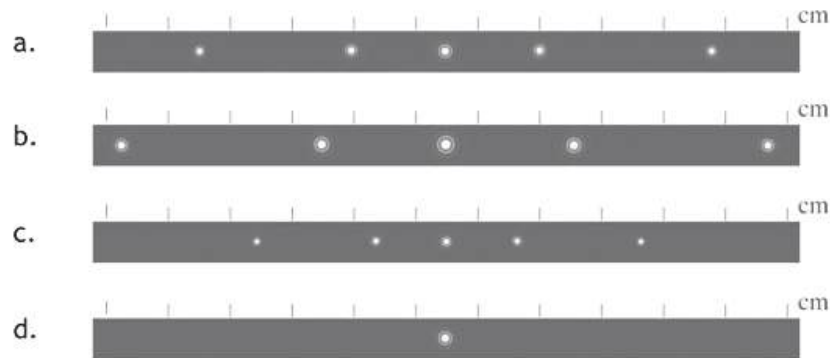
$(m = 0, 1, 2, 3, \dots)$

The figure shows the respective angles of deviation (θ_1 and θ_2) for the first order maxima ($n = 1$) of λ_1 and λ_2 . The first order maximum occurs at the angle where the wave path difference for adjacent slits equals 1 wavelength. For each wavelength, maxima also occur at the angles (as long as $\theta < 90^\circ$) for $n = 2, 3$ etc. wavelengths path difference between adjacent slits.

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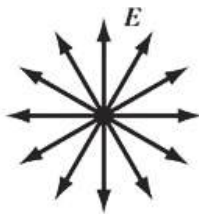


The image above shows the zeroth, first and second spectral orders cast on a screen by the beam of a green argon gas-ion laser ($\lambda = 514.5 \text{ nm}$) incident on a diffraction grating. Which pattern results after the entire assembly of laser, grating and screen are immersed in water?



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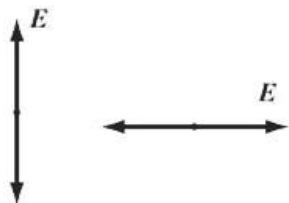
Polarization of Light



Direction of propagation is perpendicular to the page.

Unpolarized Light

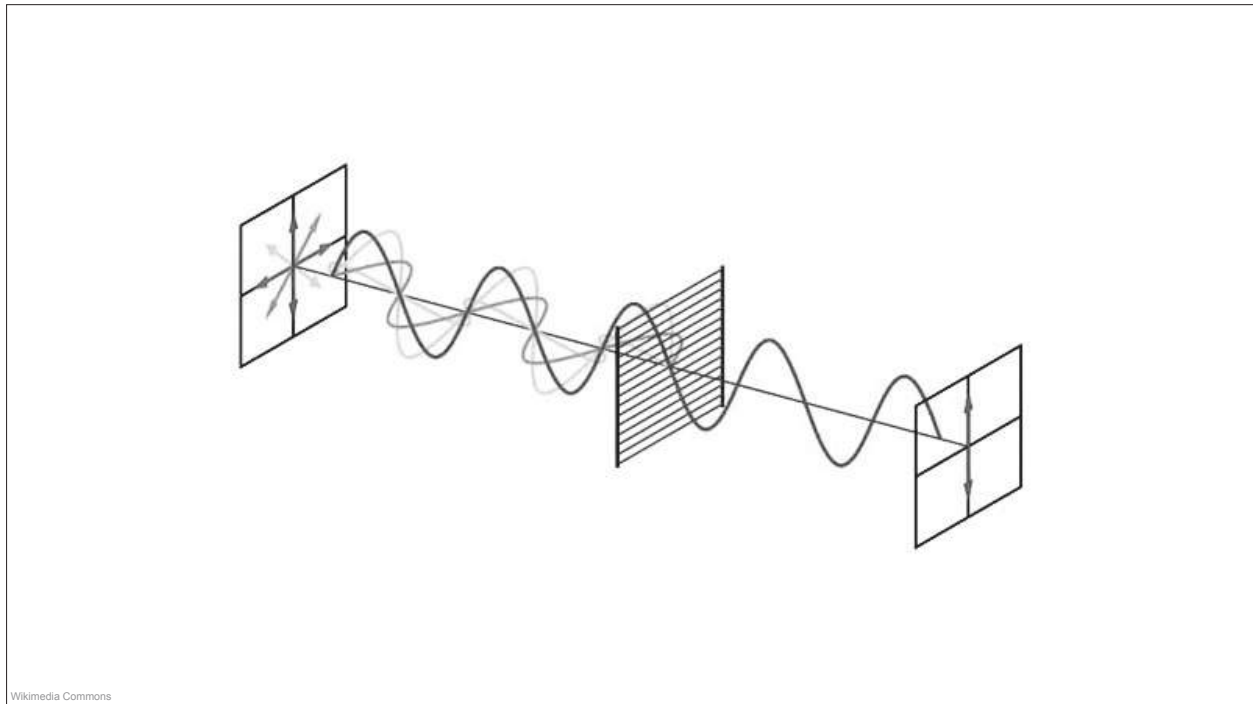
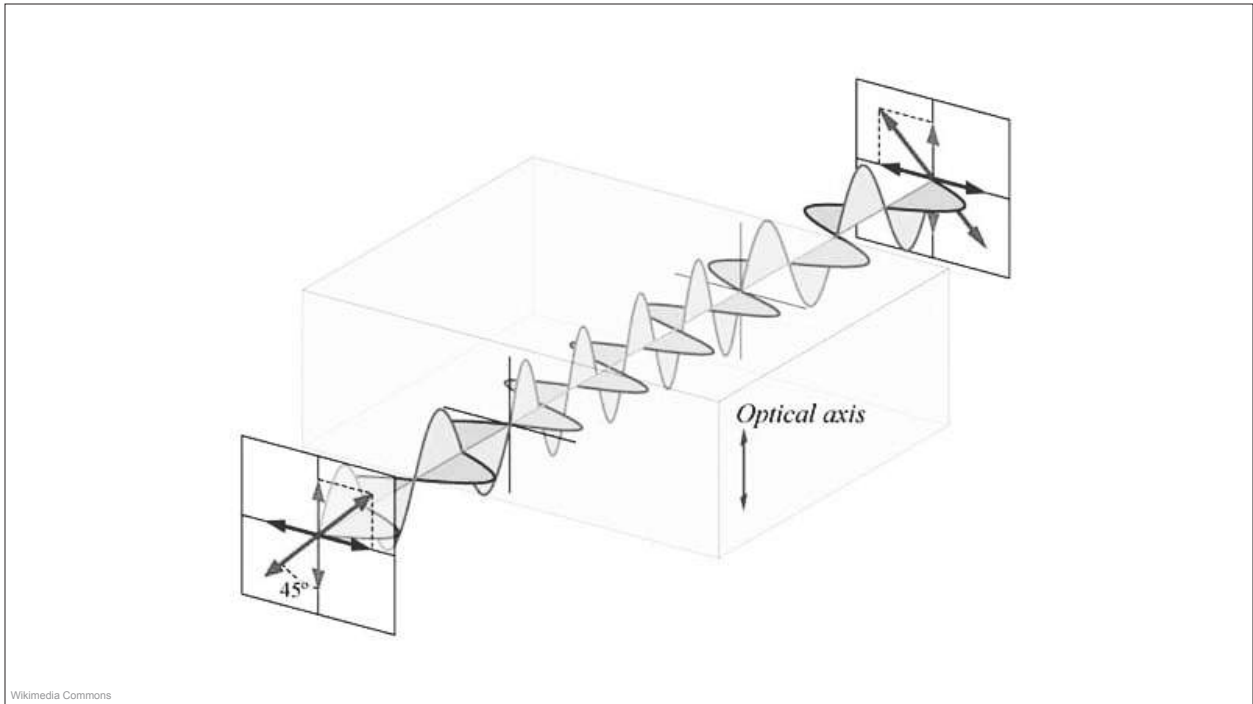
With unpolarized light, all directions of electric field vibrations perpendicular to the direction of wave propagation are possible. Most light sources produce unpolarized light.



Polarized Light

With plane polarized light, the electric field vibrates in a single plane perpendicular to wave propagation. Different means exist to produce polarized light from an unpolarized source including reflection, selective absorption, double refraction and scattering.

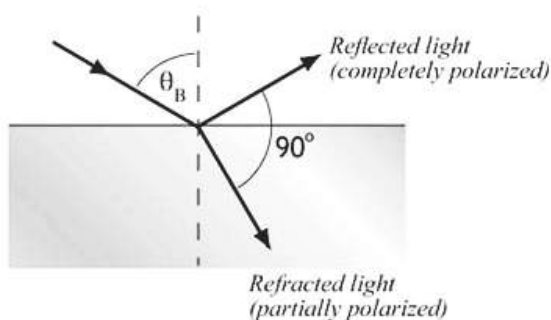
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- *Reflection* polarizes light. For intermediate angles of incidence, between 0° and 90° , at least some of the reflected light is polarized because light in which the electric field vibrations parallel to the surface are more strongly reflected.
- *Selective absorption* polarize light. A *polaroid film* only allows the components of the electric field vibrations to pass that are parallel to its transmission axis.
- *Double refraction* produces polarized light within *birefringent materials*. In these substances, such as calcite and quartz, the index of refraction is not the same in all directions. Double refraction causes an unpolarized light beam to be split into an *ordinary (O) ray* and an *extraordinary (E) ray*, which are polarized in mutually perpendicular directions.
- *Scattering* produces polarized light. For example, the vibrations of air molecules in the horizontal plane reaches the earth while the vibrations in the vertical plane travel into space.

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Brewster's Angle

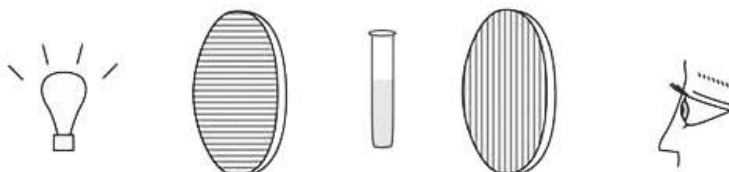


$$\tan \theta_B = \frac{n_2}{n_1} \quad (\text{if } n_1 \sim 1) \quad \tan \theta_B = n_2$$

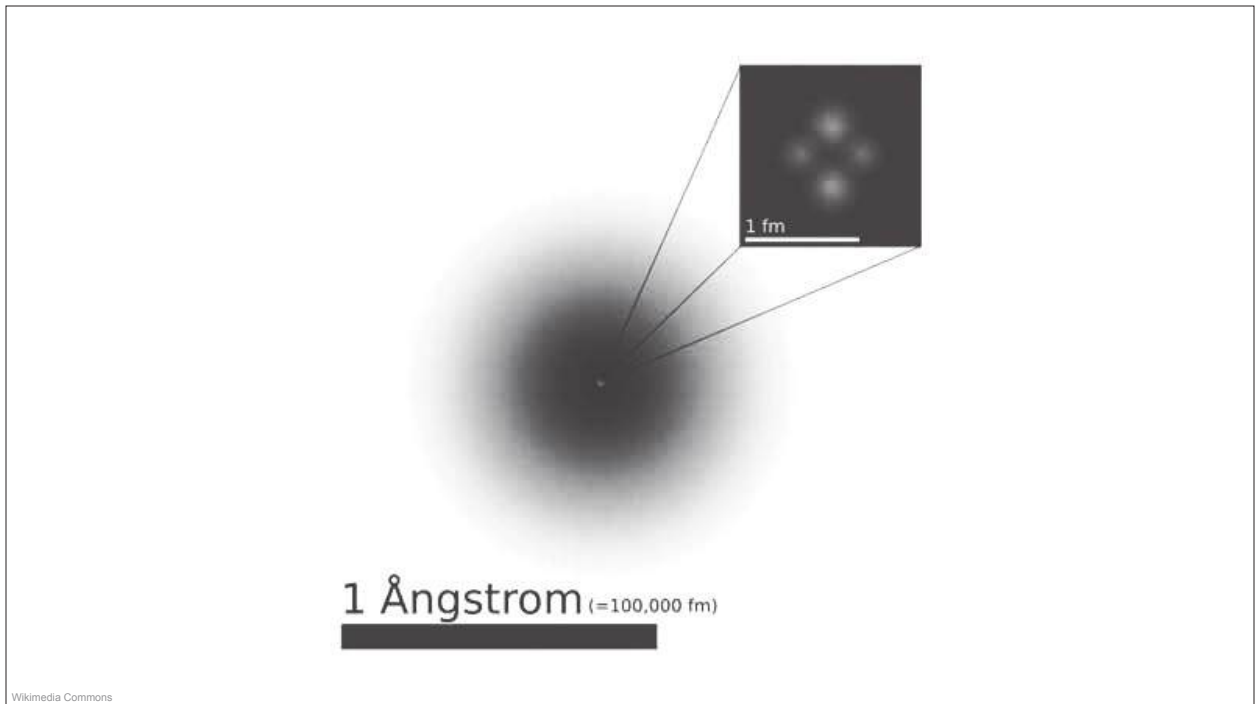
Brewster's angle, at which the reflected light is completely polarized, depends on the indices of refraction of the two media. (Note that the index of refraction of air is very close to 1, so Brewster's Law can often be simplified to $\tan \theta_B = n_2$).

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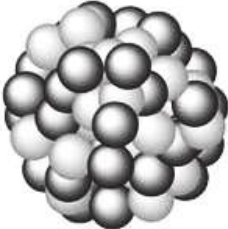
Optically active substances possess the ability to rotate the plane of polarization of plane polarized light. To determine whether a transparent substance was optically active, a biochemist placed it between two crossed polarizers, illuminated the assembly as below, and viewed through the 2nd polarizer. Which of the following indicated optical activity?



- a. Angular rotation of the image of the substance
- b. Greater brightness where light was passing through the substance
- c. A double image of the substance
- d. The substance appeared opaque through the 2nd polarizer



The Nucleus



$\begin{matrix} A \\ Z \end{matrix} X$

chemical symbol, X , for the element


atomic number, Z , equals the number of protons in the nucleus.

mass number, A , equals the number of nucleons (protons plus neutrons) in the nucleus.


neutron number, $N = A - Z$

Isotopes of an element have the same number of protons but a different number of neutrons in the nucleus, in other words, the same atomic number, Z , but different neutron number, N , and, therefore, different mass number, A .


Isotopes of Hydrogen

$\begin{matrix} 1 \\ 1 \end{matrix} \text{H}$


normal hydrogen nucleus

$\begin{matrix} 2 \\ 1 \end{matrix} \text{H}$


deuterium nucleus

$\begin{matrix} 3 \\ 1 \end{matrix} \text{H}$


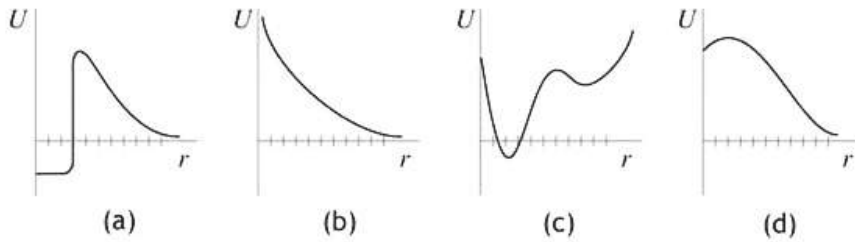
tritium nucleus

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The femtometer (fm) is a convenient unit of length for nuclear physics because its value is on the order of nuclear radii:

$$1 \text{ fm} = 10^{-15} \text{ m}$$

Through observations of scattering experiments, nuclear physicists have developed a potential energy curve for the interaction of two protons. For a system of two protons, which of the the following is the best representation of potential energy versus separation in femtometers?



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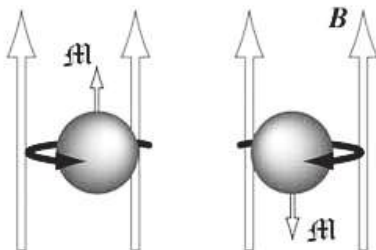
Nuclear Spin States

Nuclear spin quantum number, I .

Number of allowed spin states is $I + 1$.

Spin states: $-I, (-I + 1), \dots, (-I + 1), I$

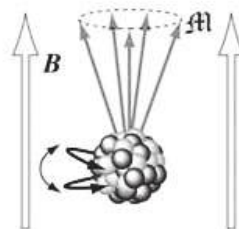
Element	${}^1\text{H}$	${}^2\text{H}$	${}^{12}\text{C}$	${}^{13}\text{C}$
Spin Quant #, I	$\frac{1}{2}$	1	0	$\frac{1}{2}$
# of states	2	3	0	2



An applied magnetic field splits the two spin states of a proton into states of unequal energy. Energy is lower for the state in which the spin magnetic moment is aligned with the external field.

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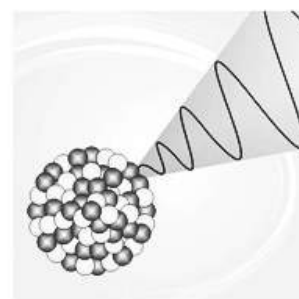
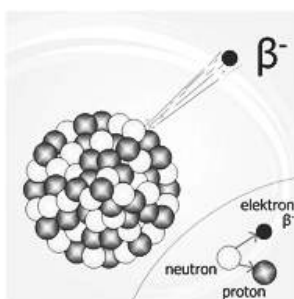
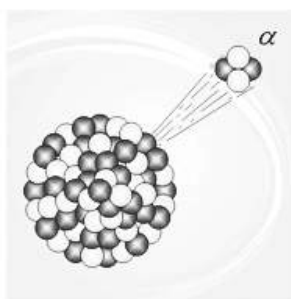
The greater the *gyromagnetic ratio* of a nucleus with a net nuclear magnetic moment placed within an external magnetic field, B , the greater will be its precessional frequency. Due to differences in magnetic moment and angular momentum, the gyromagnetic ratio of ${}^1\text{H}$ is 42.6, and the gyromagnetic ratio of ${}^{13}\text{C}$ is 10.7. Which of the following statements is true regarding the comparison of the behavior of these nuclei in nuclear magnetic resonance?



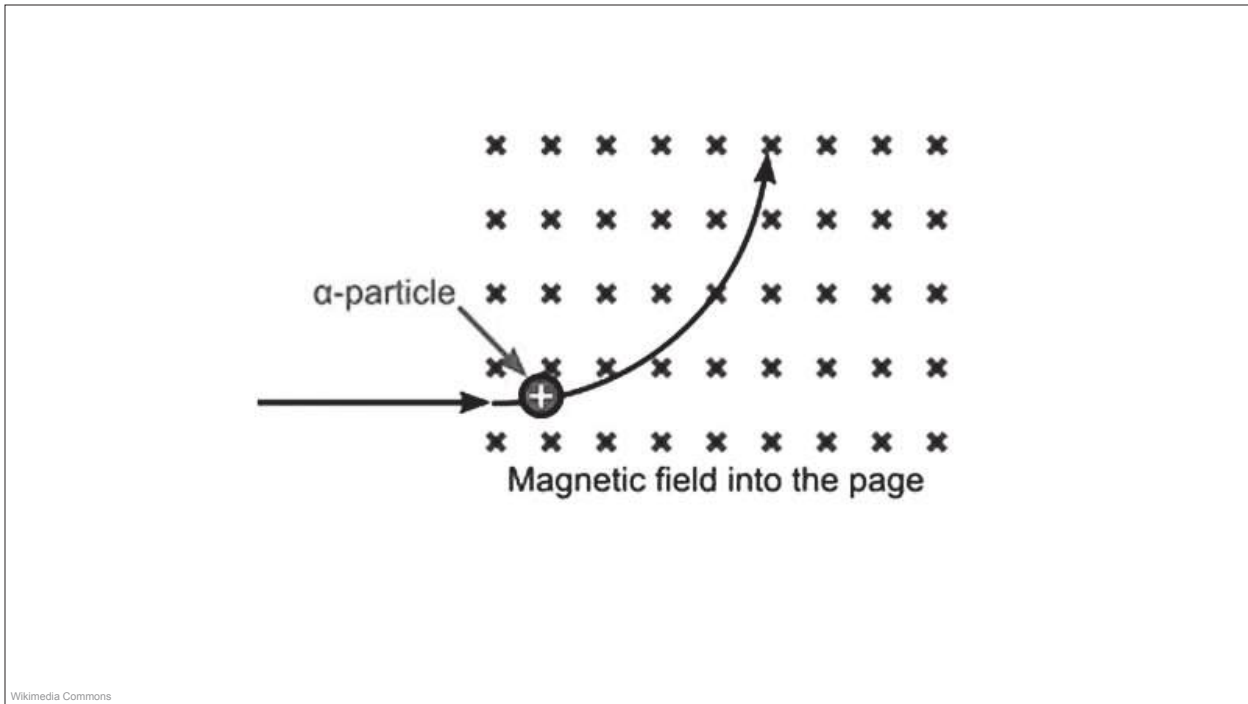
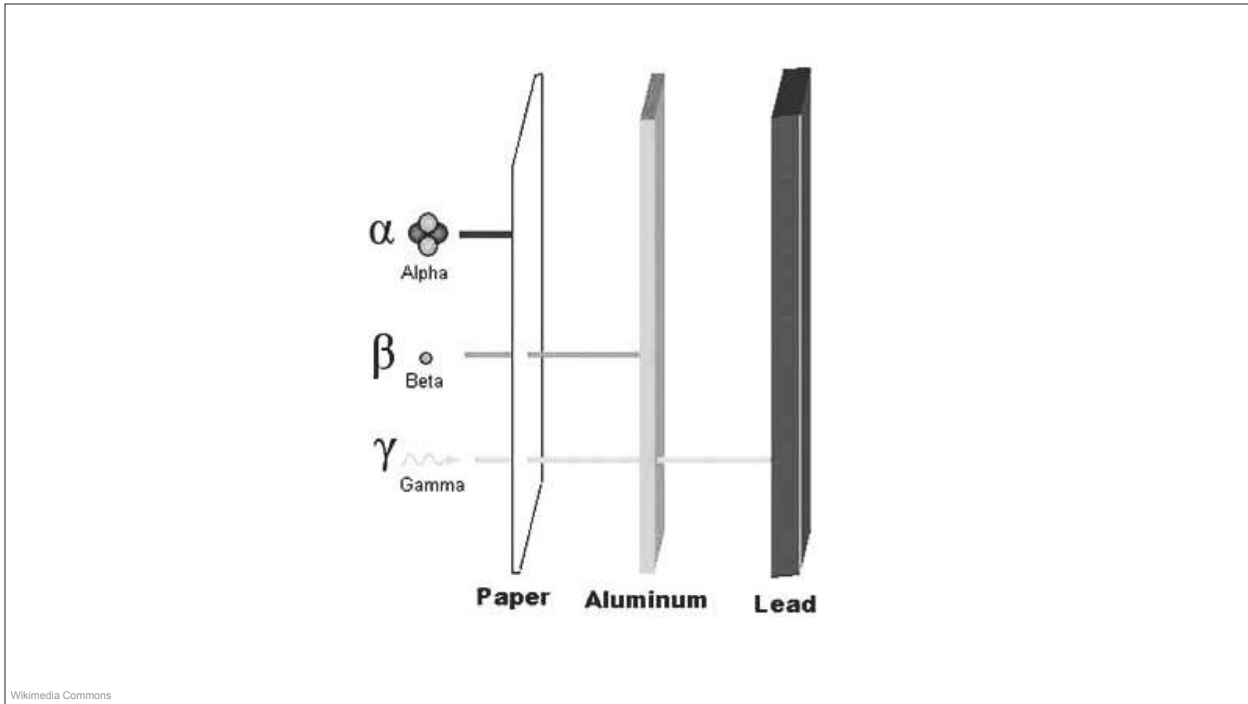
Precession represents motion of the axis of a spinning body, such as the wobble of a spinning top.

- Within a given external magnetic field, the resonant frequency corresponding to spin flip is higher for ${}^1\text{H}$ than for ${}^{13}\text{C}$.
- The precessional frequency is always greater for ${}^{13}\text{C}$ than for ${}^1\text{H}$.
- The angular momentum of ${}^1\text{H}$ is greater than ${}^{13}\text{C}$.
- Both nuclei absorb radio waves at the frequency that their magnetic moments flip in orientation with respect to the applied field.

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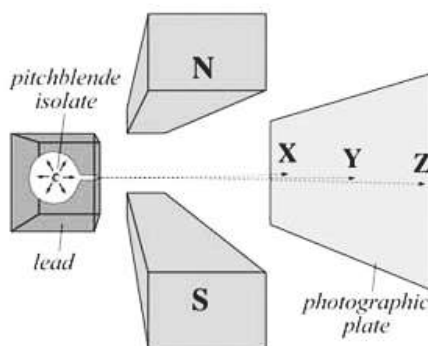


Radioactive Decay

<p>Alpha Decay</p> ${}^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$	<p>A nuclei undergoes alpha decay by emitting an α particle, which is identical to a helium nucleus (${}^4_2\text{He}^{2+}$, two protons and two neutrons), Z decreases by 2 and A decreases by 4.</p>
<p>Beta Decay</p> ${}^{14}_6\text{C} \longrightarrow {}^{14}_7\text{N} + {}^0_{-1}\beta^- + \bar{\nu}$	<p>In β^- decay, a β^- particle, which is a high speed electron, and an antineutrino, $\bar{\nu}$, are emitted. A neutron changes into a proton in the nucleus (Z increases by 1 with A unchanged).</p>
${}^{13}_7\text{N} \longrightarrow {}^{13}_6\text{C} + {}^0_{+1}\beta^+ + \nu$	<p>In β^+ decay, a β^+ particle, (a positron, the anti-particle of the electron) and a neutrino, ν, are emitted. A proton changes into a neutron in the nucleus (Z decreases by 1 with A unchanged).</p>
<p>Electron Capture</p> ${}^7_4\text{Be} + {}^0_{-1}\text{e} \longrightarrow {}^7_3\text{Li} + \nu$	<p>In electron capture, a nucleus captures one of the atom's own electrons, changing a proton to a neutron (Z decreases by 1 with A unchanged), and a neutrino, ν, is emitted.</p>
<p>Gamma Decay</p> ${}^{125}_{53}\text{I}^* \longrightarrow {}^{125}_{53}\text{I} + \gamma$	<p>Gamma decay occurs when a nucleus in an excited energy state (very often as the result of a prior decay event) emits a very high energy photon, a gamma ray, as it transitions to a lower energy state.</p>

Premed Village

An isolate of the ore, pitchblende, is significantly radioactive. When the radiation is deflected by the magnetic field at right and detected photographically, one component of the radiation, X, is found to bend into the plane of the figure, and another component, Z, bends out of the plane. The third component, Y, is not affected by the magnetic field. Which of the following describes the components?

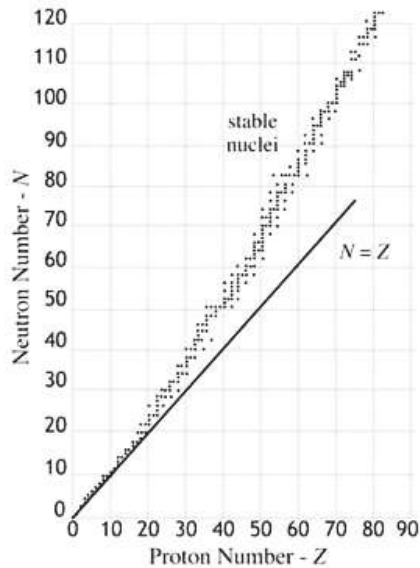


- X is composed of β^- rays; Y is γ rays; and Z is α rays
- X is composed of α rays; Y is anti-neutrinos; and Z is β^- rays
- X is composed of β^+ rays; Y is neutrinos; and Z is β^- rays
- X is composed of α rays; Y is γ rays; and Z is β^- rays

Premed Village

Stable nuclides are represented by a narrow band of proton-to-neutron ratios on the graph of neutron number vs. proton number. Nuclei falling outside this region are unstable and subject to radioactive decay. Unstable nuclei above the band are said to be neutron rich, and those below it are neutron poor. What type of decay would be expected for the isotope of phosphorus, $^{33}_{15}\text{P}$?

- a. α decay
- b. β^+ decay
- c. β^- decay
- d. electron capture



Premed Village

Activity and Half-Life

$$A = \frac{\Delta N}{\Delta t} = -\lambda N$$

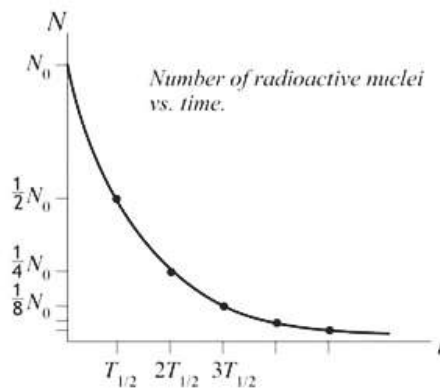
A = activity (disintegrations per second)
 N = number of radioactive nuclei
 t = time
 λ = decay constant

$$N = N_0 e^{-\lambda t}$$

N = number of radioactive nuclei
 N_0 = number of nuclei initially present
 λ = decay constant
 t = time

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

$T_{1/2}$ = half-life
 λ = decay constant

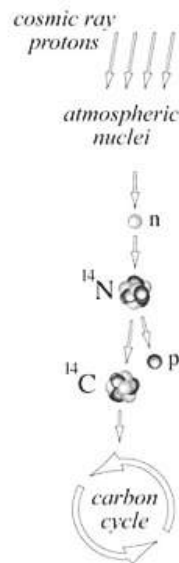


The half-life is the time required for half of an amount of a given radionuclide to undergo decay.

Premed Village

In the upper atmosphere, cosmic ray protons collide with nuclei causing reactions that produce neutrons. These neutrons in turn lead to the transformation of ^{14}N into ^{14}C . This is a continuous process which maintains a ratio of ^{14}C to ^{12}C in the atmosphere that is fairly constant through millenia. After an organism dies, it ceases exchanging carbon with the atmosphere, and the ratio ^{14}C to ^{12}C decreases through the beta decay of ^{14}C which has a half-life of 5730 years.

Measuring the level of radioactive decay of ^{14}C in the preserved epidermal tissue of a mummy, it was found to sustain 20% of the activity of living tissue. What is the approximate age of the mummy?



- a. 1400 yrs b. 13,500 yrs c. 25,000 yrs d. 30,000 yrs

Premed Village

Mass / Energy Equivalence in Nuclear Processes

Reaction Energy

$$Q = \Delta m c^2$$

Q = total energy released in a nuclear process
 Δm = mass difference between products and reactants
 c = speed of light (3×10^8 m/s)

Binding Energy

$$E_b = [Zm_p + Nm_n - M_{Nu}] \times c^2$$

$$E_b = [Zm_p + Nm_n - M_{Nu}] \times 931.5 \text{ MeV/u}$$

E_b = nucleus binding energy

Z = atomic number

m_p = free proton mass

N = neutron number

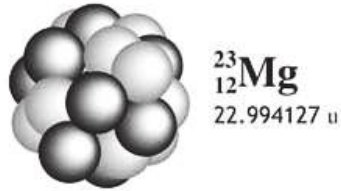
m_{Nu} = free neutron mass

M_{Nu} = atomic mass of combined nucleus

c = speed of light (3×10^8 m/s)

Premed Village

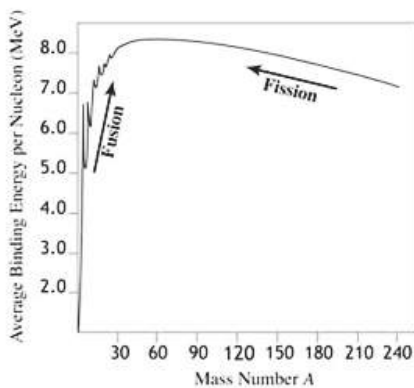
The rest mass of a free neutron is 1.008665, and the rest mass of a free proton is 1.007276 u. Which of these two nuclei is the most stable?



- ${}^{23}_{11}\text{Na}$
- ${}^{23}_{12}\text{Mg}$
- Their stabilities are equal.
- ${}^{23}_{12}\text{Mg}$ is more stable against α decay, while ${}^{23}_{11}\text{Na}$ is more stable against β^- decay.

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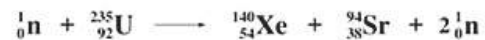
Fusion and Fission



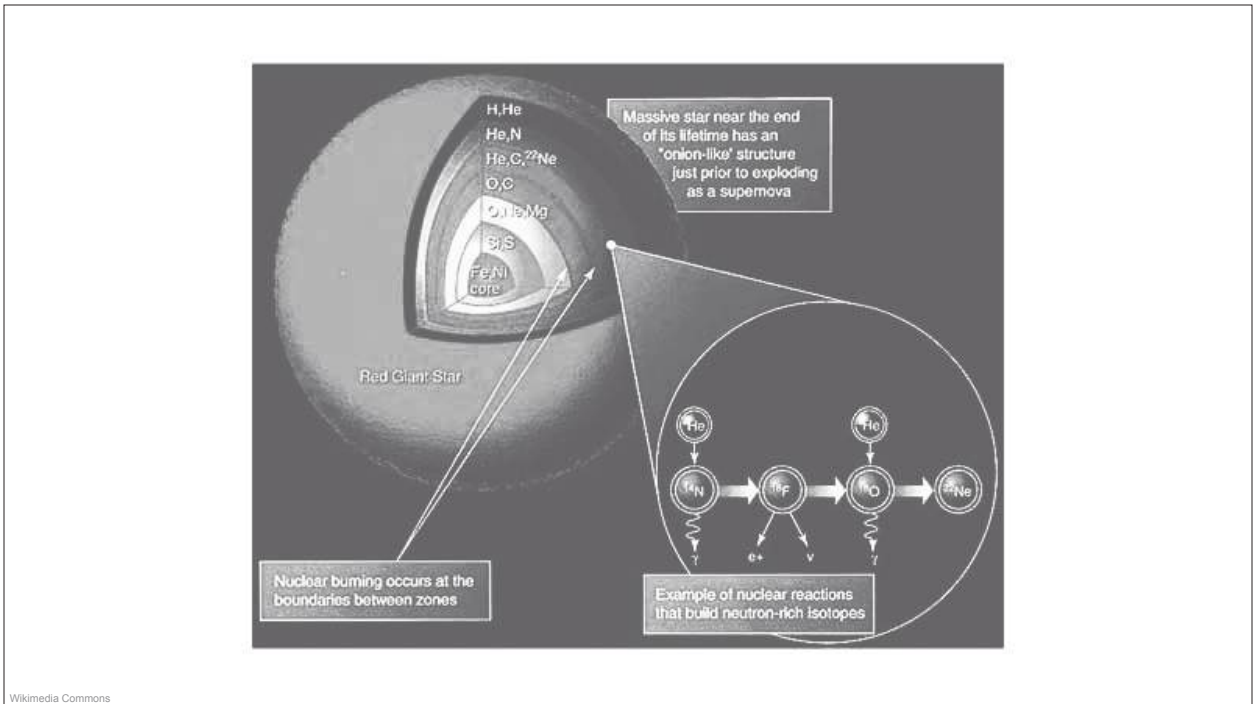
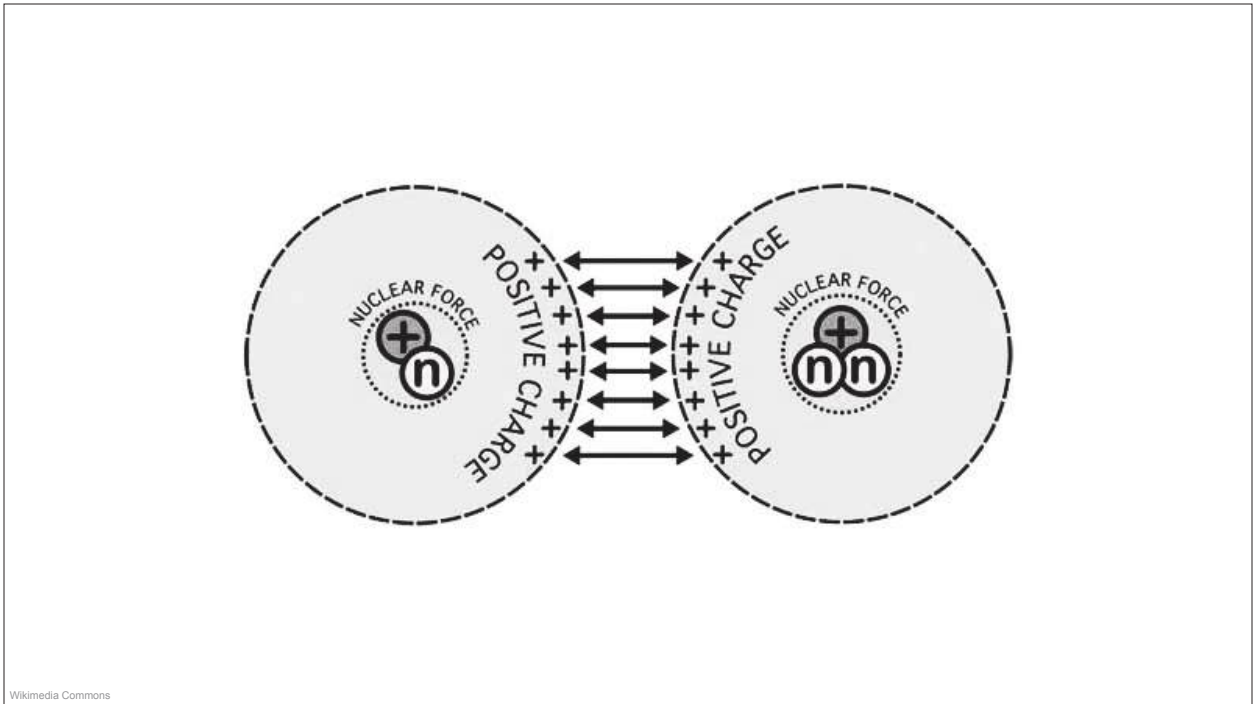
Fusion combines two light nuclei to produce a heavier nuclei. It requires very high concentrations of reactants and high temperature conditions.



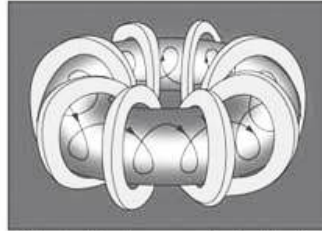
Fission is the splitting of a heavy nucleus into two lighter nuclei. In the reaction below, note that a neutron initiates fission and that more neutrons are produced by fission. Thus a nuclear *chain reaction* is possible if the mass of ${}^{235}_{92}\text{U}$ is sufficiently concentrated (critical mass).



Premed Village



Most nuclear fusion reactions achieved in the laboratory require the reactant atoms to be in the form of a plasma. Plasma is a very high temperature form of matter in which the atoms are completely ionized. Which of the following best describes the required plasma temperature for the sustained fusion of deuterium and tritium?



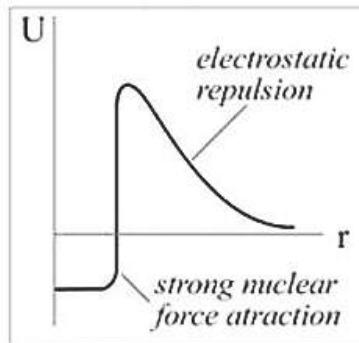
The helical magnetic field of a tokamak fusion reactor traps the high temperature plasma, preventing it from contacting the container walls.



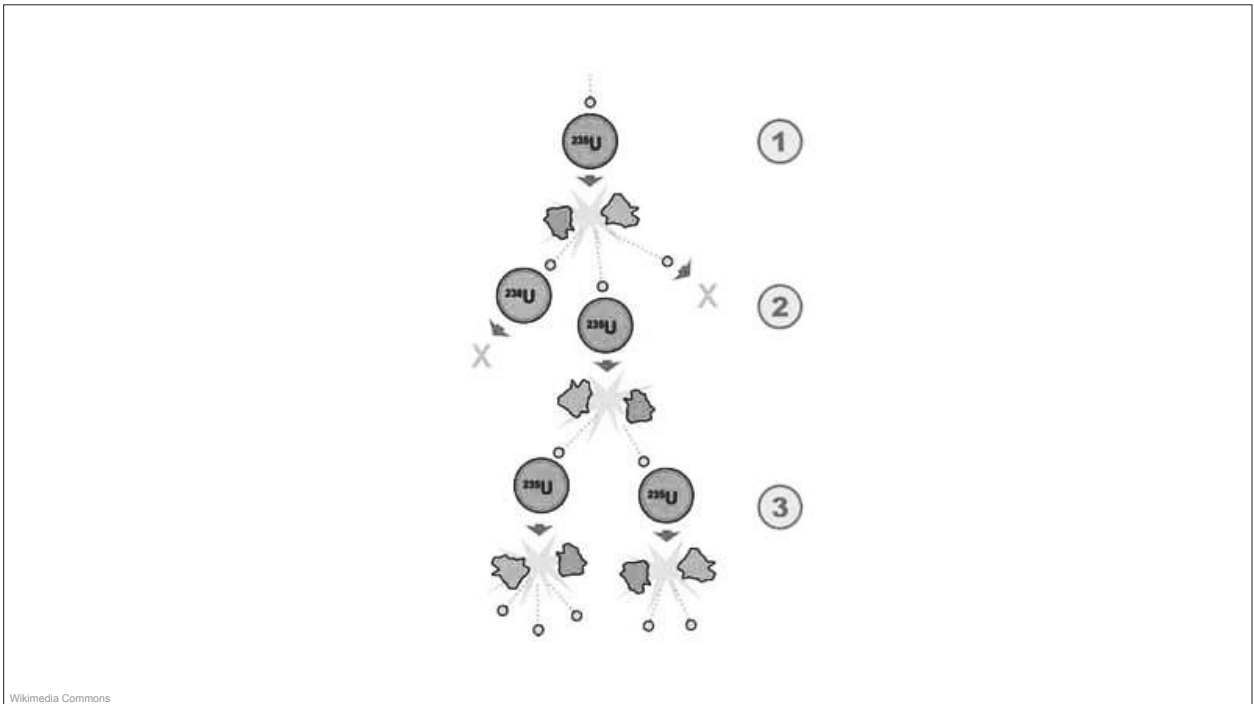
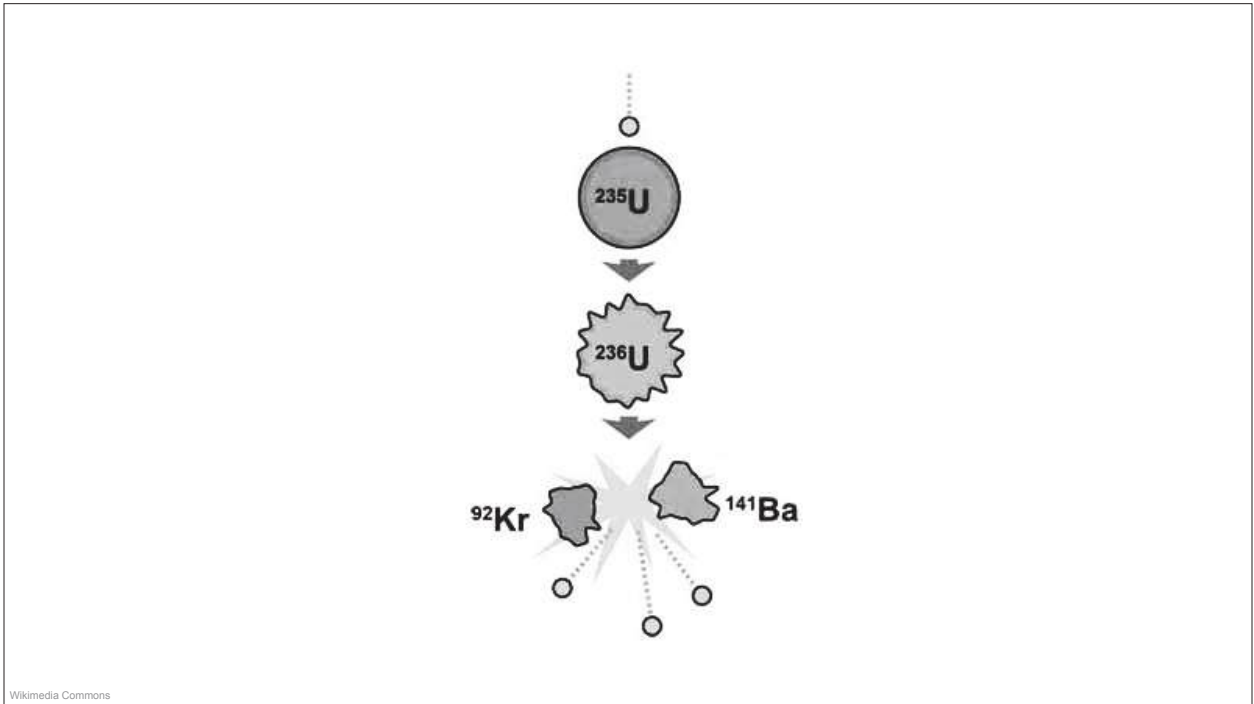
- the temperature necessary to fully ionize deuterium and tritium
- a temperature great enough for the kinetic energy of two typical colliding nuclei to exceed their electrostatic potential energy barrier
- the core temperature of the sun
- the temperature where the average particle speed produces a magnetic force greater than the electrostatic repulsion between nuclei

Premed Village

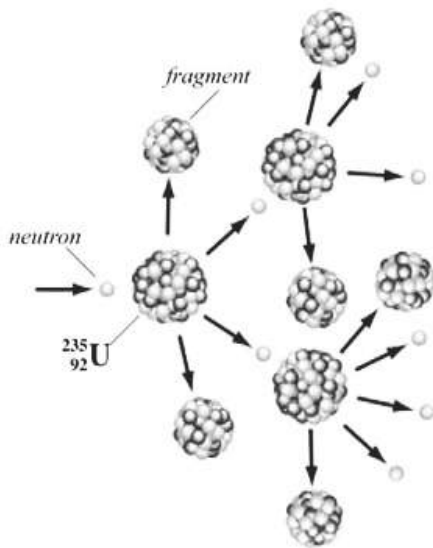
The graph at right shows potential energy vs. distance between a deuteron and a tritium nucleus. Before fusion can occur, the electrostatic force of repulsion between the two nuclei must be overcome by their kinetic energy. This allows the colliding nuclei to approach within a few femtometers (fm) ($1 \text{ fm} = 10^{-15} \text{ m}$) of each other where the strong nuclear force prevails and fusion can occur.



Premed Village

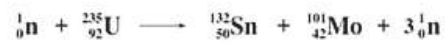
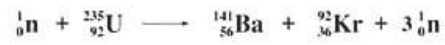
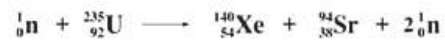


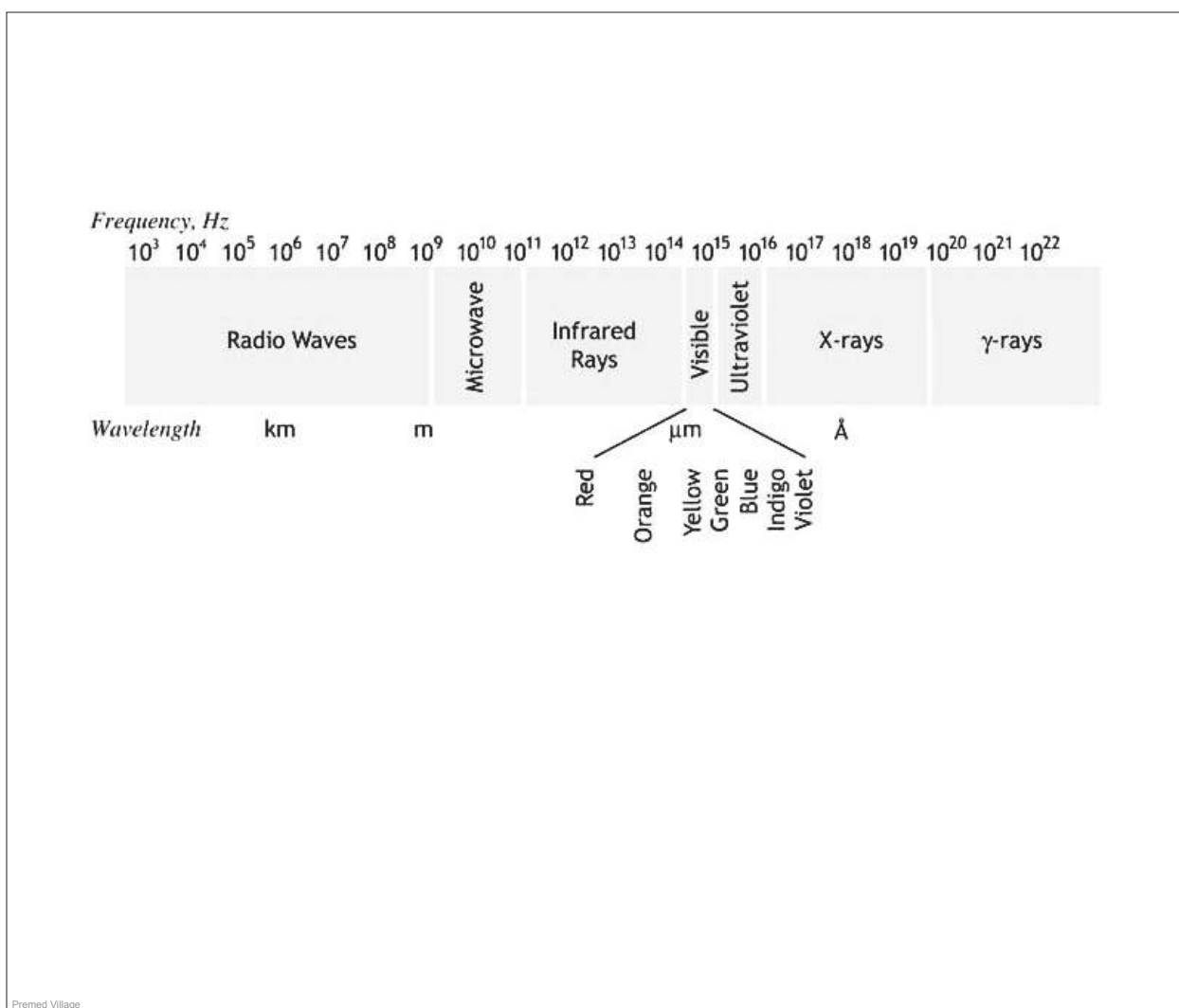
Chain Reaction Fission of $^{235}_{92}\text{U}$



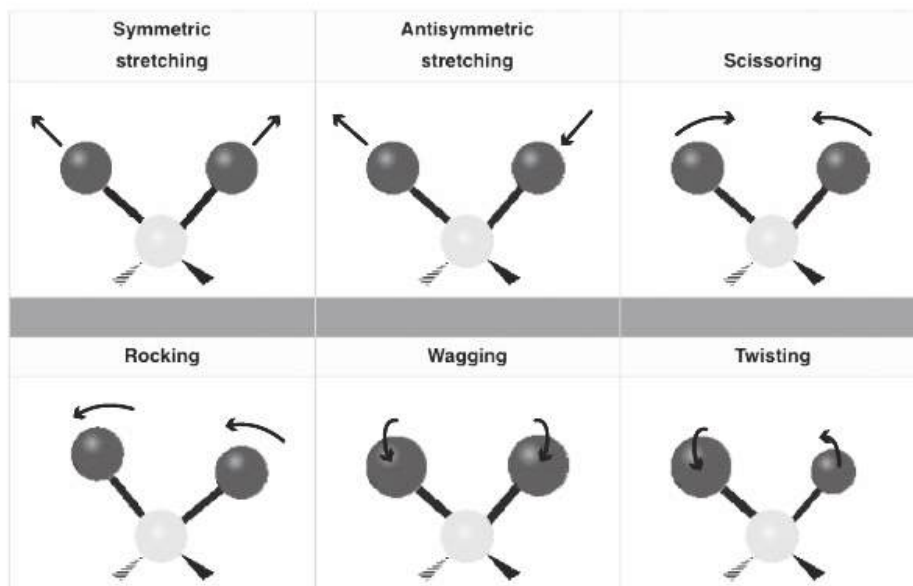
The $^{235}_{92}\text{U}$ nucleus undergoes fission after capturing a thermal neutron. The fission reaction produces two fission fragments and, depending upon the particular daughter nuclei, two or three neutrons. These neutrons, in turn, can trigger the fission of other nuclei, leading to

Typical $^{235}_{92}\text{U}$ Fission Reactions

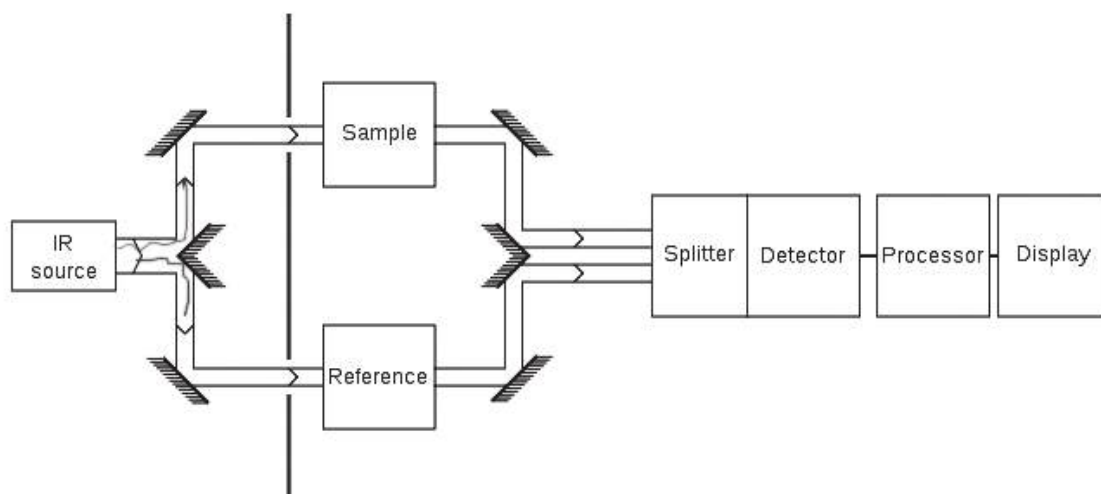




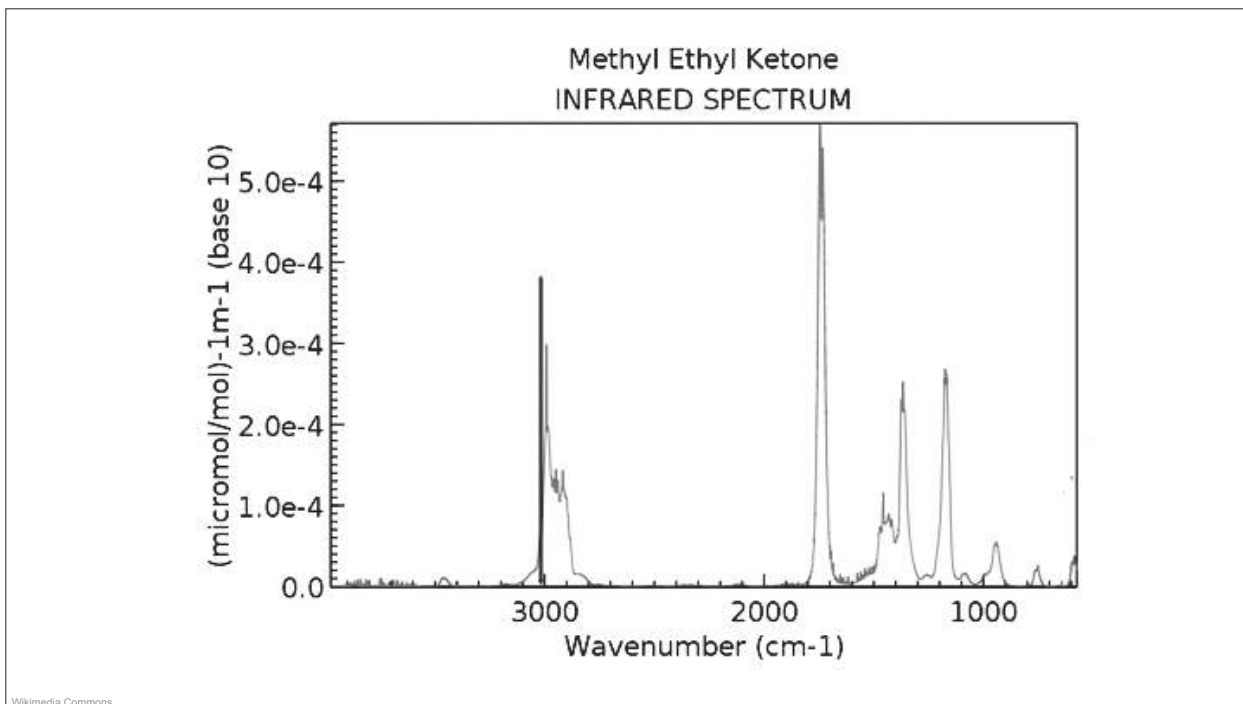
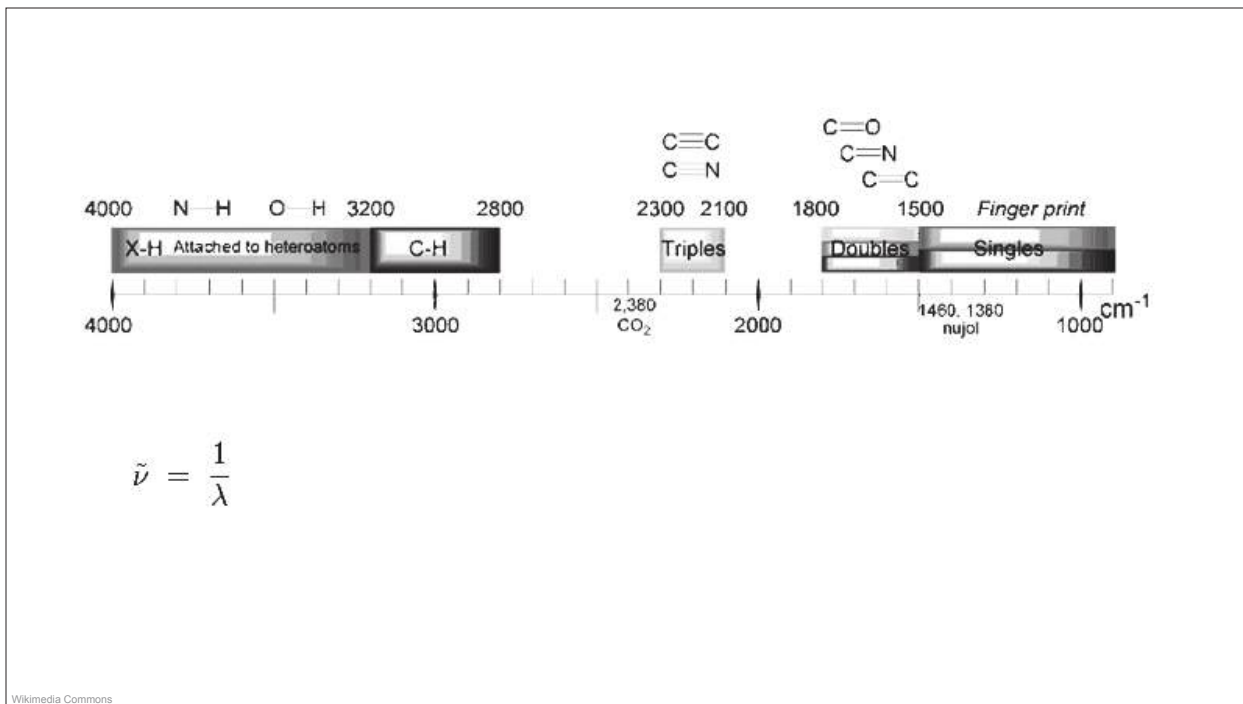
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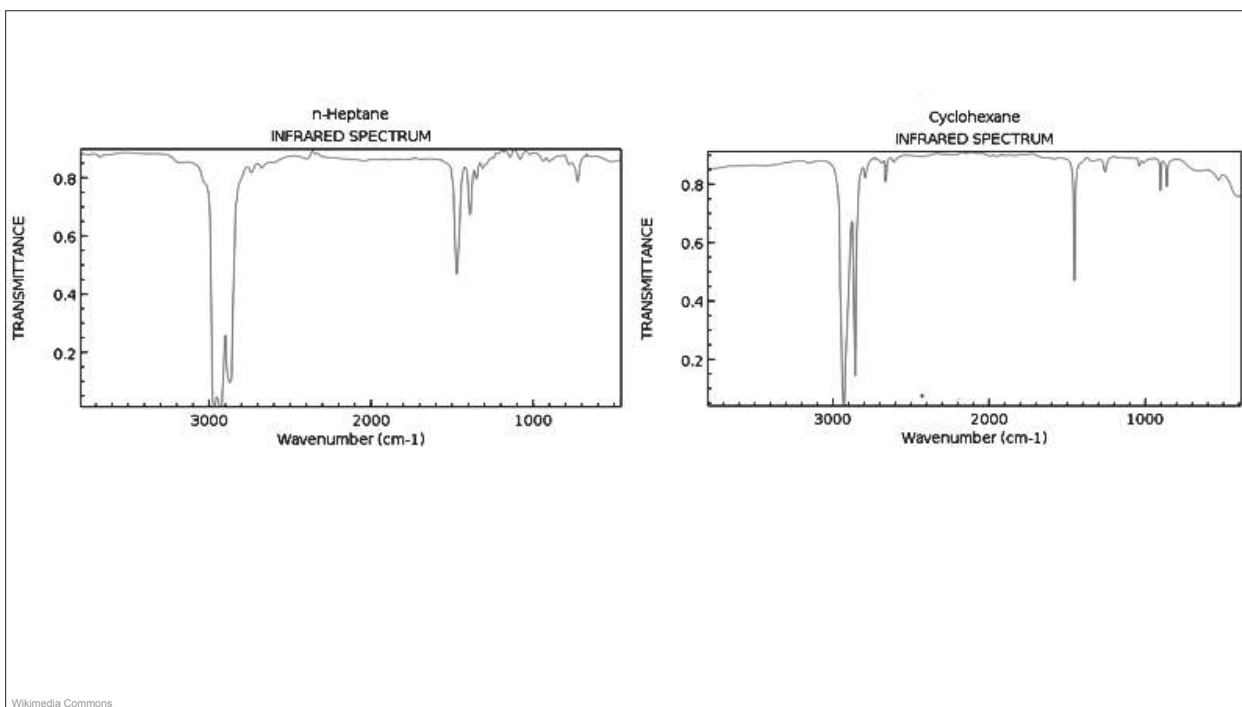
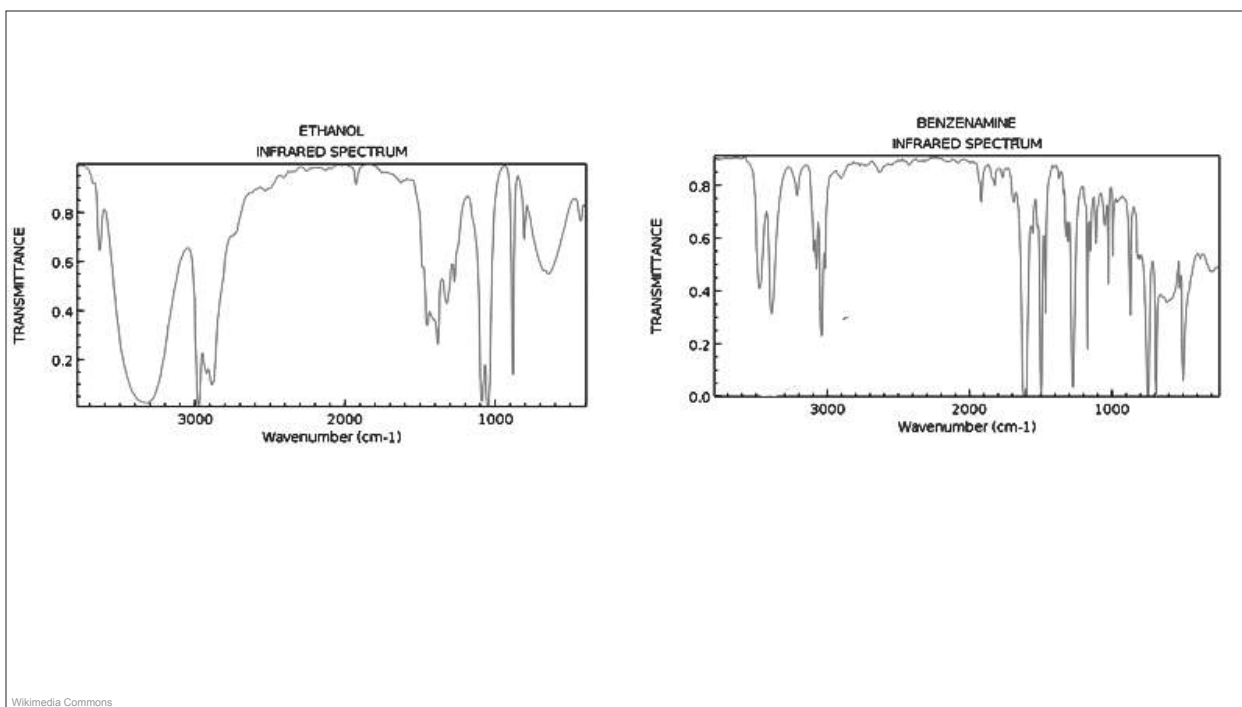


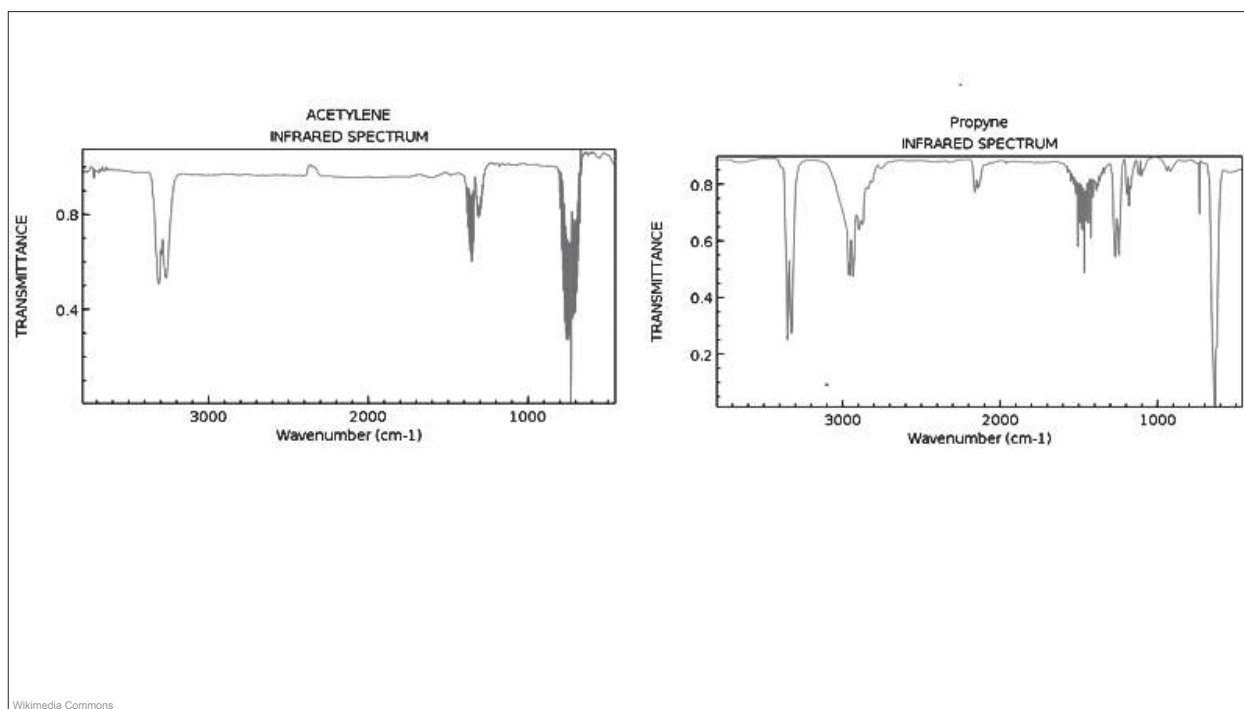
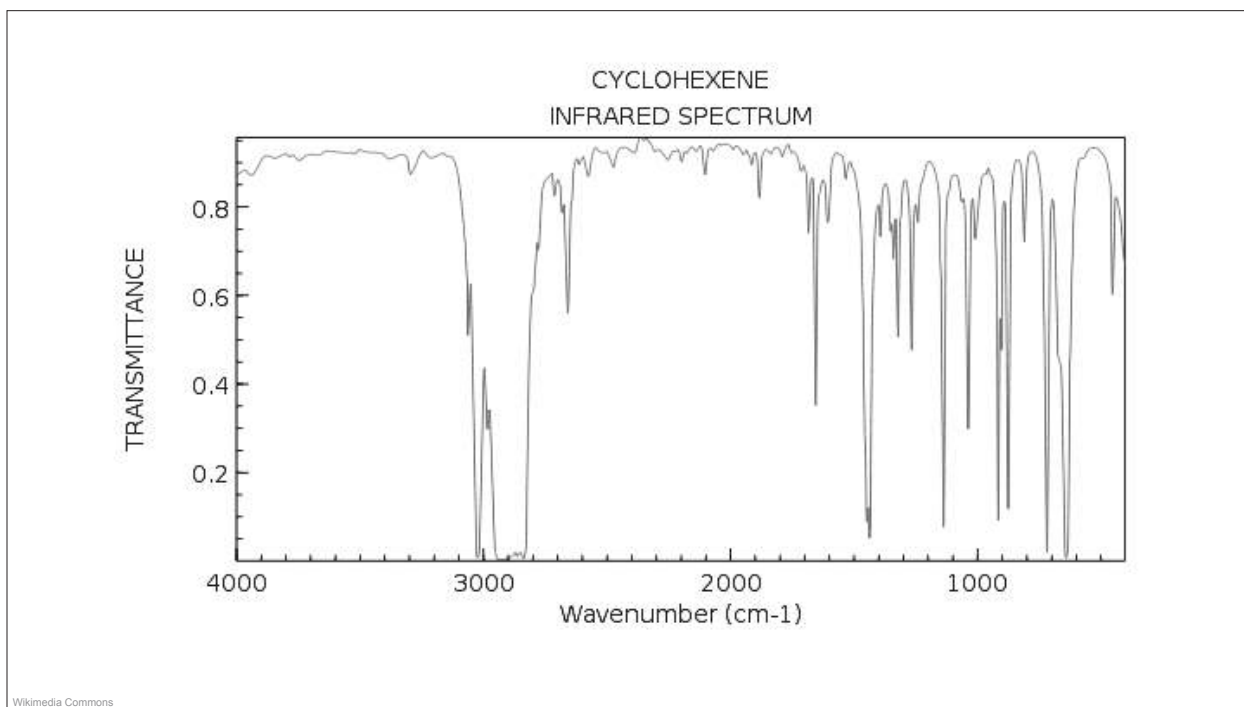
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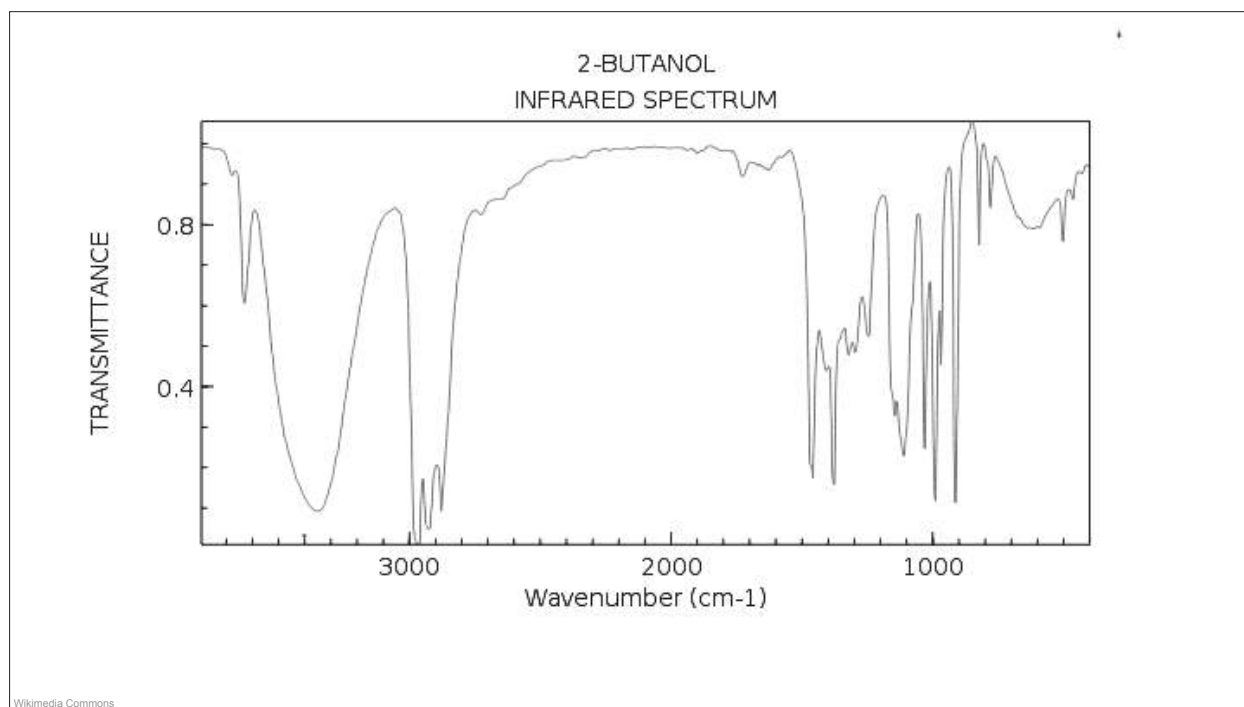
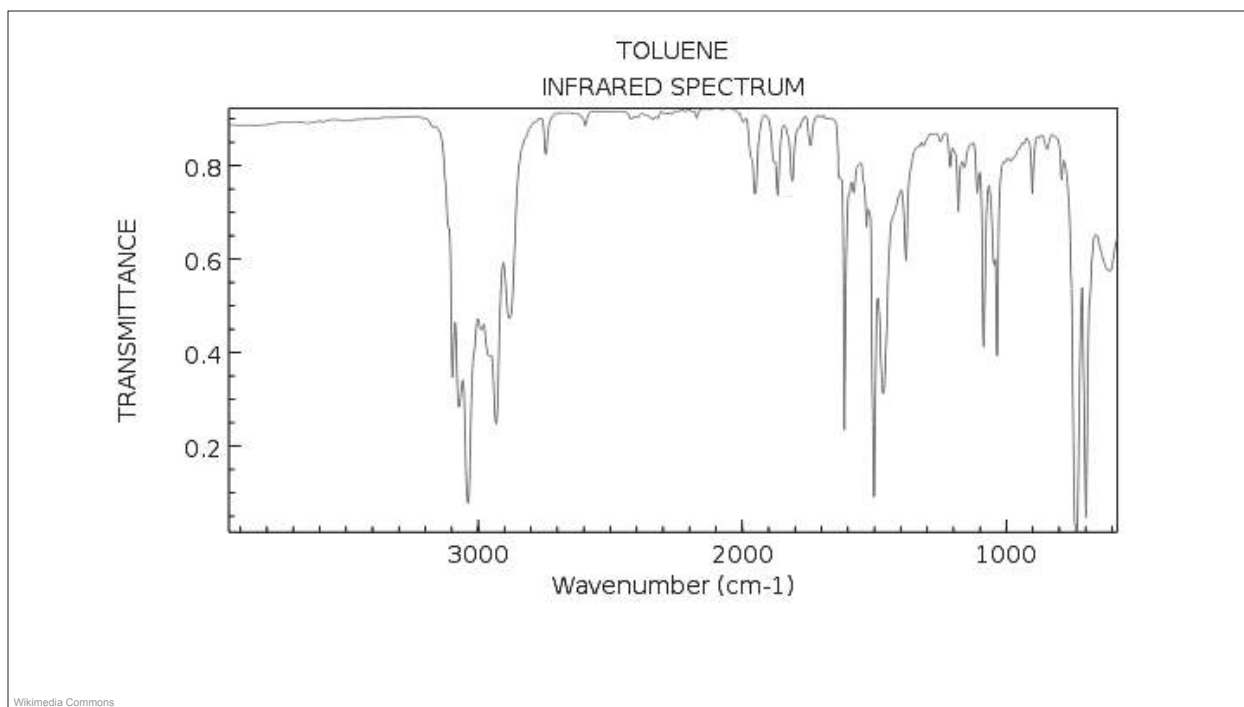


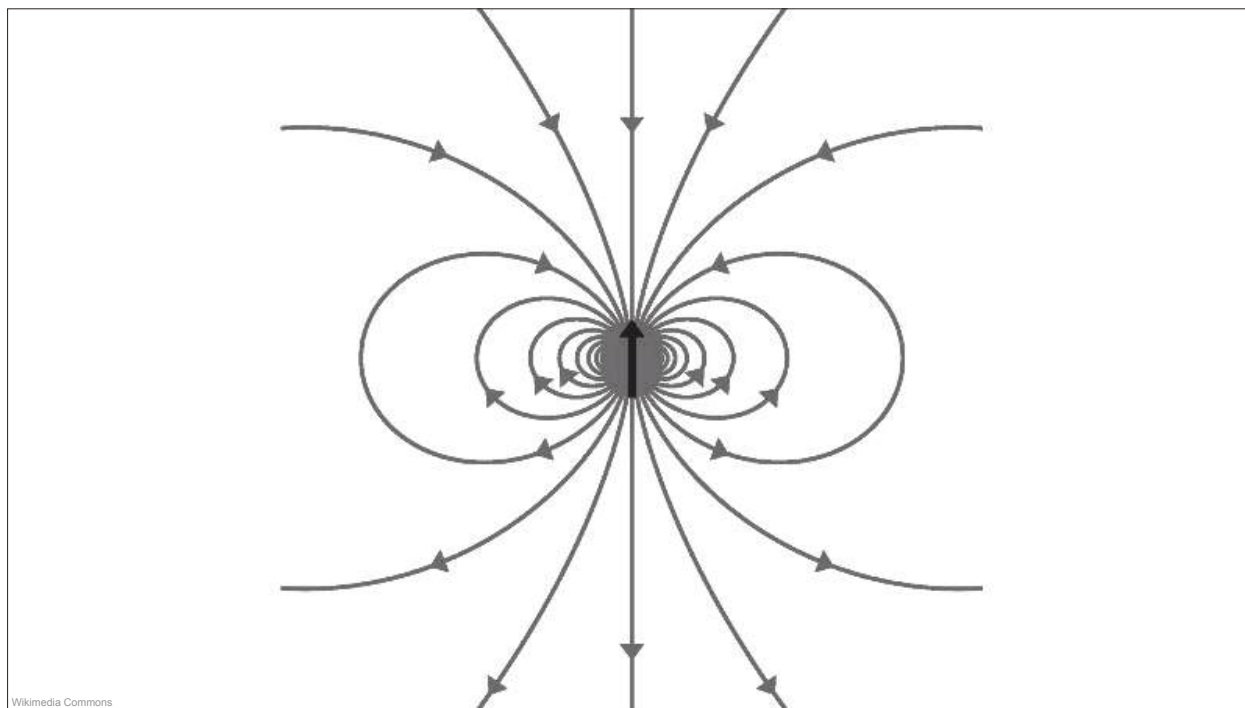
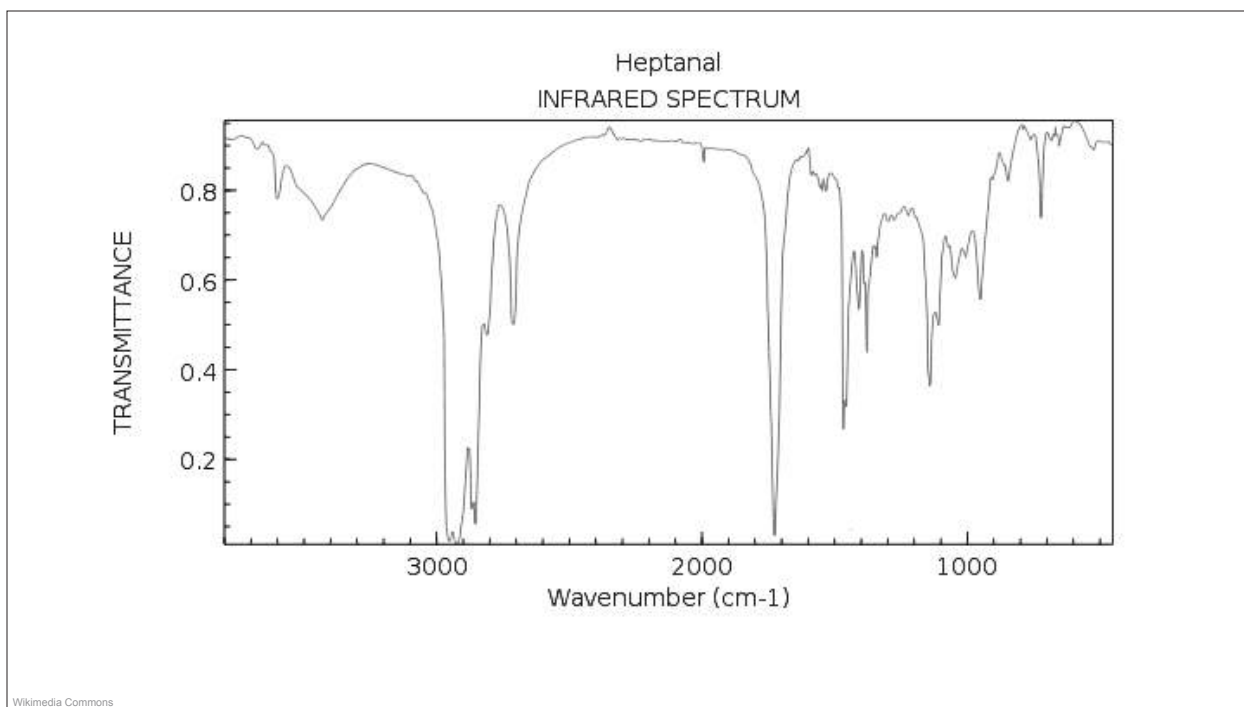
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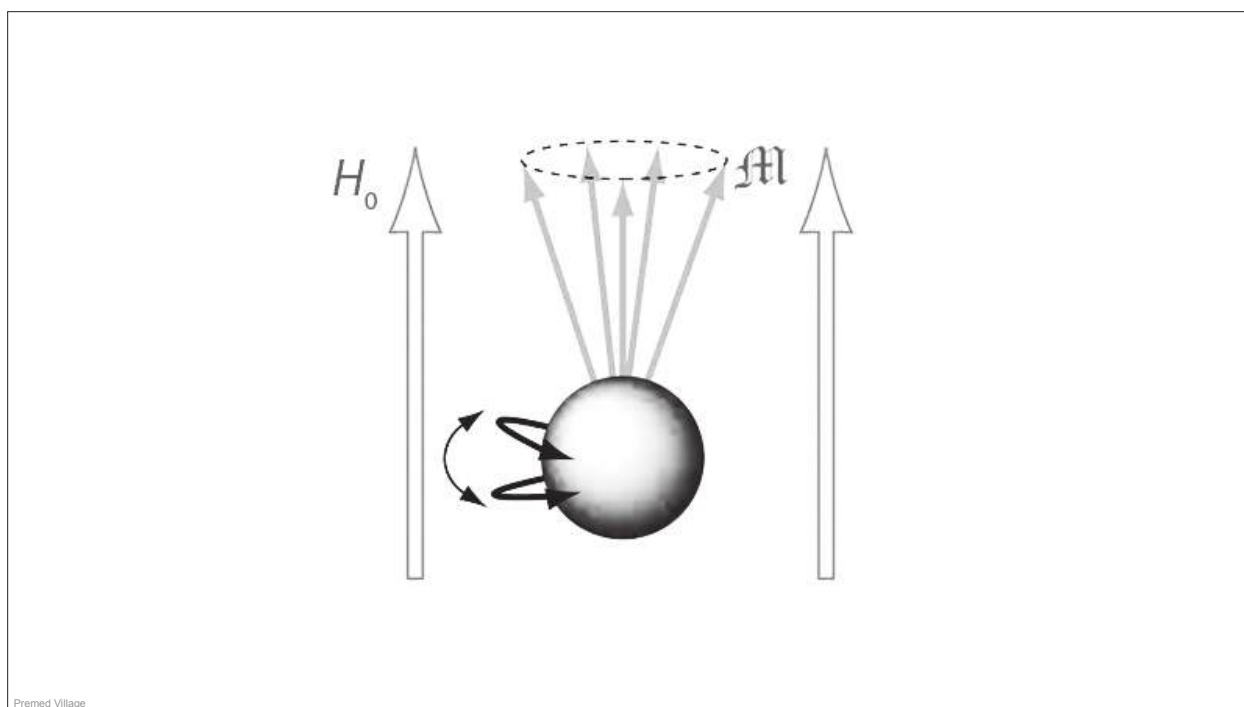
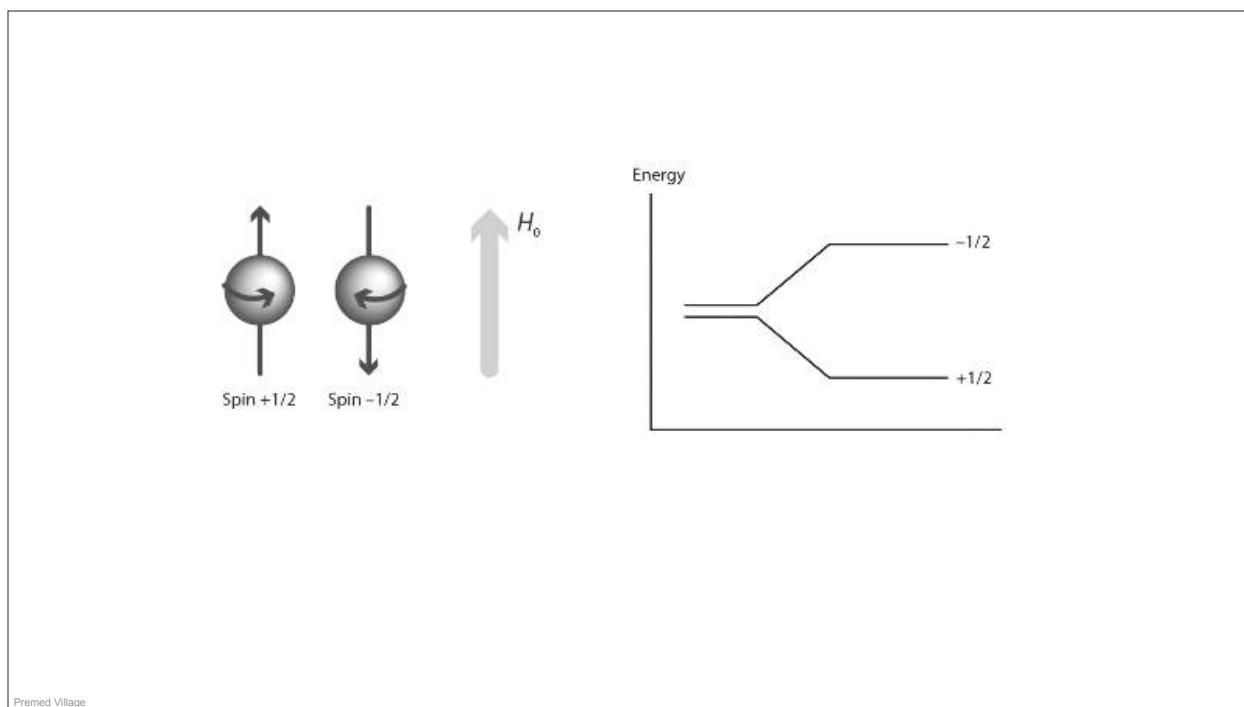


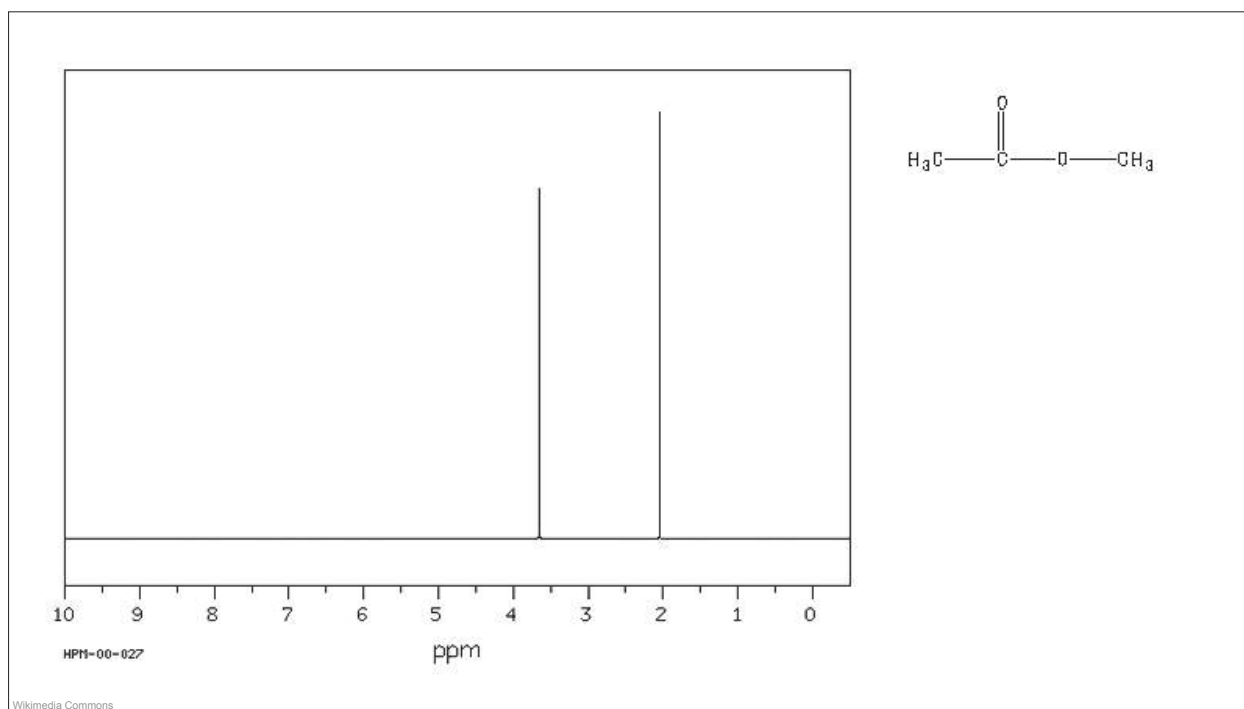
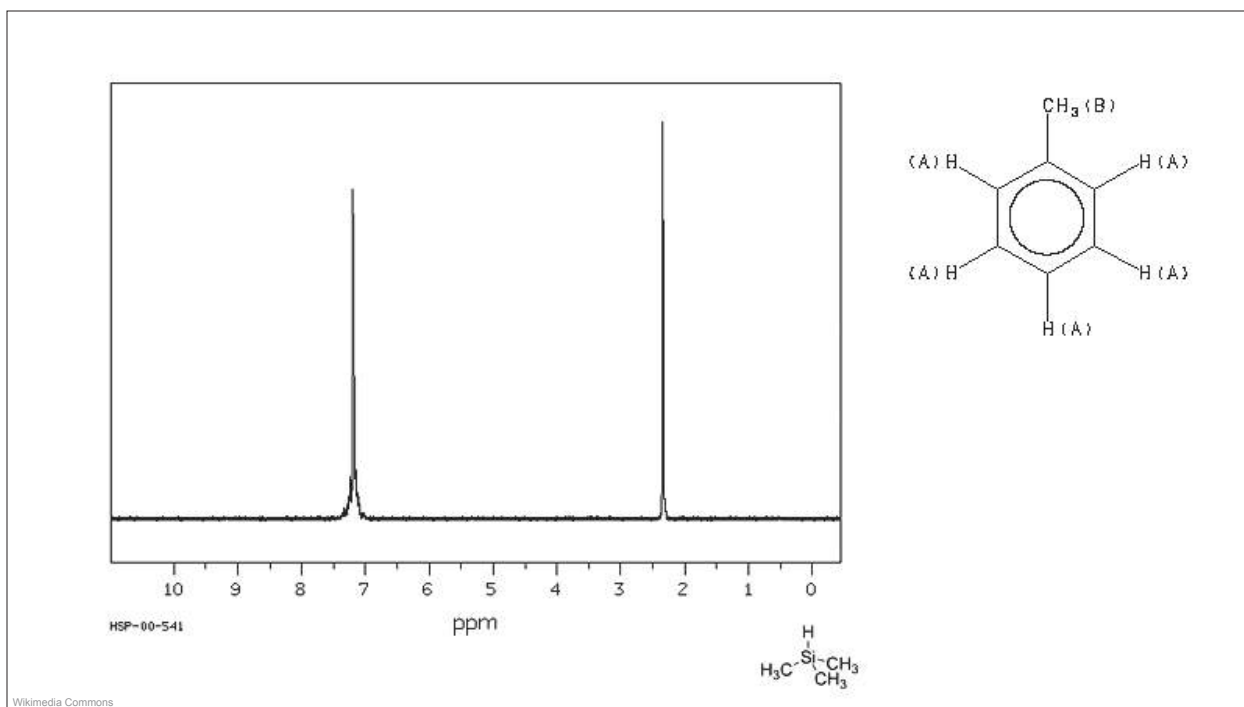


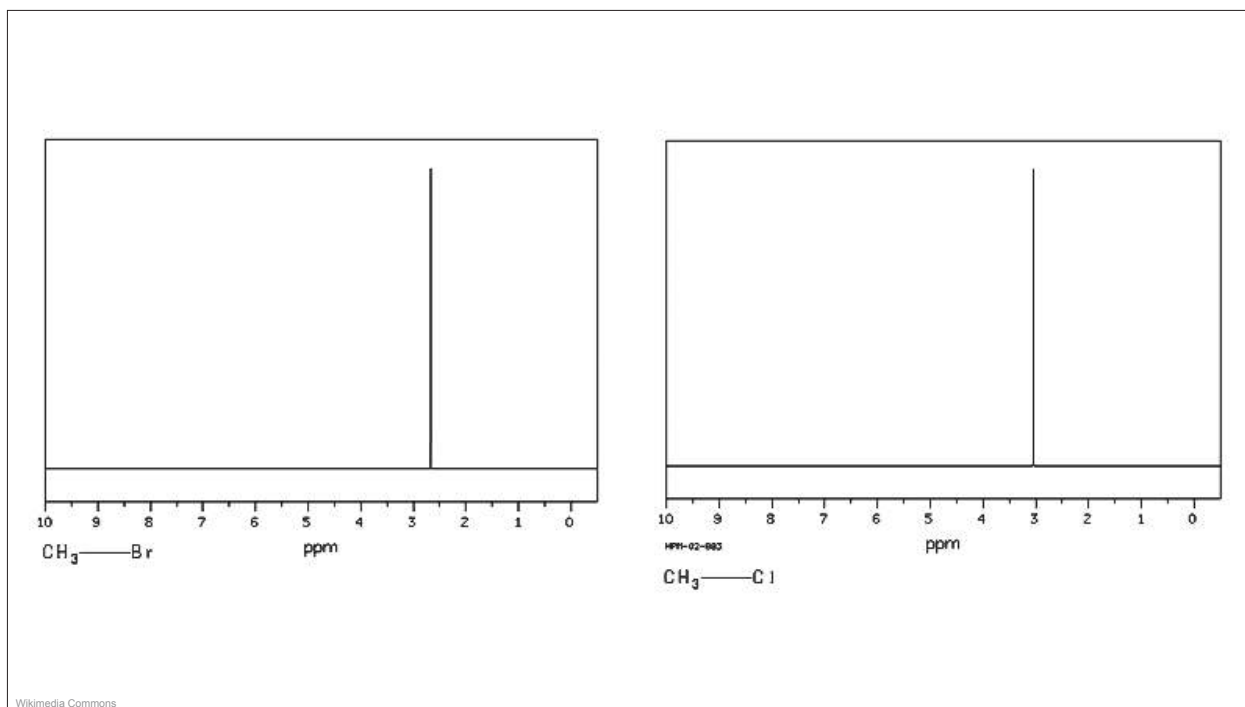
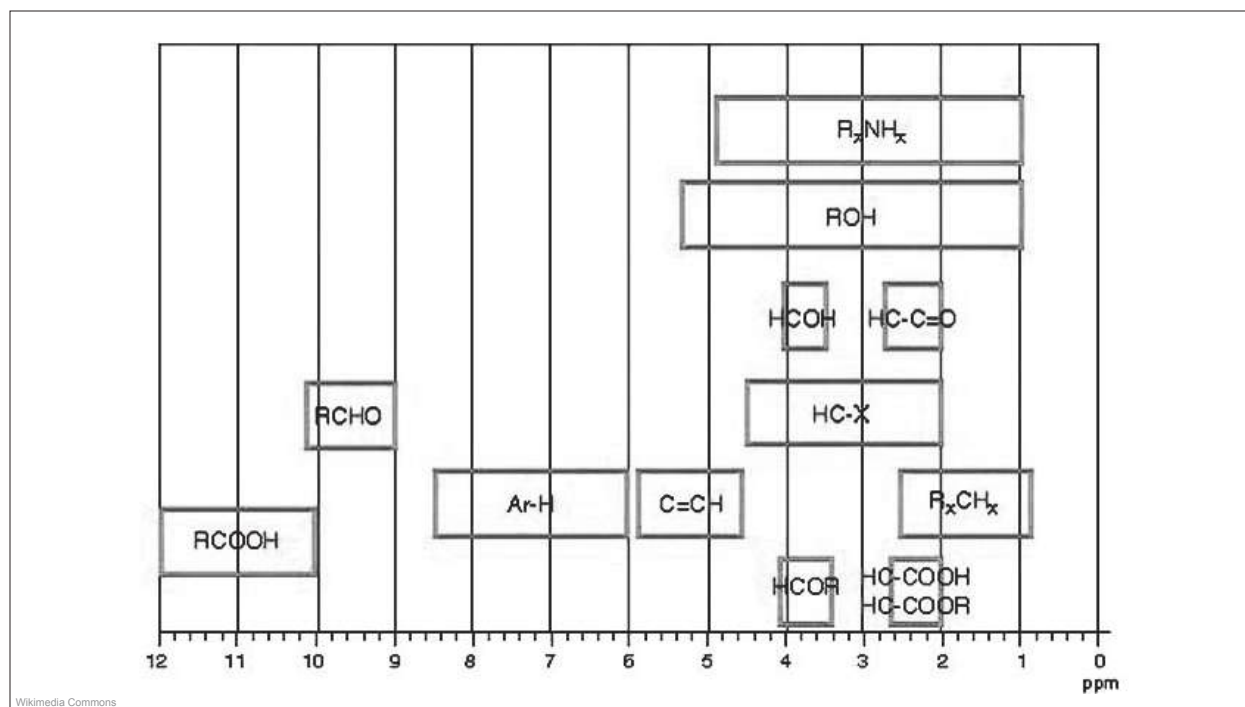


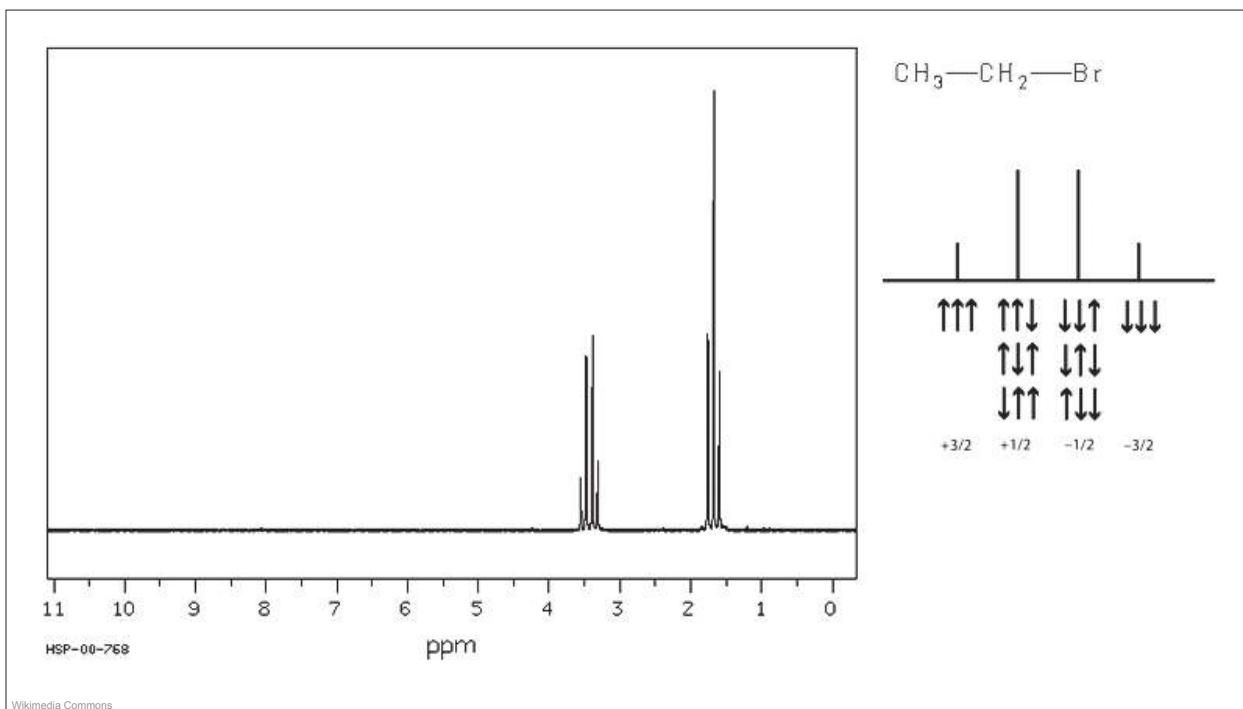
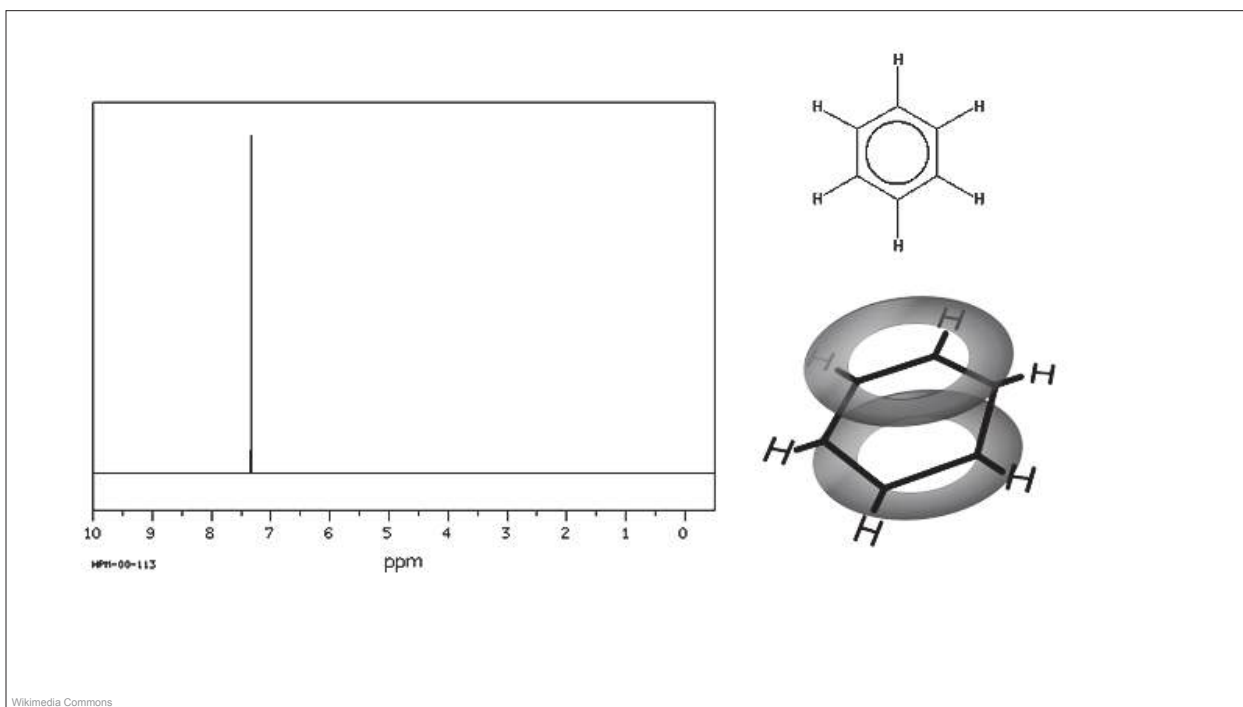




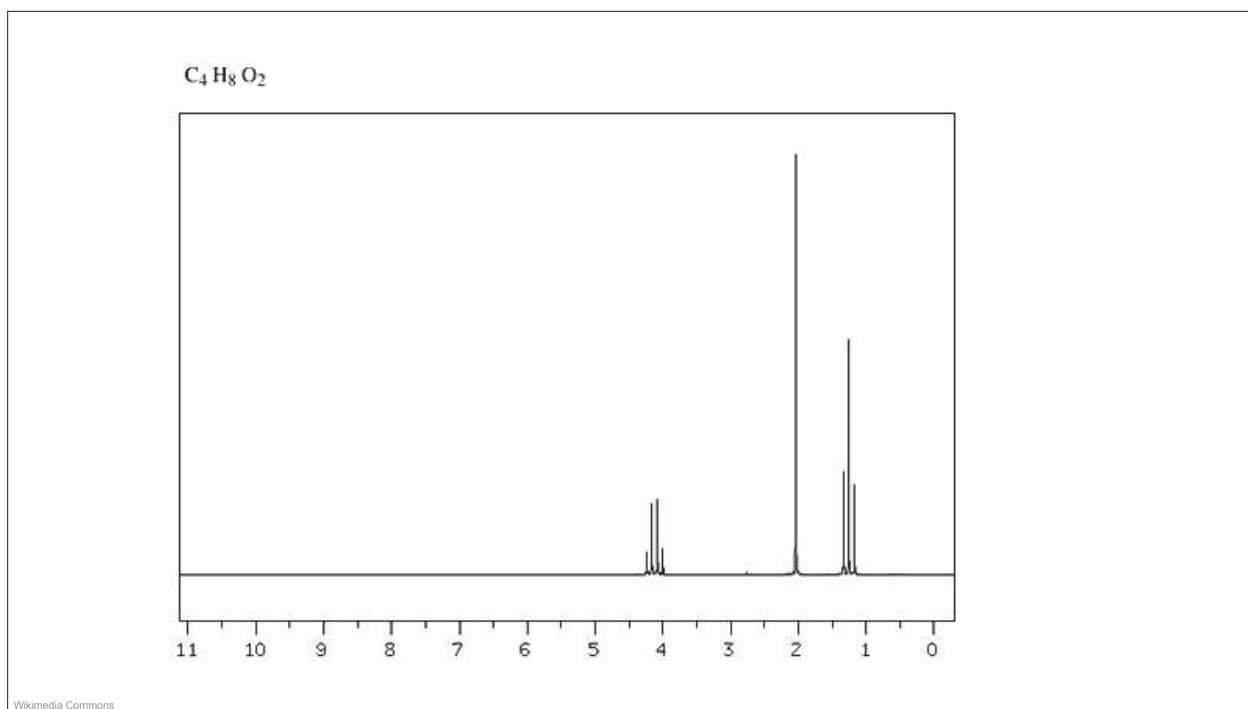
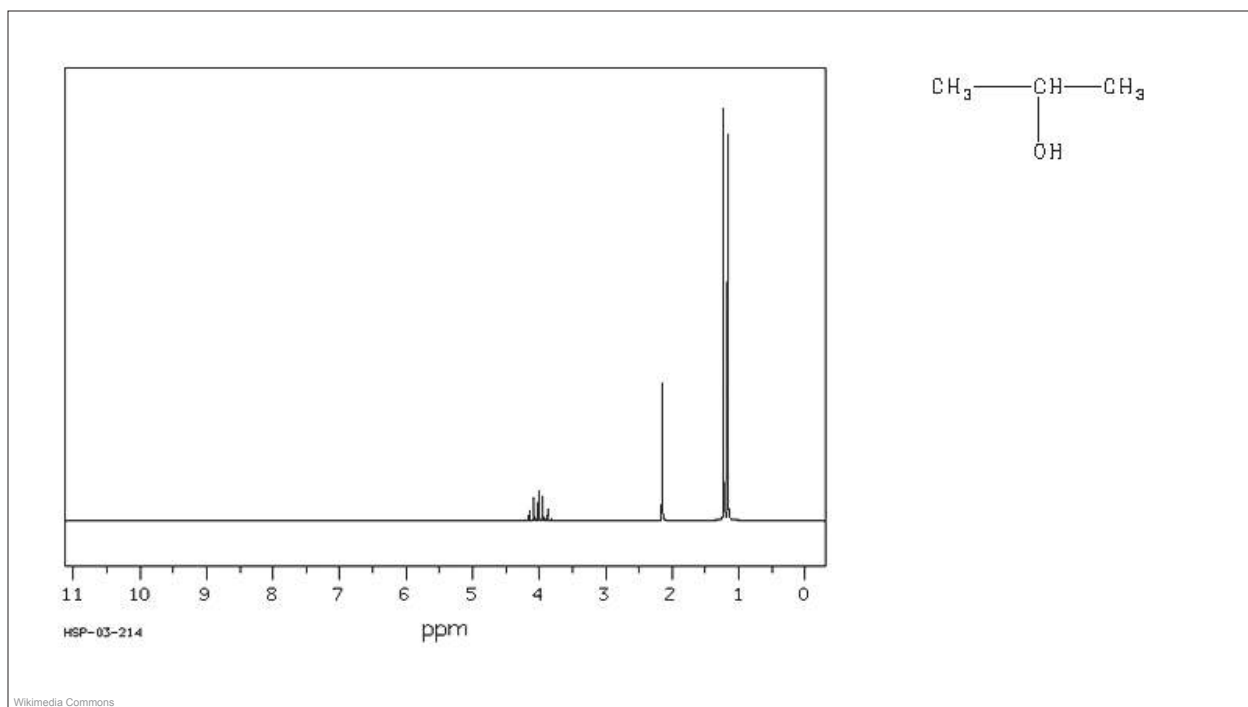


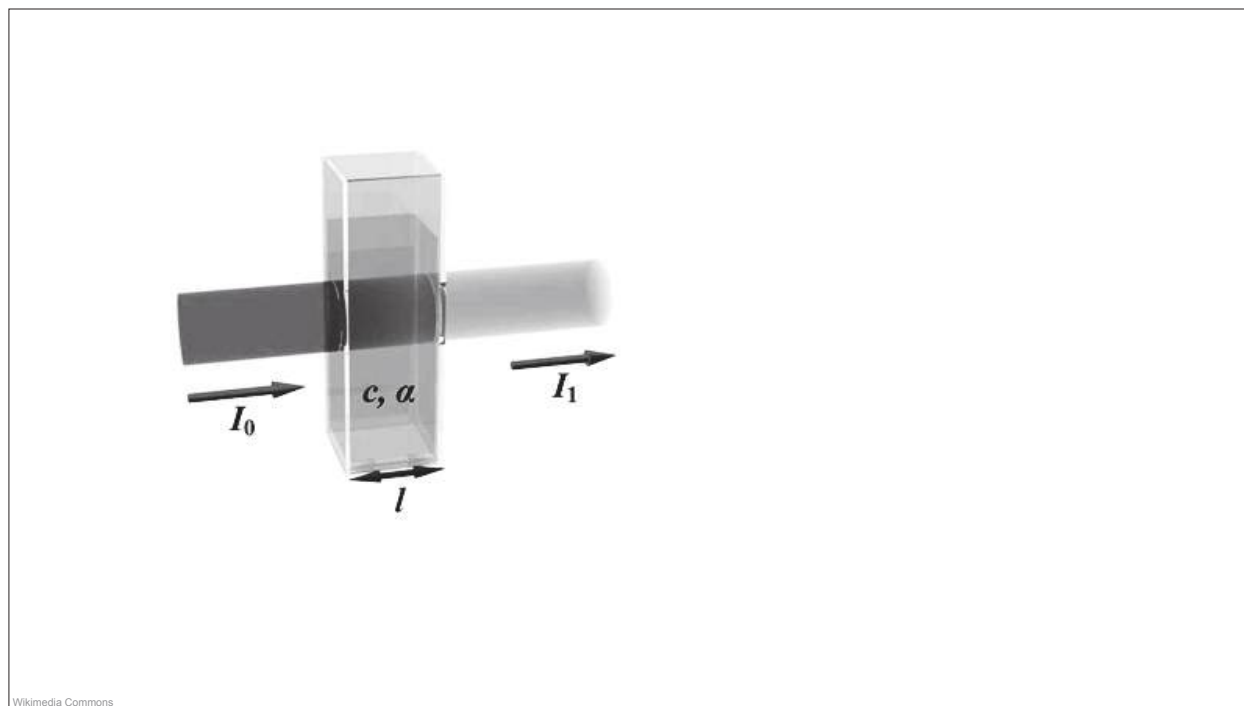
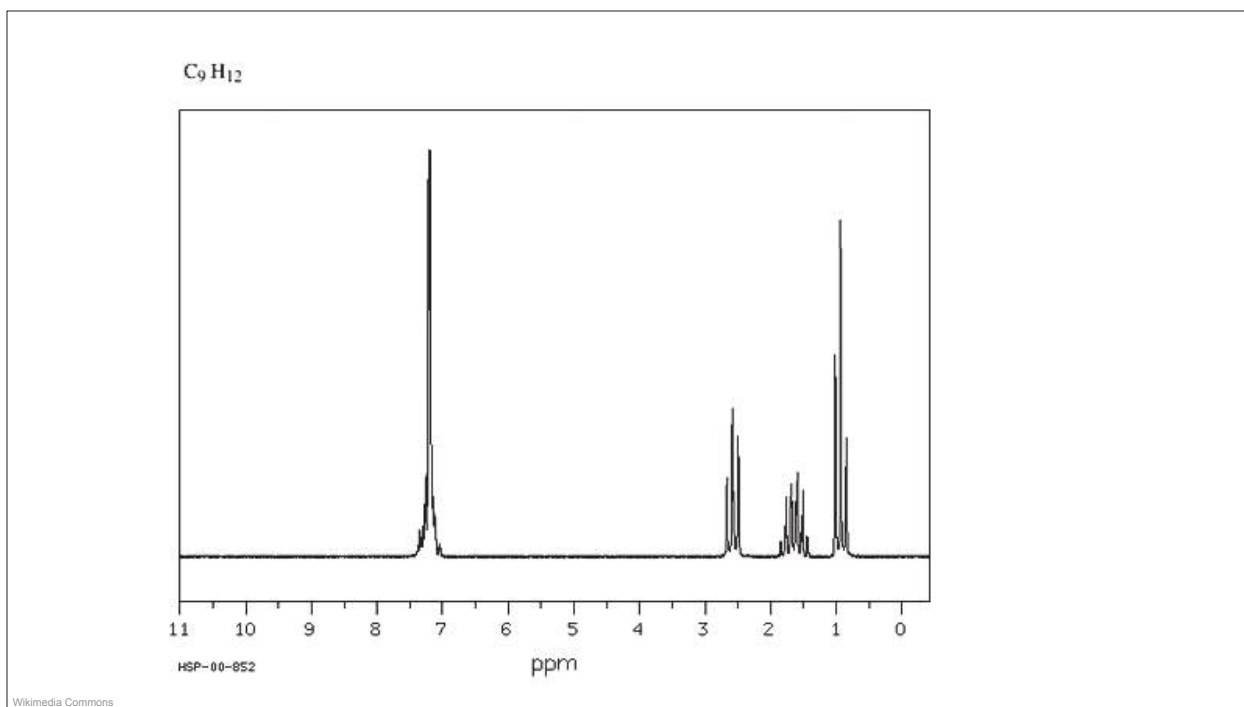


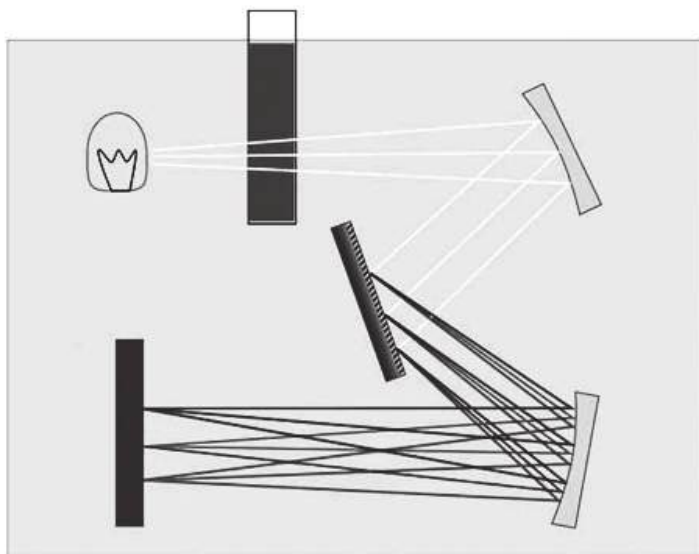




Molecular Spectroscopy

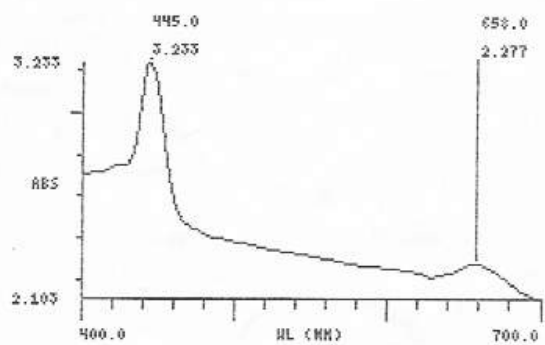




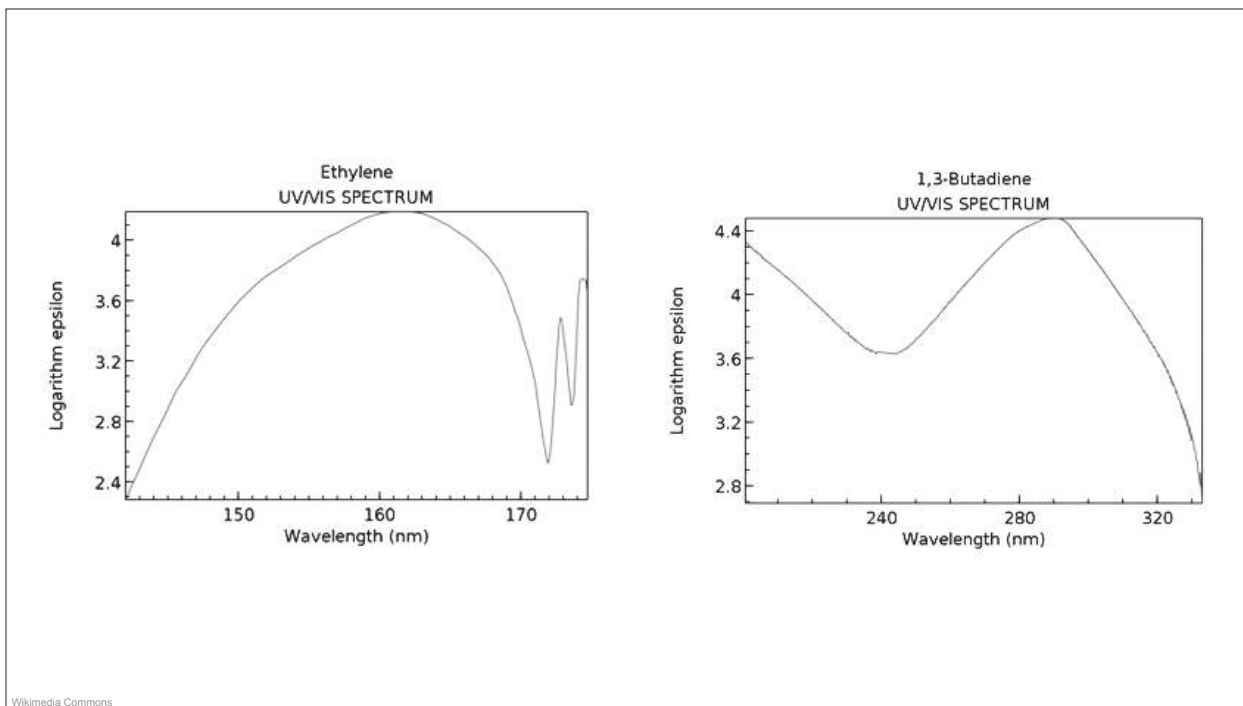
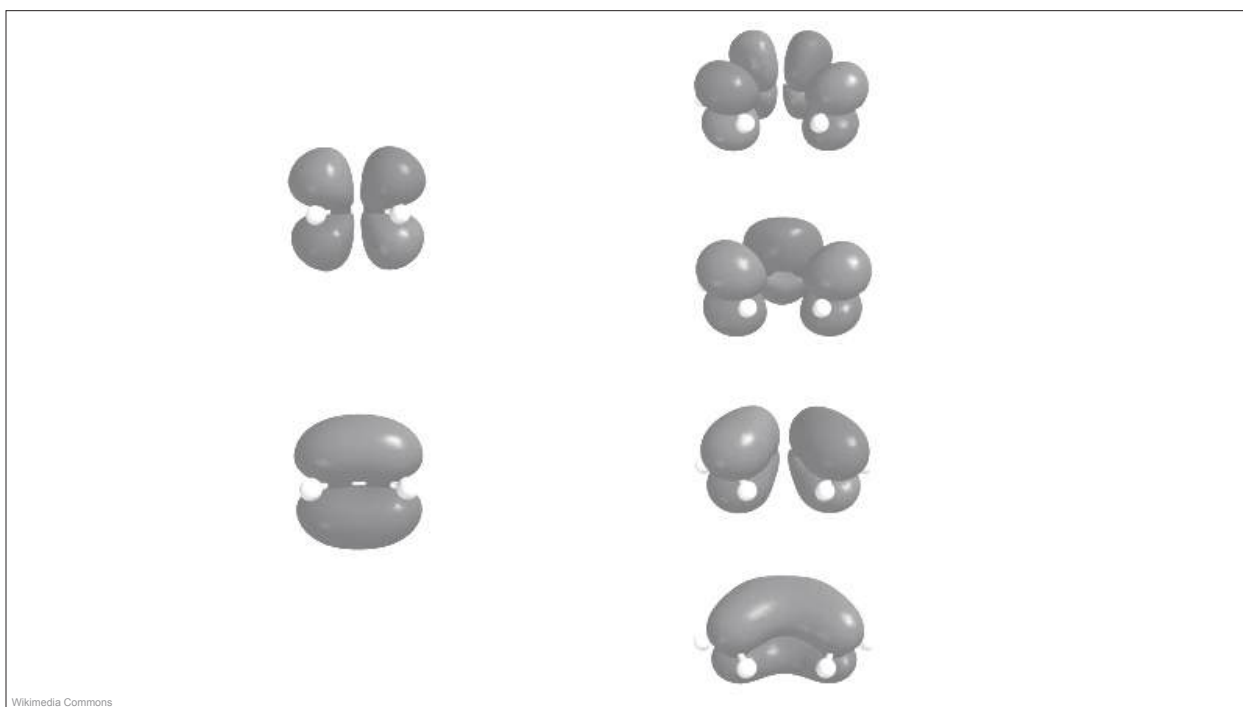


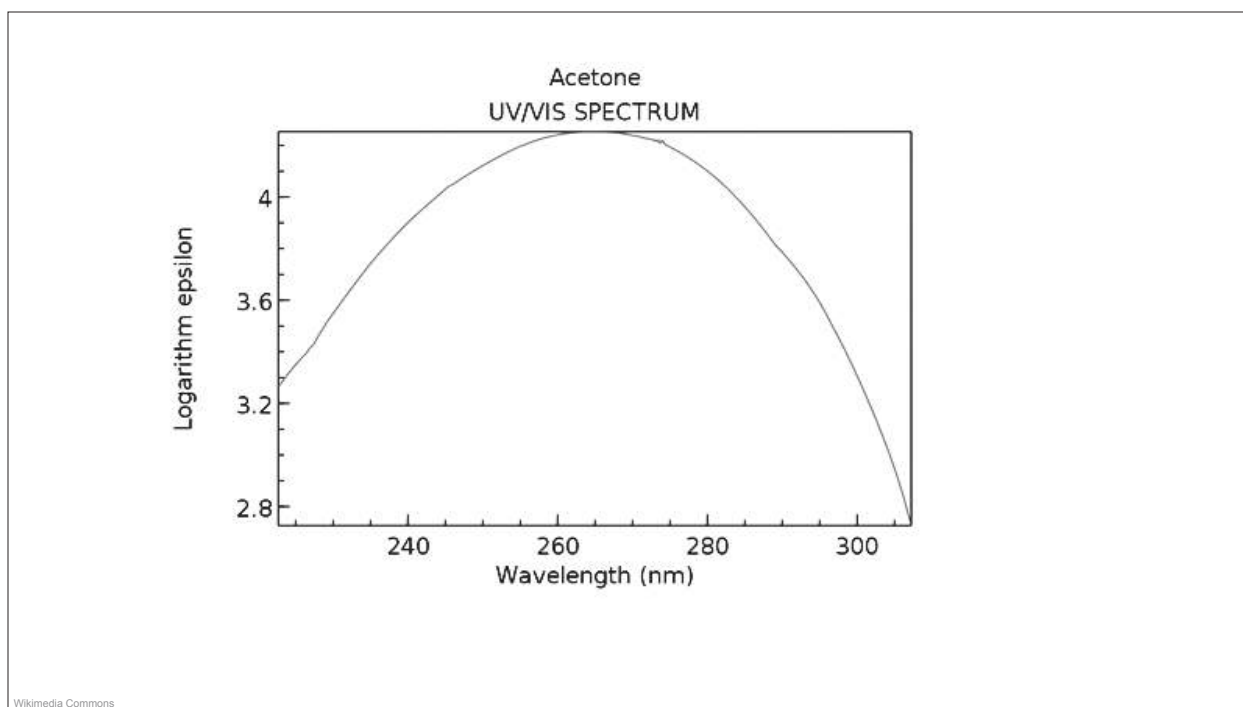
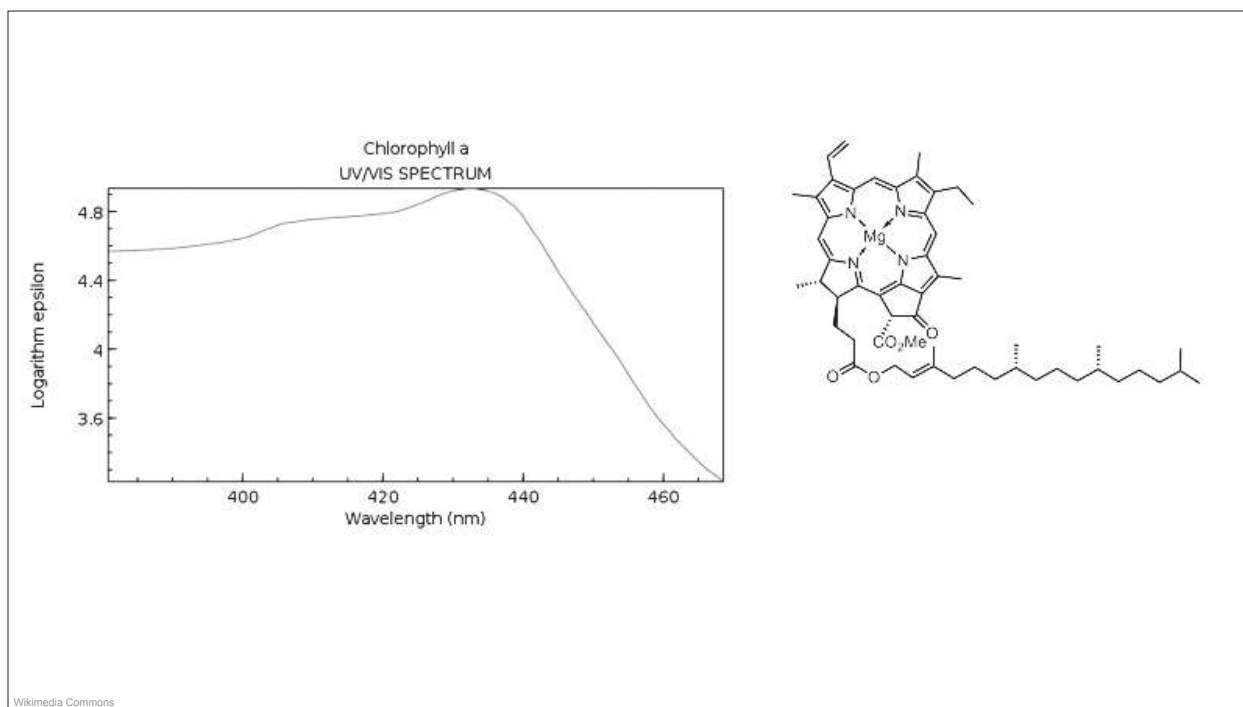
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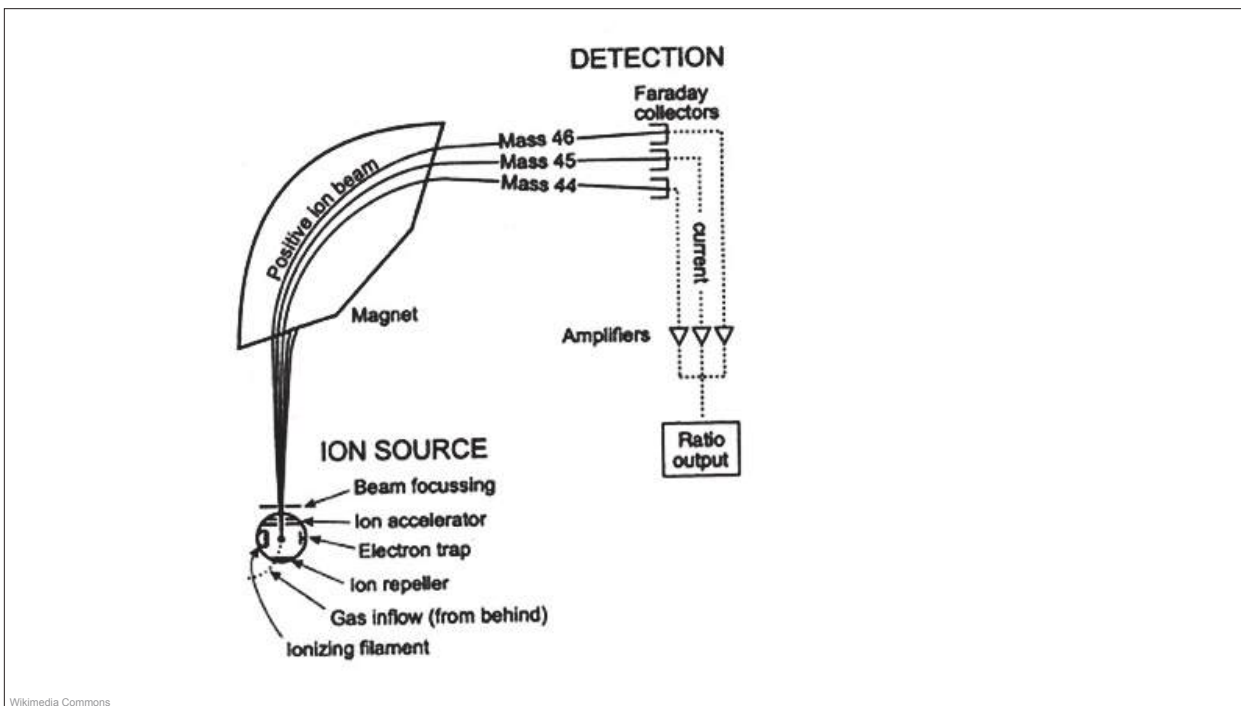
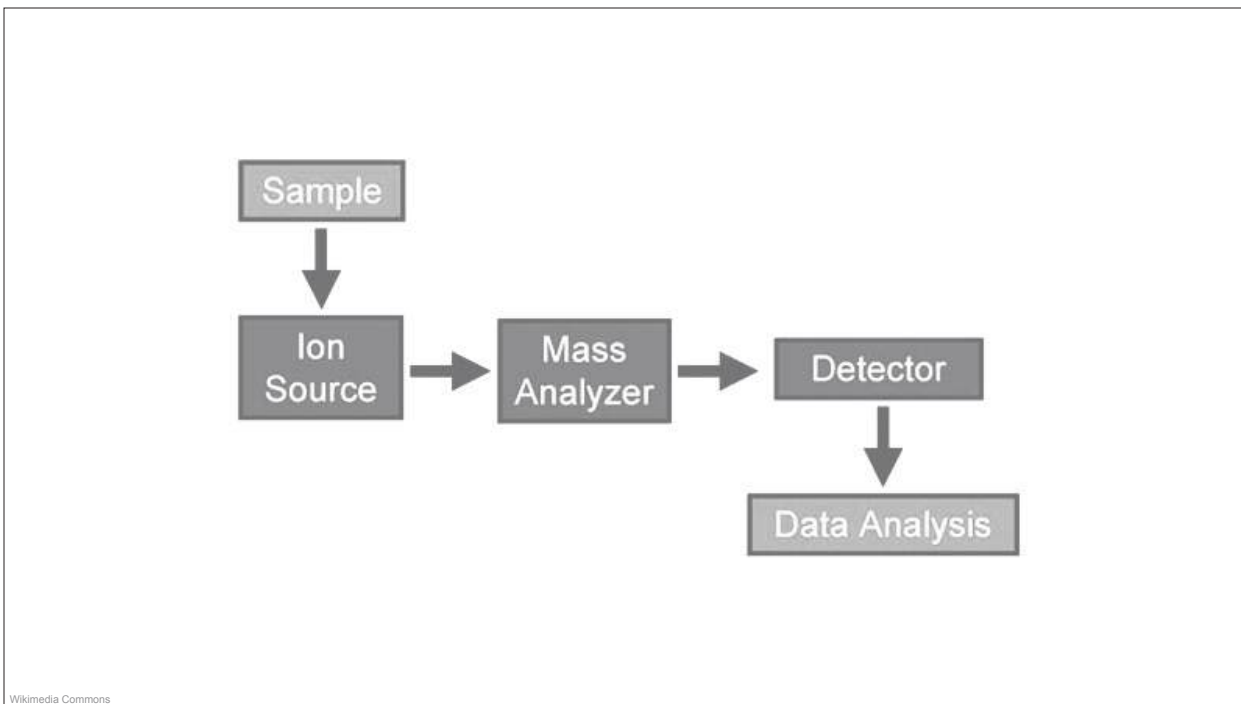
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Test name:
Data name: DEFAULT
Start Wavelength: 400.0
Stop Wavelength: 700.0



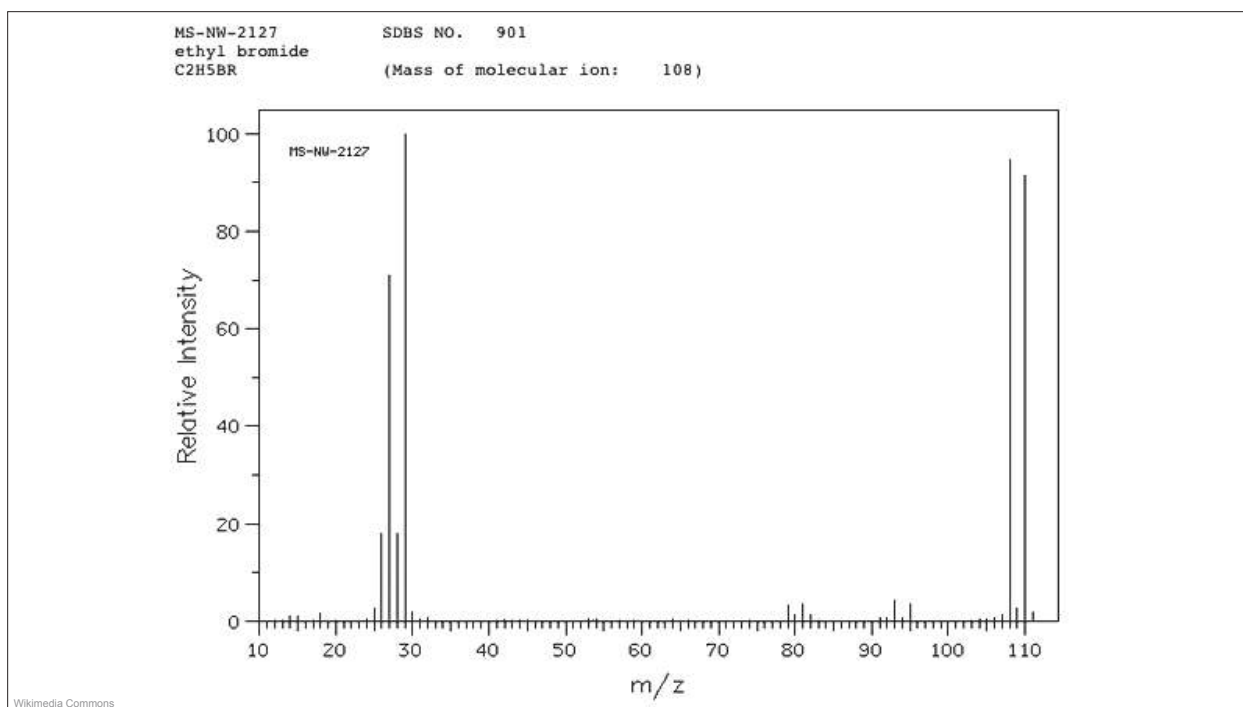
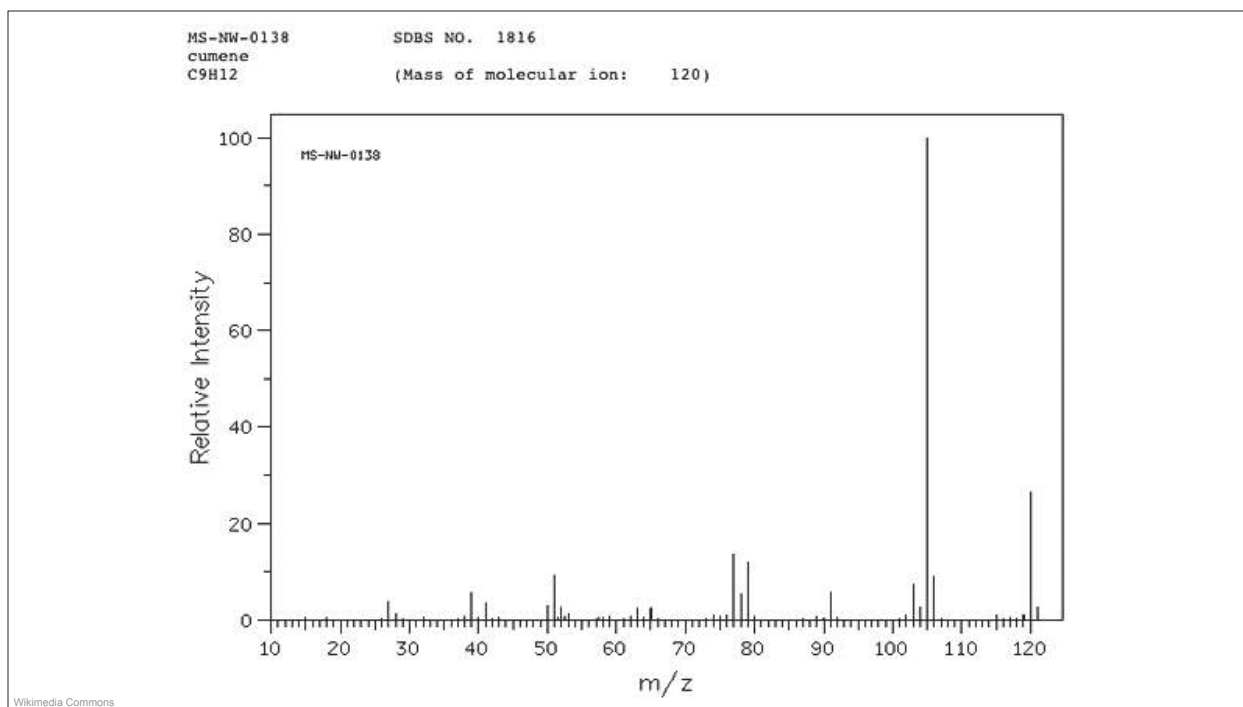
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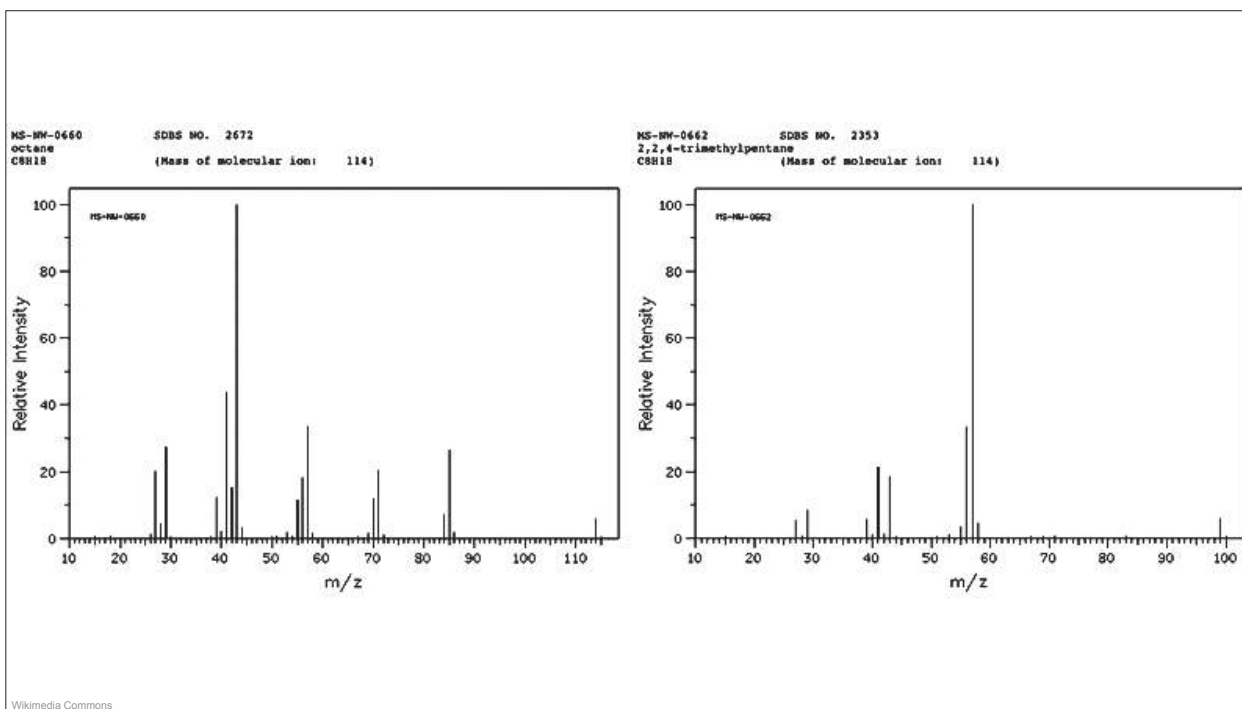
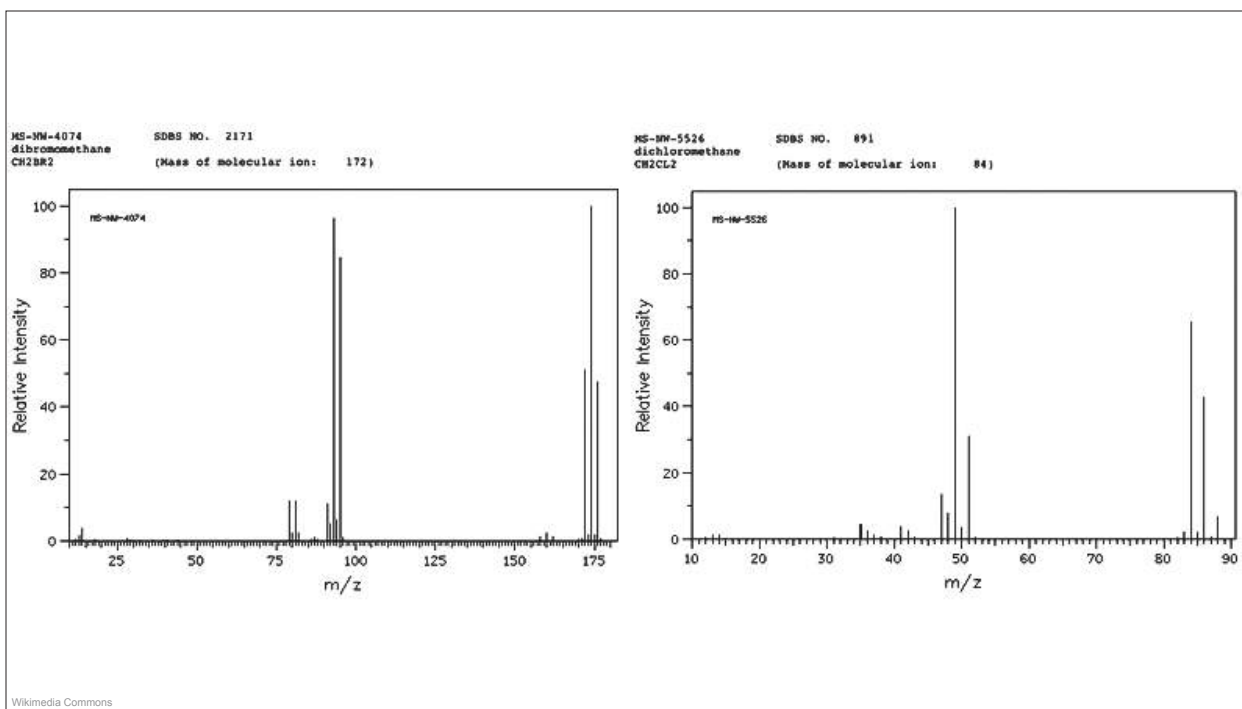




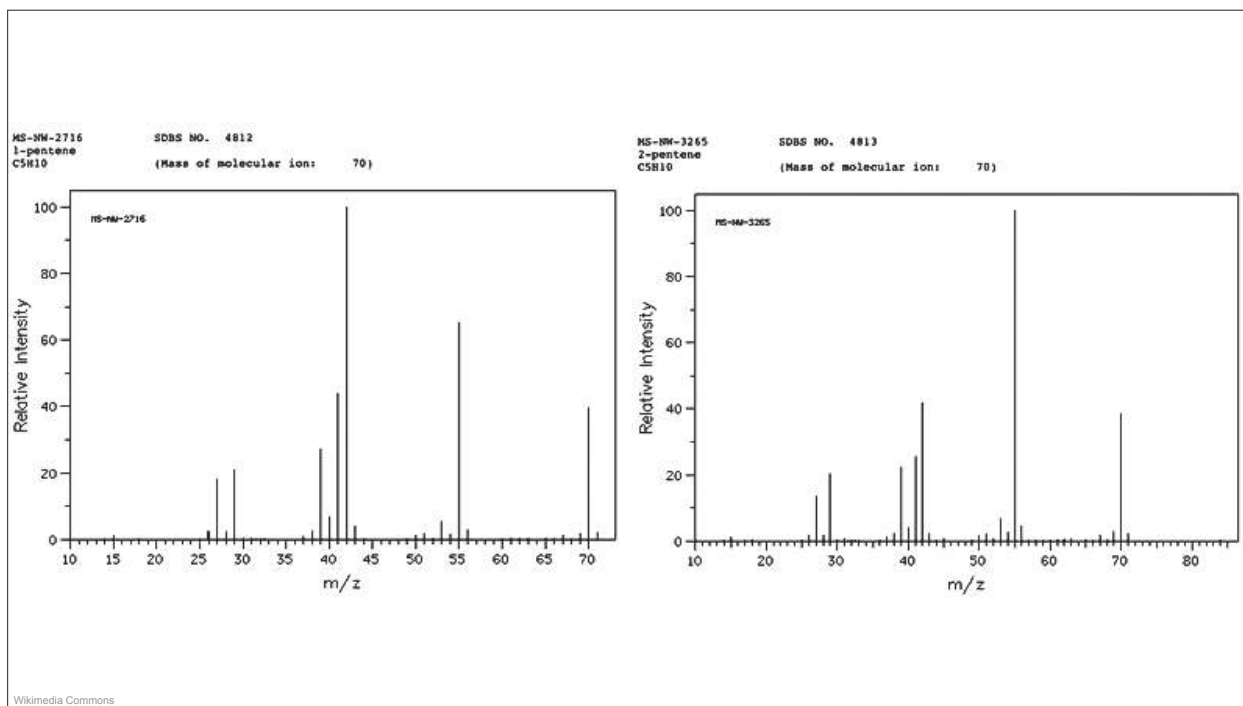
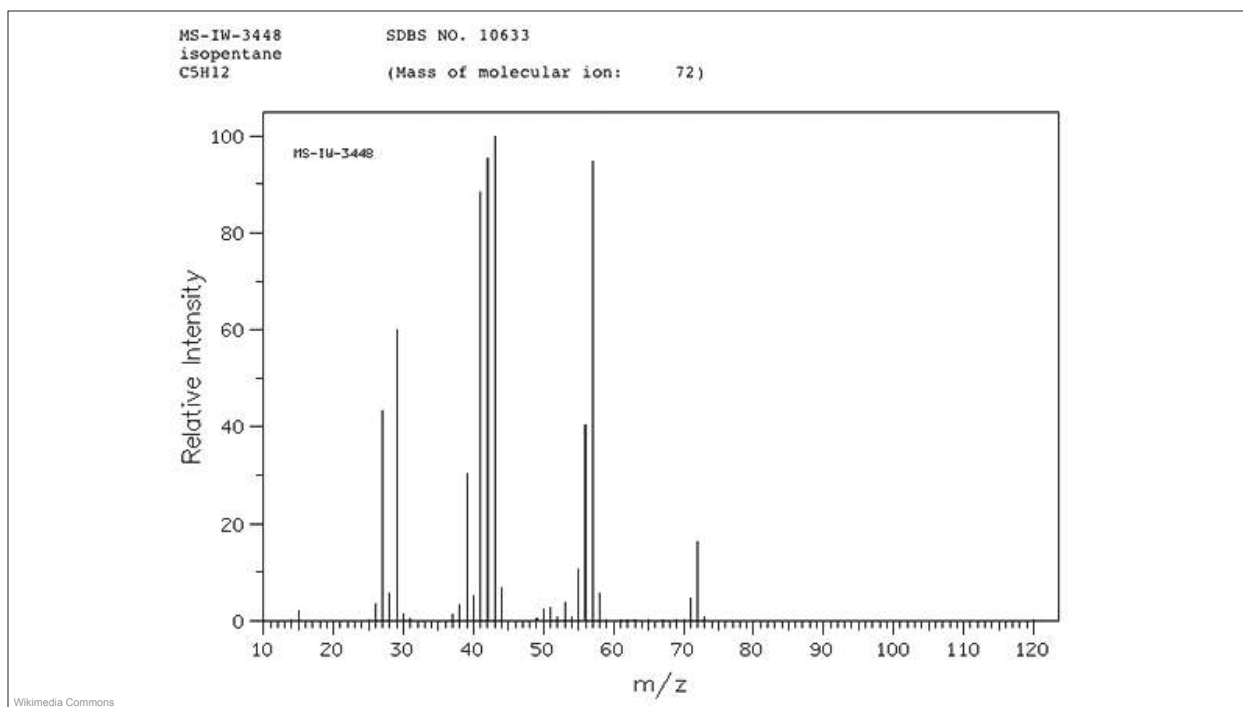


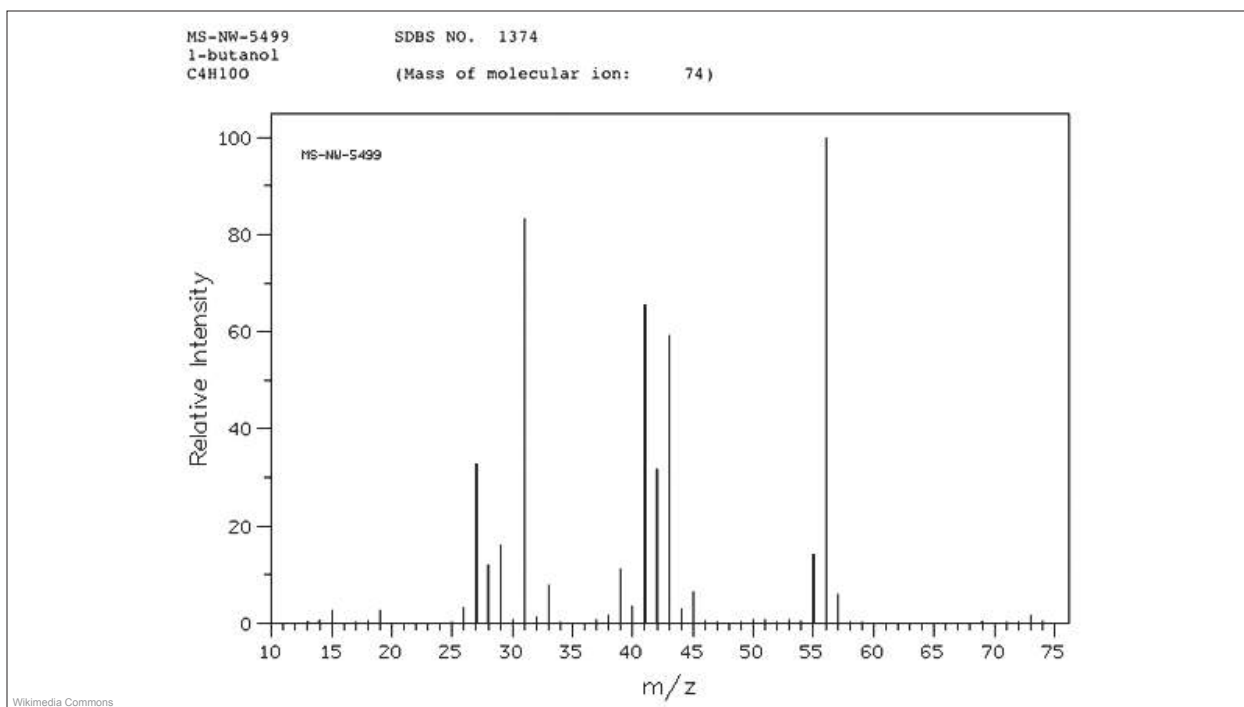
Molecular Spectroscopy

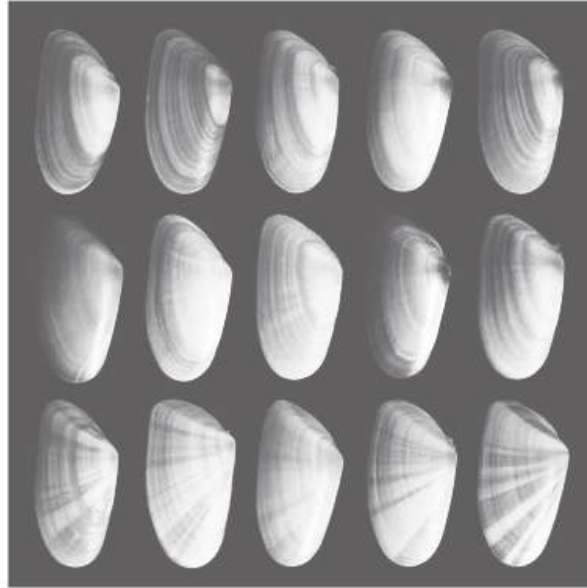




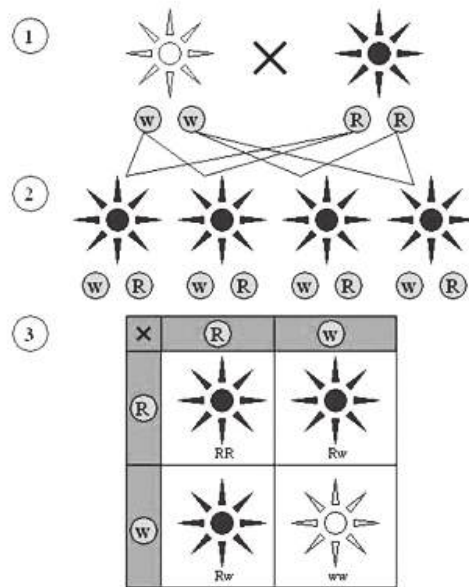
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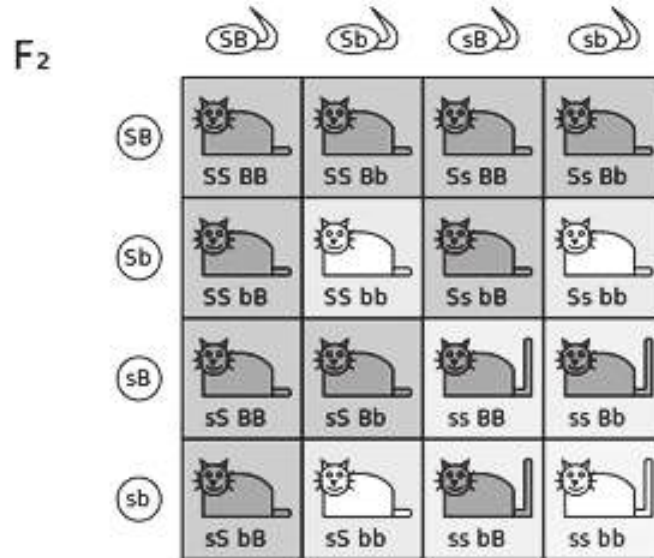
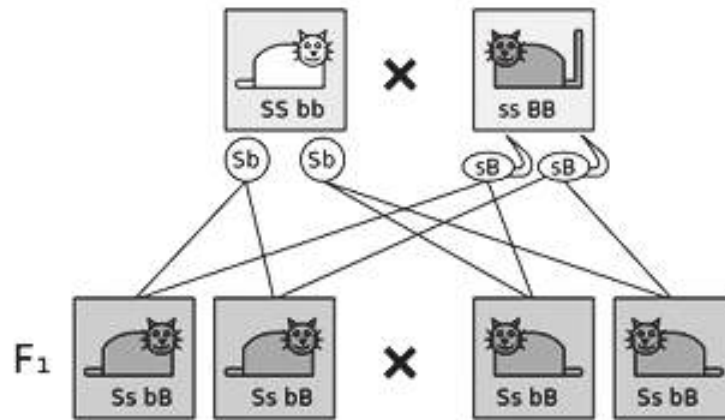




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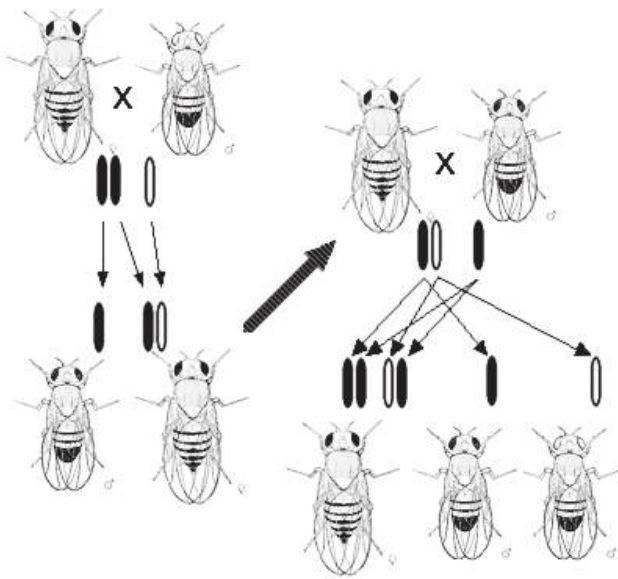


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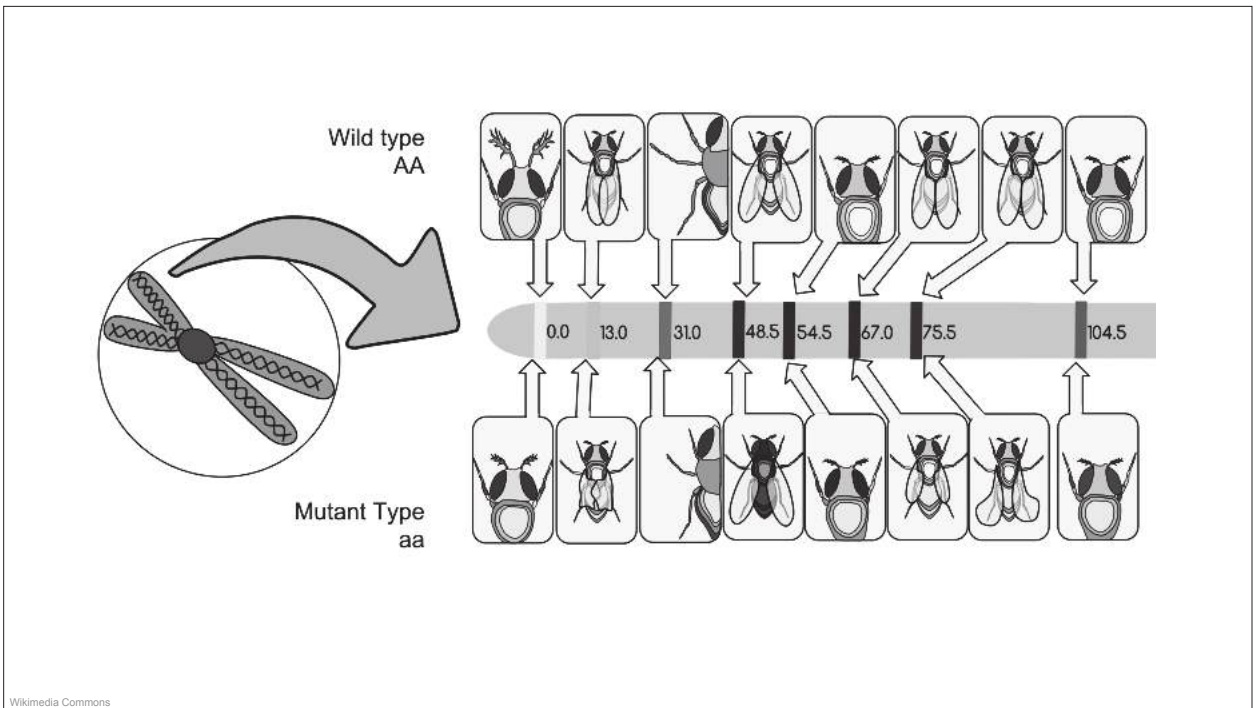
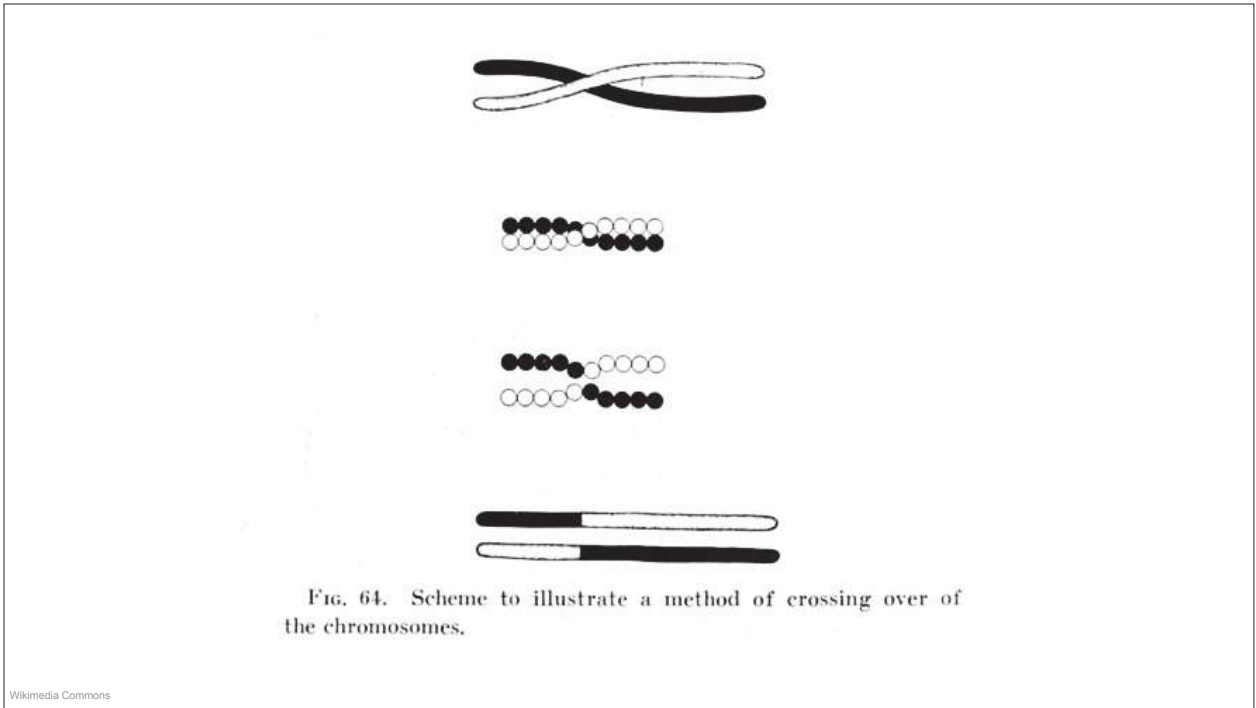


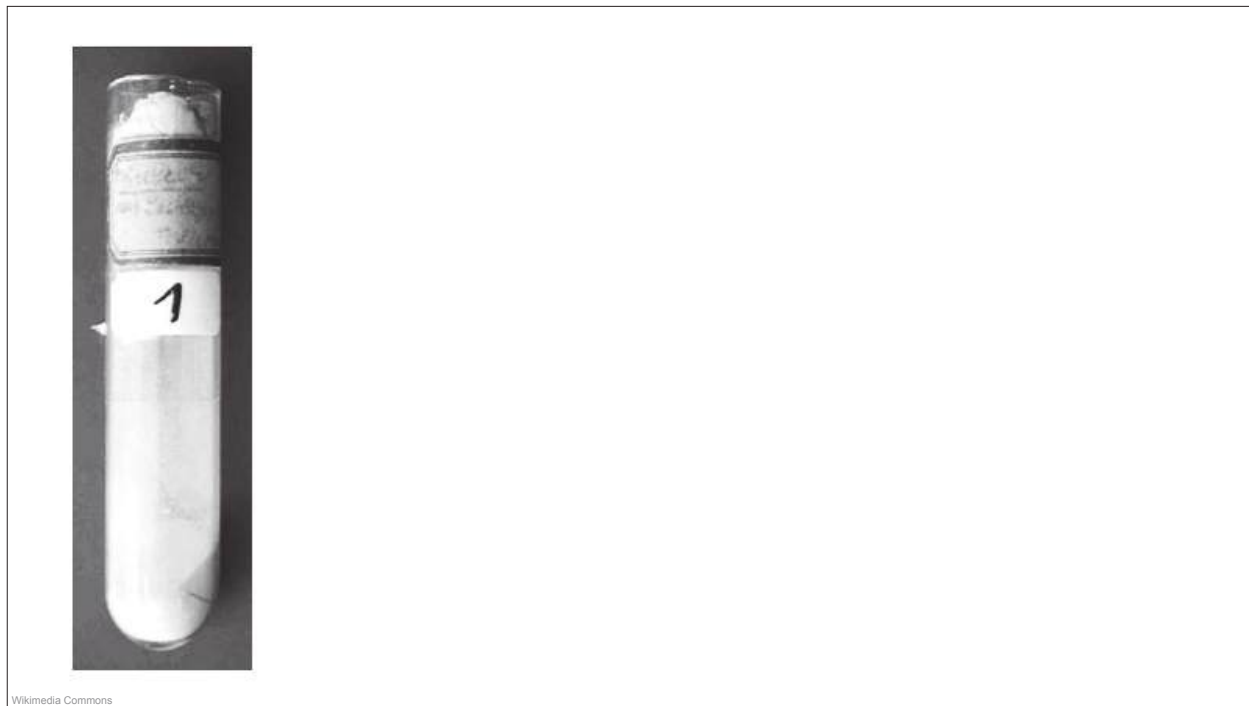
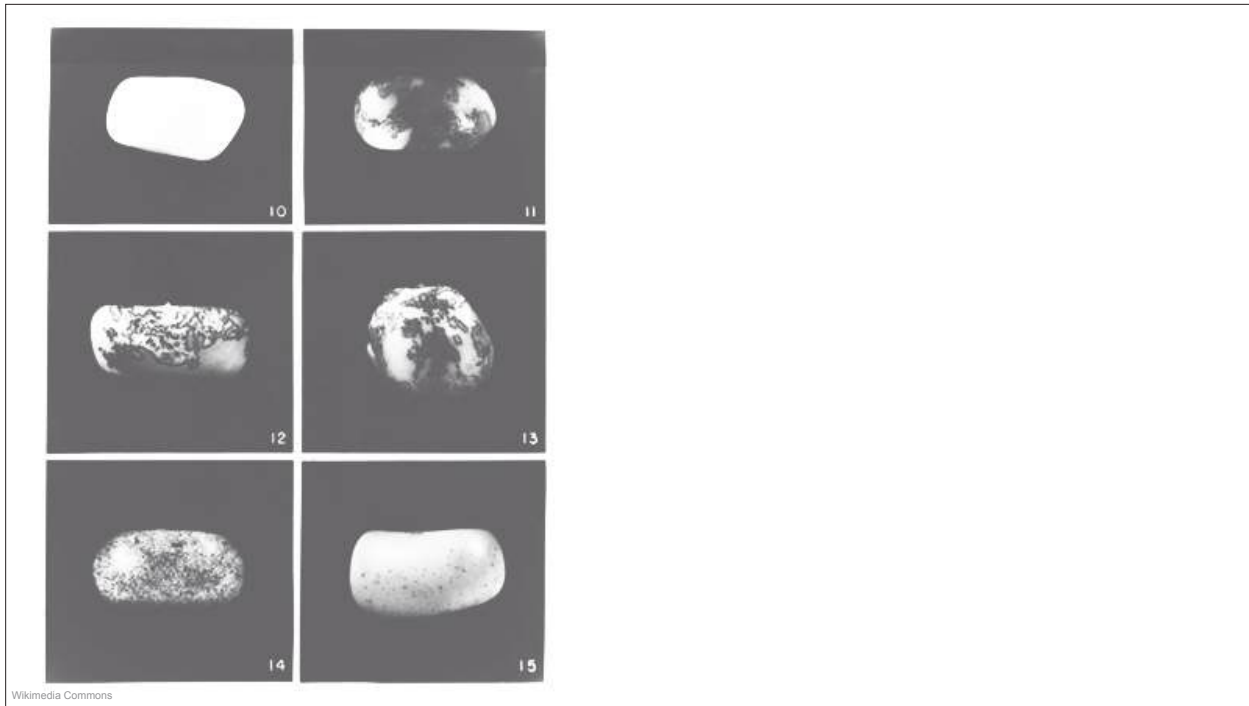


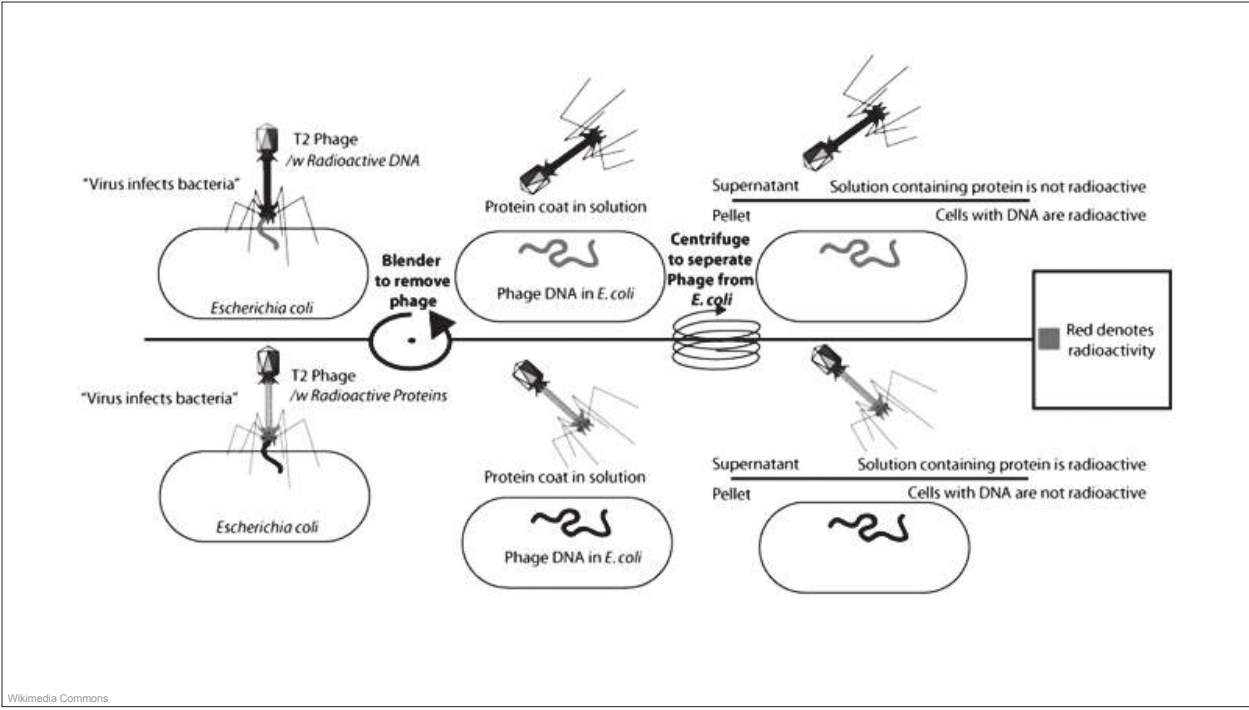
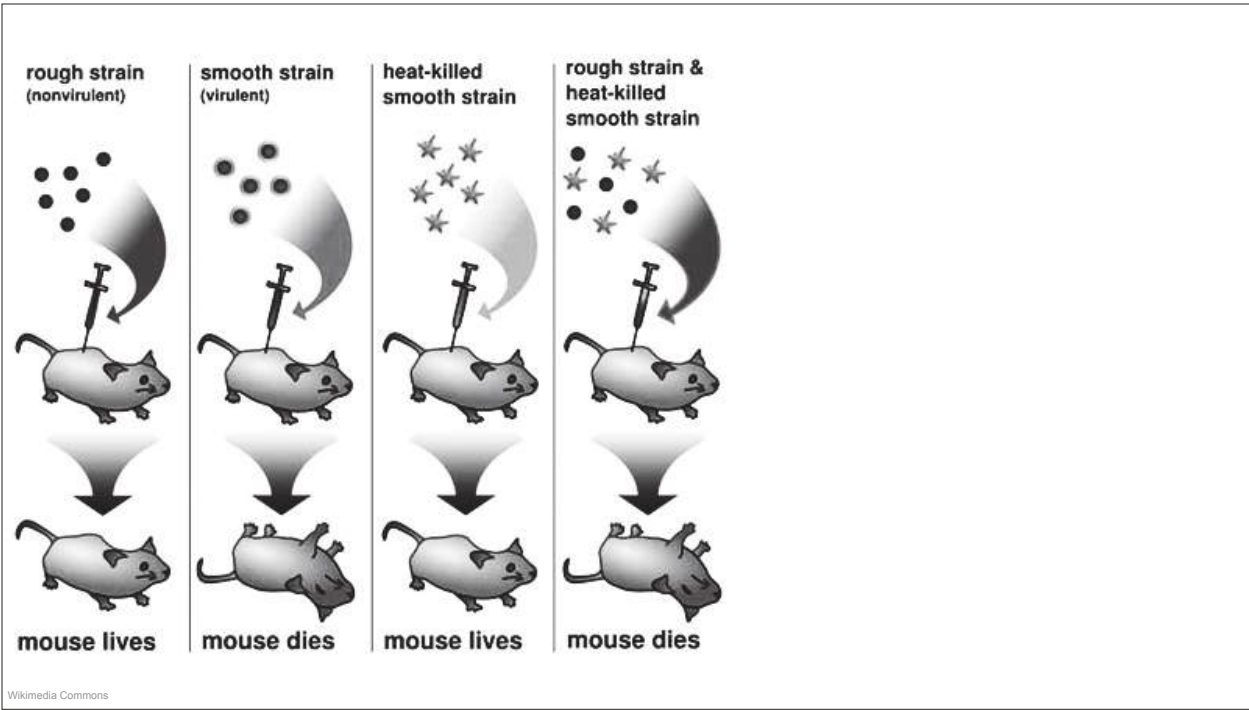
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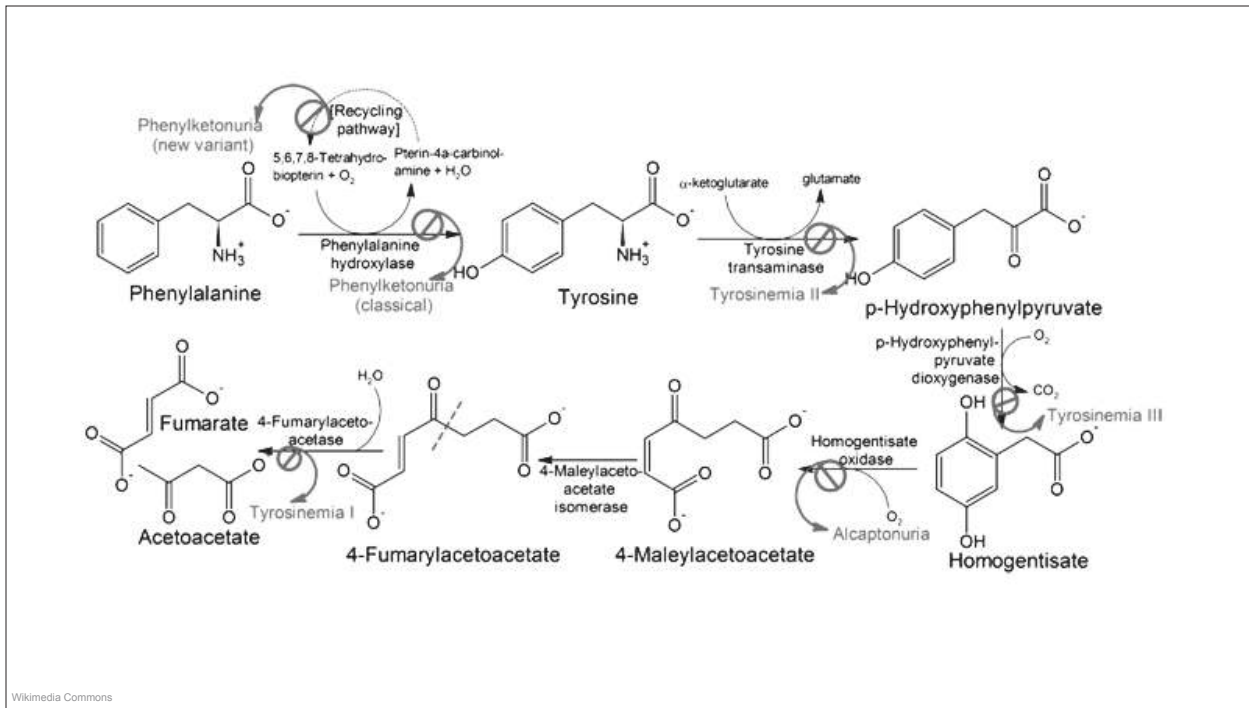


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RESULTS

Classes of *Neurospora crassa*

	Wild type	Class I mutants	Class II mutants	Class III mutants
Minimal medium (MM) (control)				
MM + ornithine				
MM + citrulline				
MM + arginine (control)				

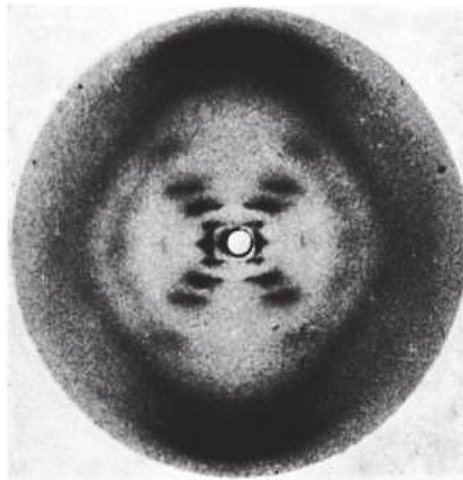
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Through careful experimentation, Chargaff discovered two rules that helped lead to the discovery of the double helix structure of DNA.

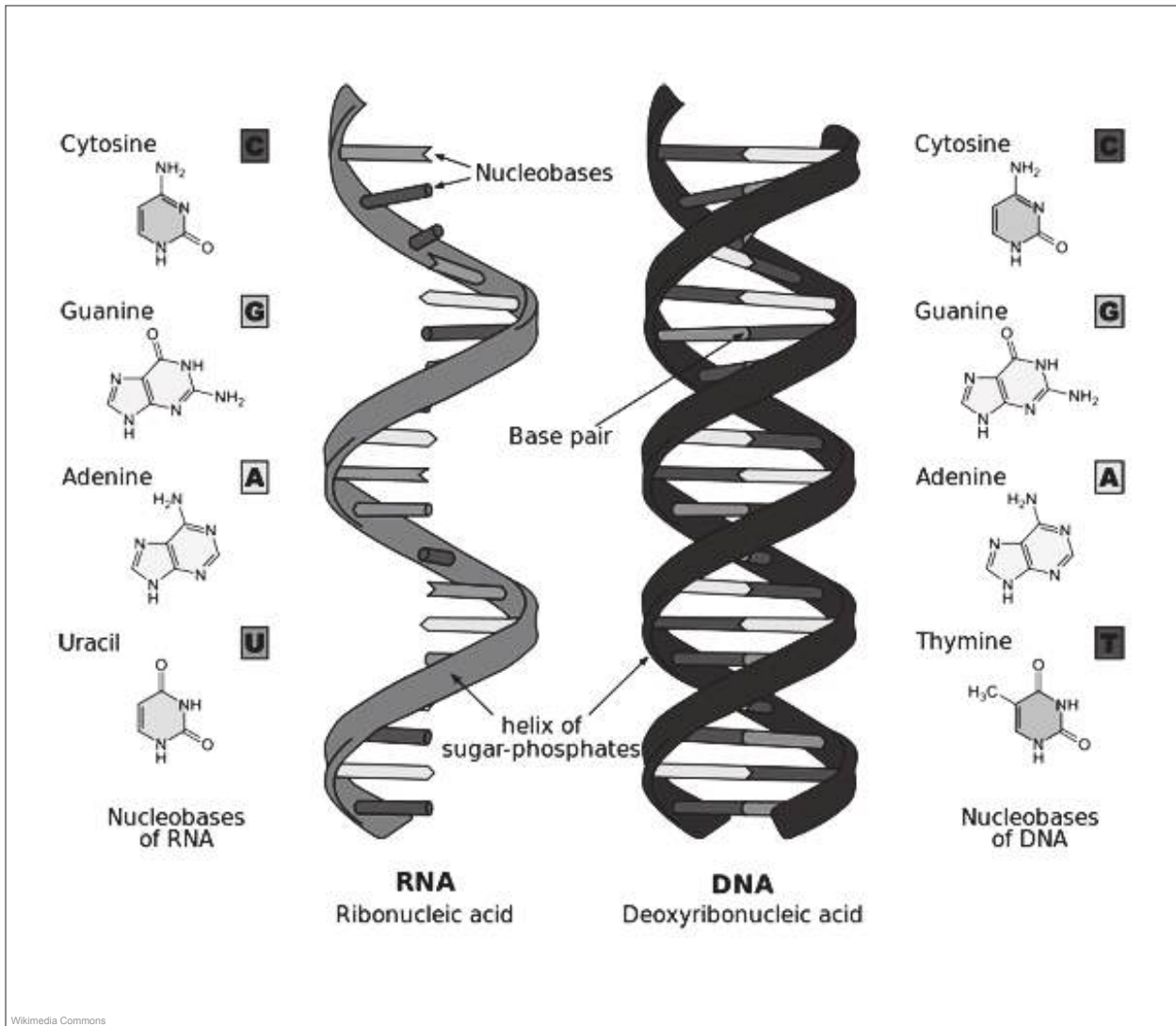
The first rule was that in DNA the number of guanine units equals the number of cytosine units, and the number of adenine units equals the number of thymine units. This hinted at the base pair makeup of DNA.

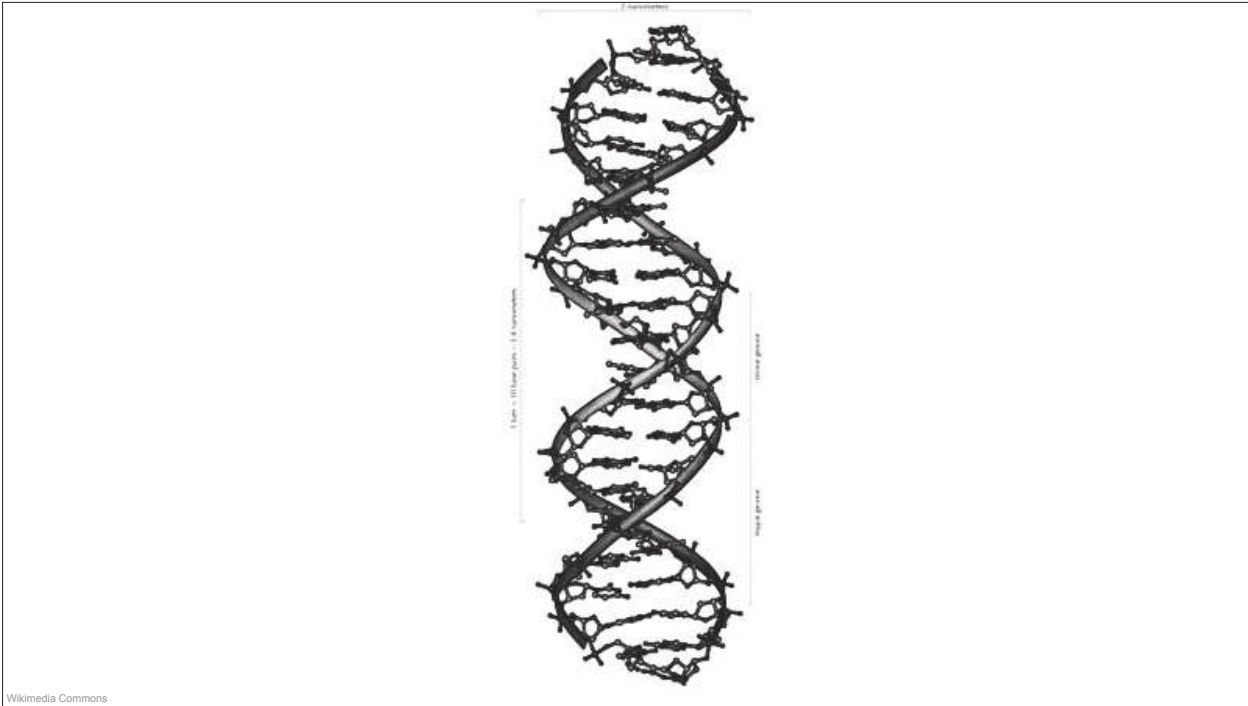
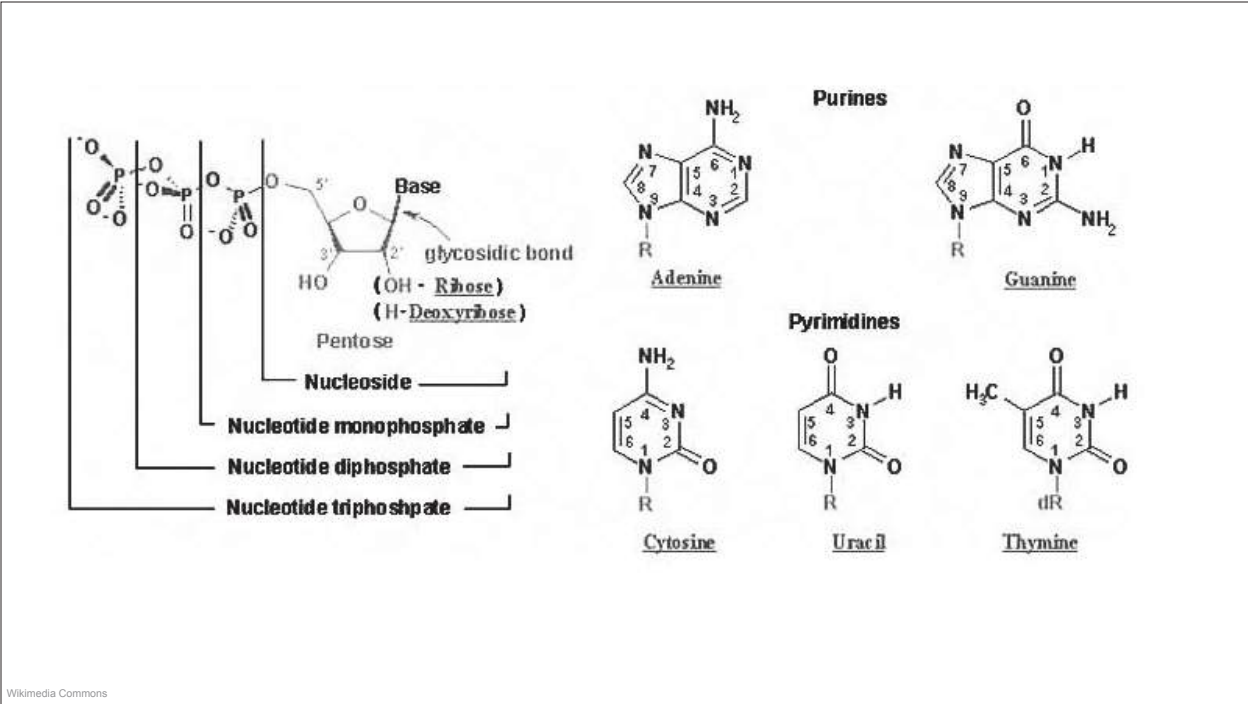
The second rule was that the relative amounts of guanine, cytosine, adenine and thymine bases varies from one species to another. This hinted that DNA rather than protein could be the genetic material.

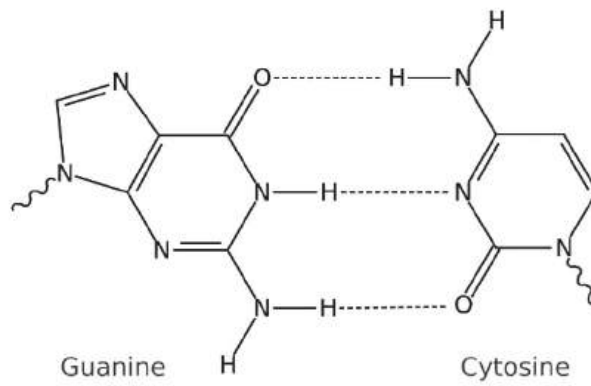
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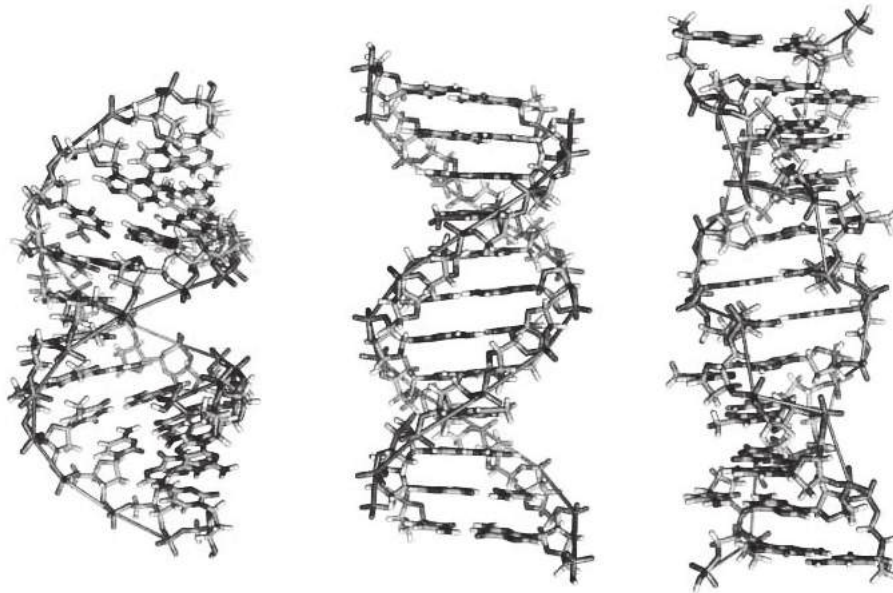
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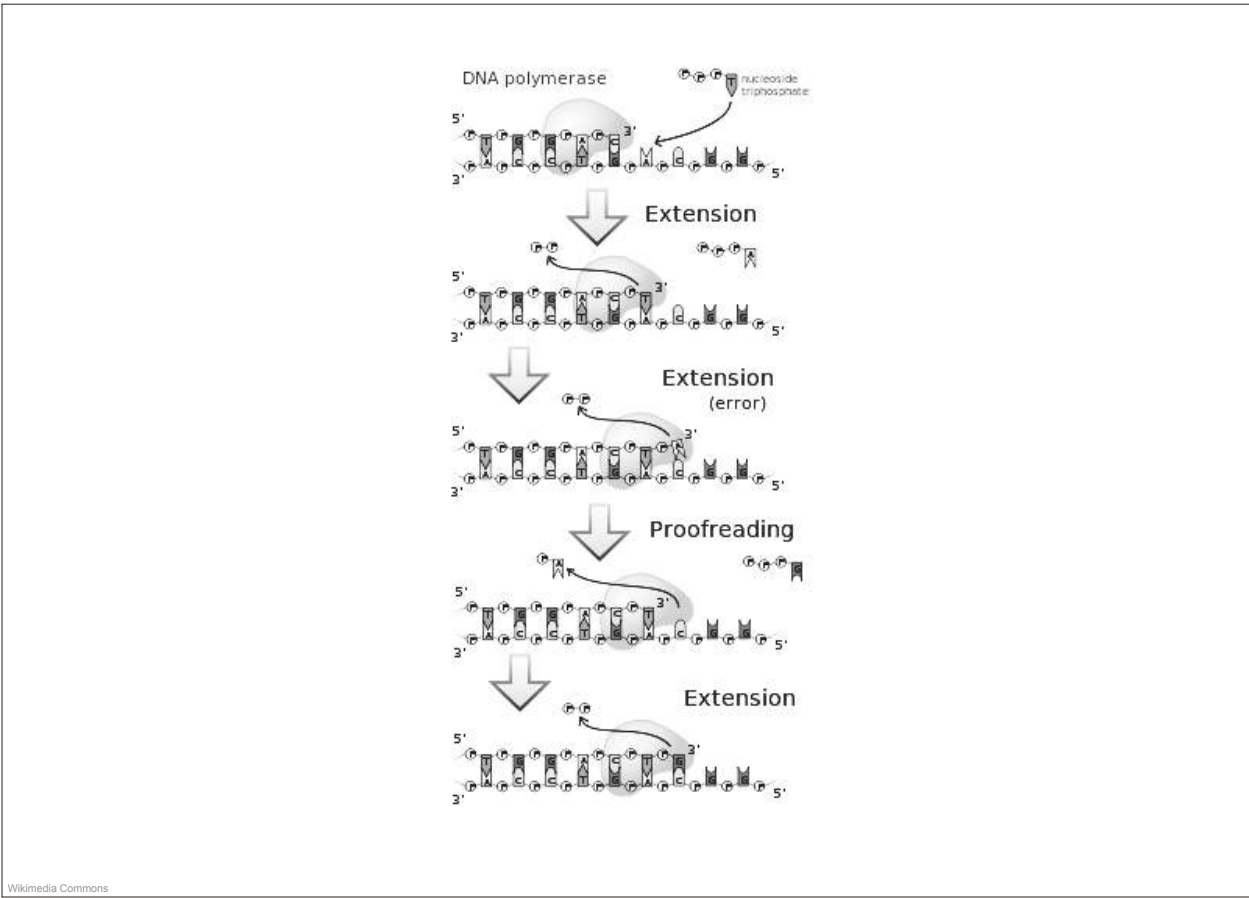
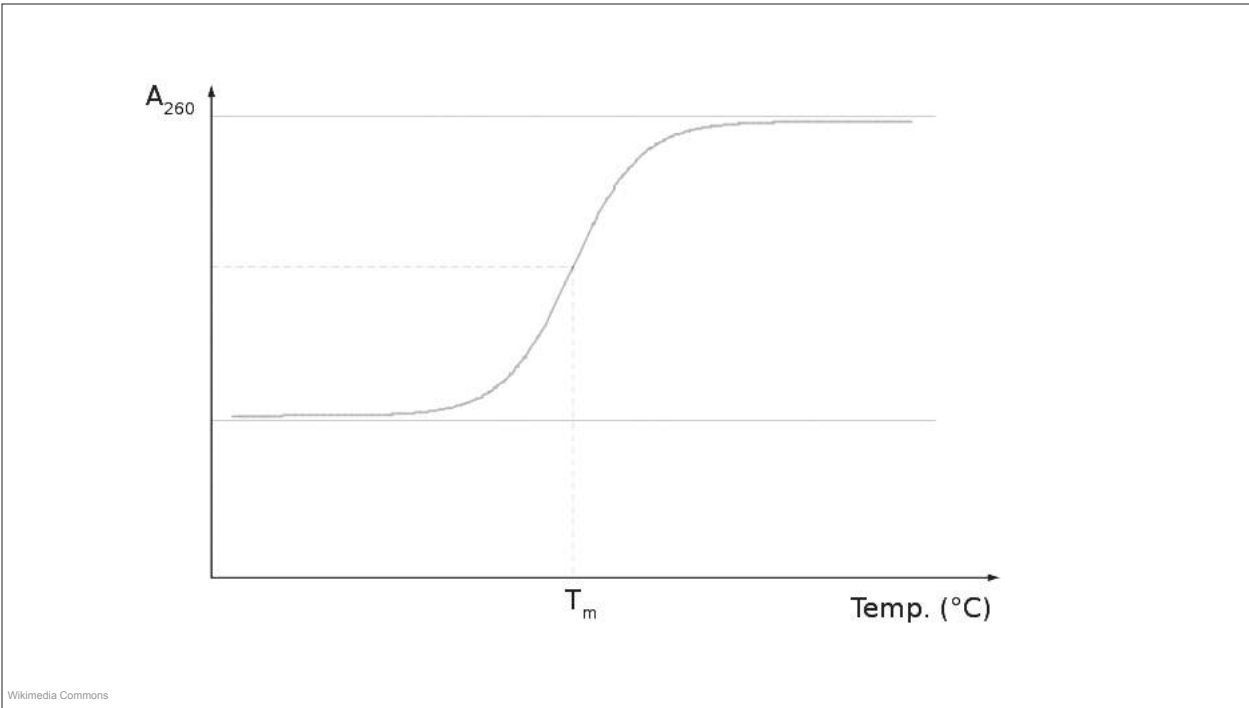


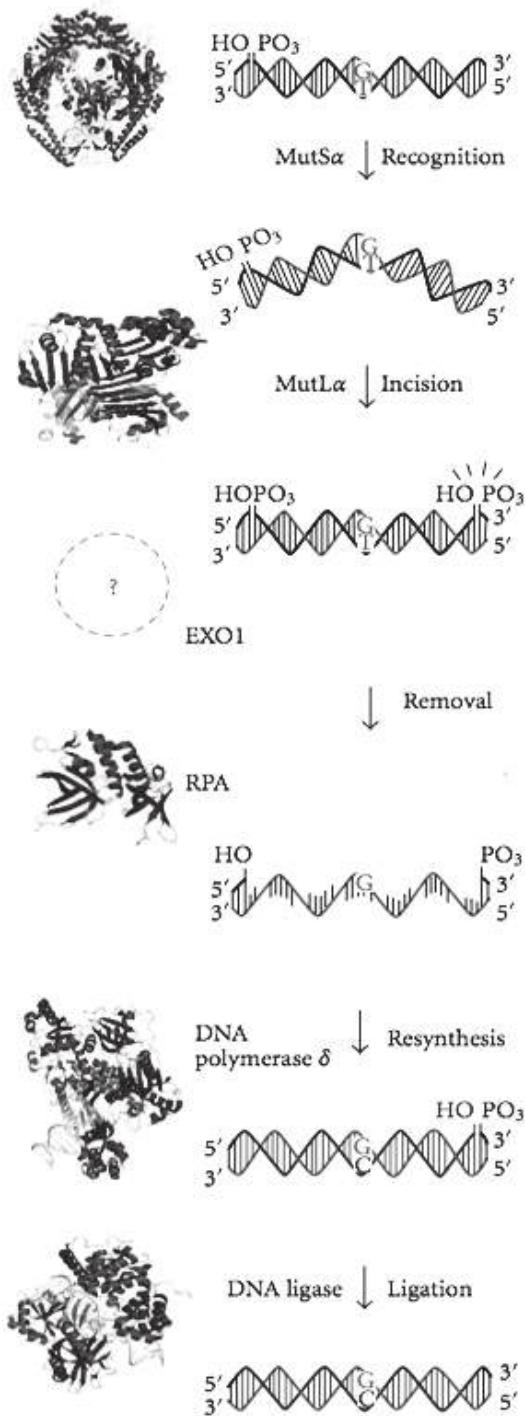


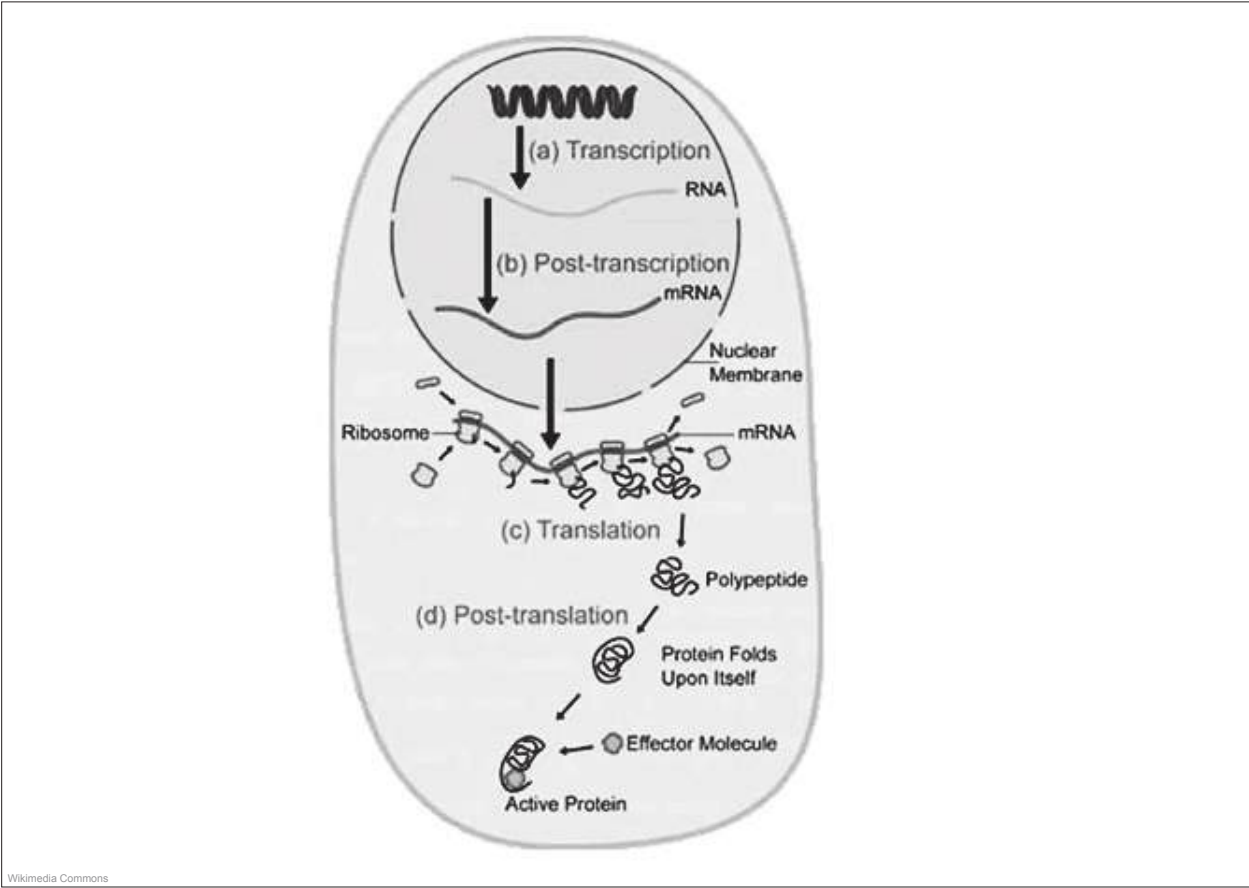
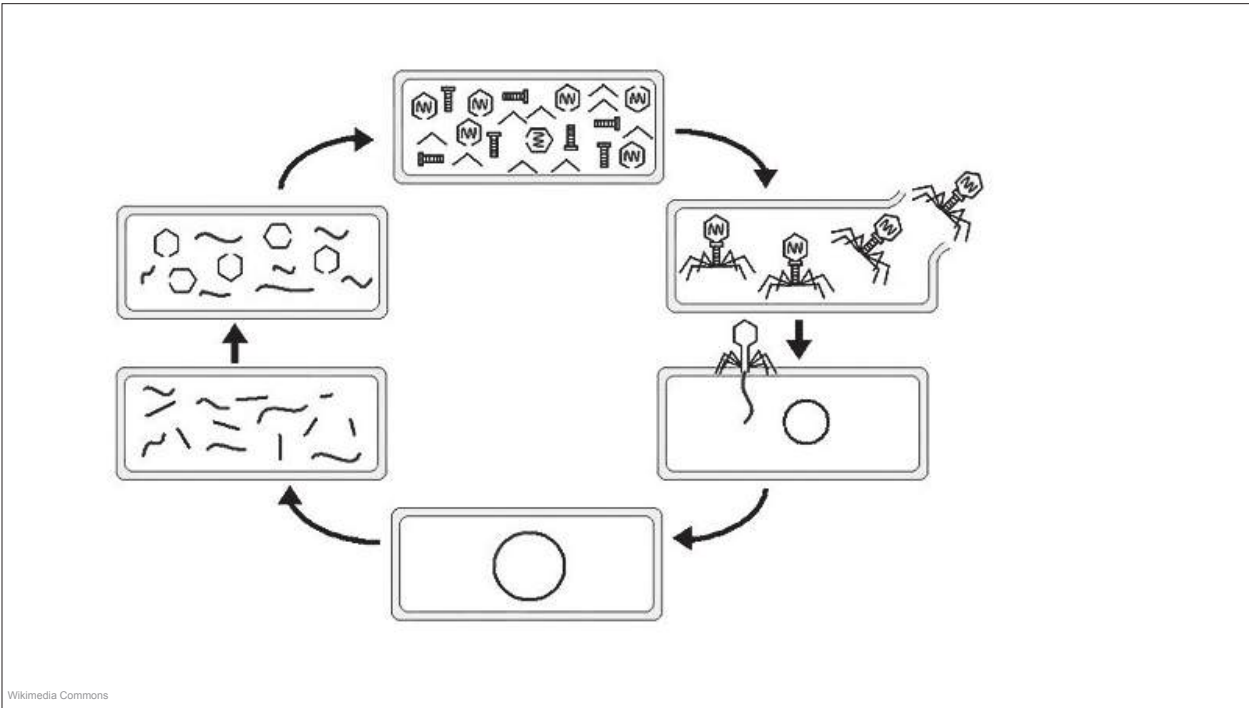
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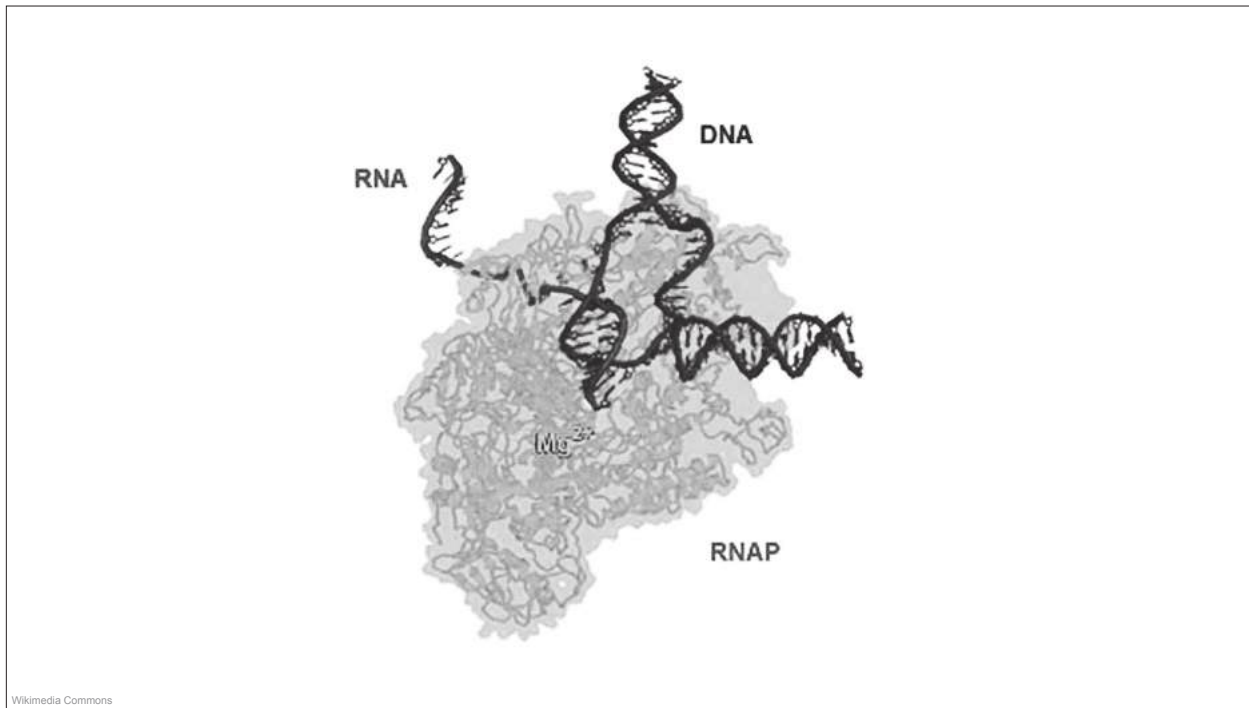
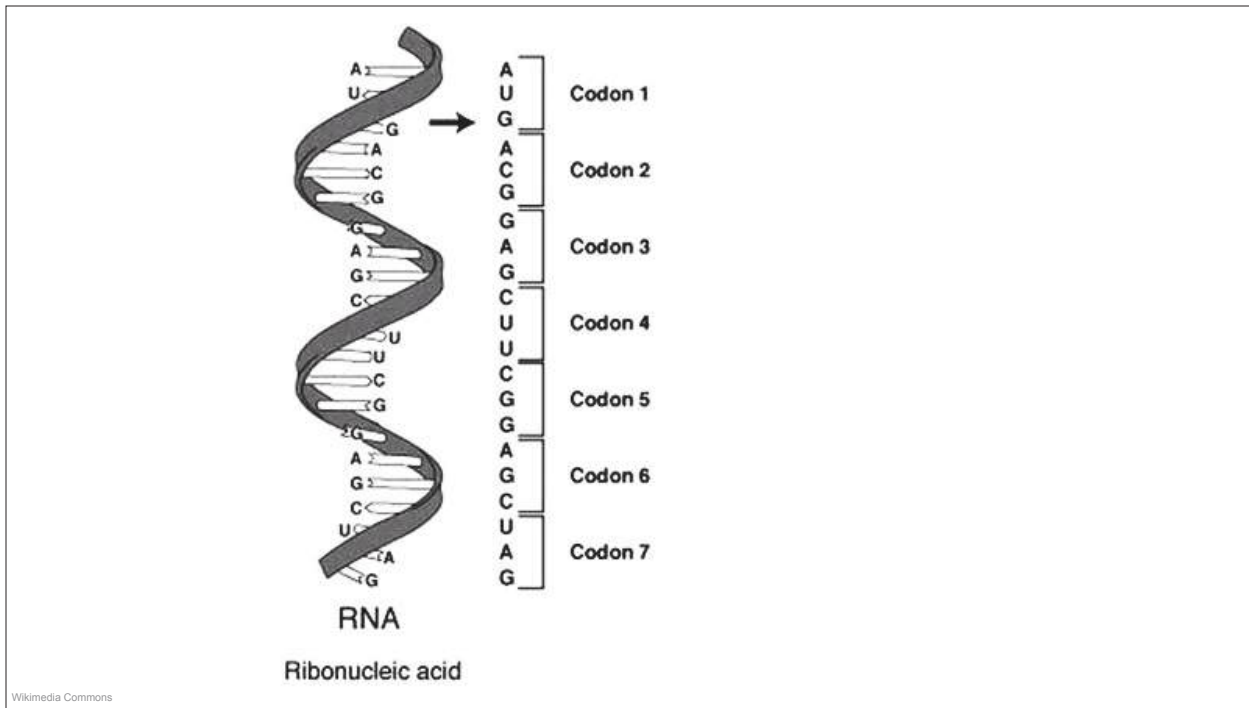


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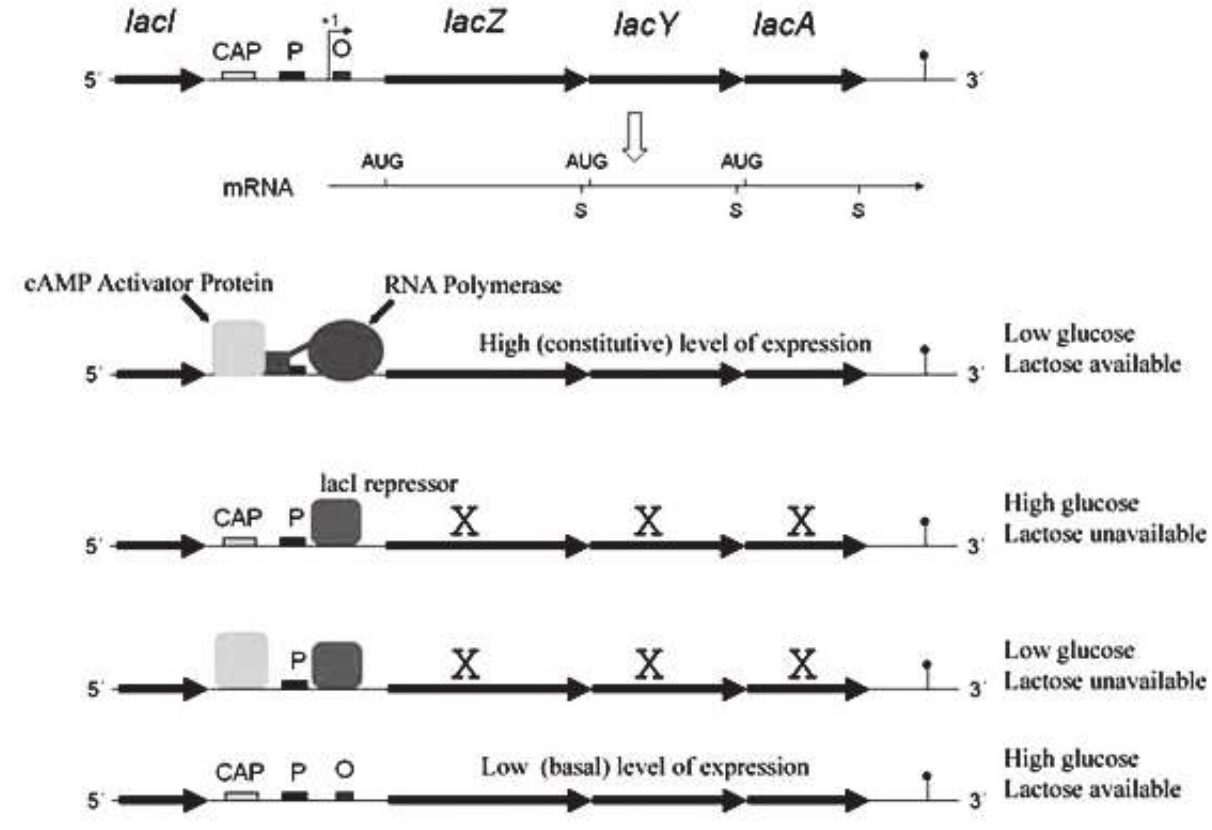




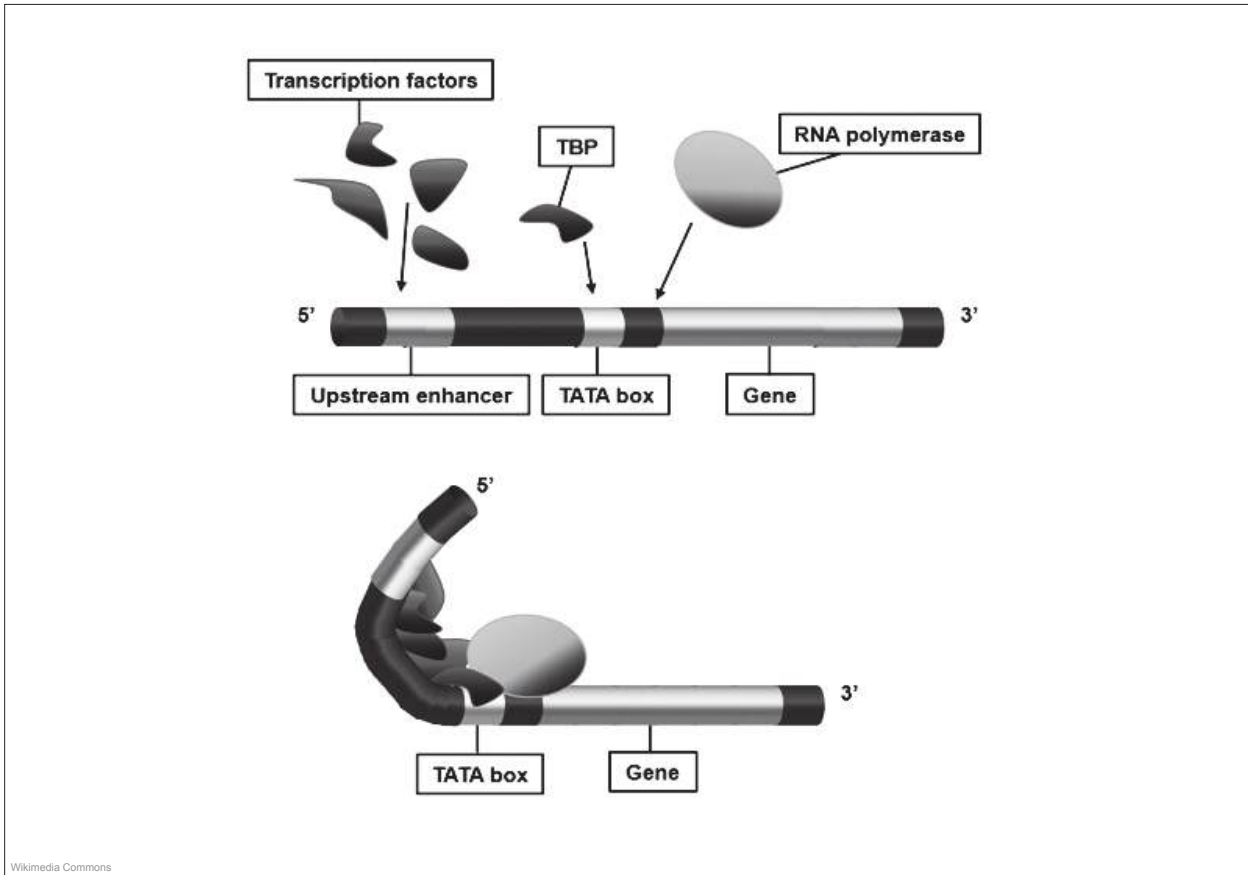
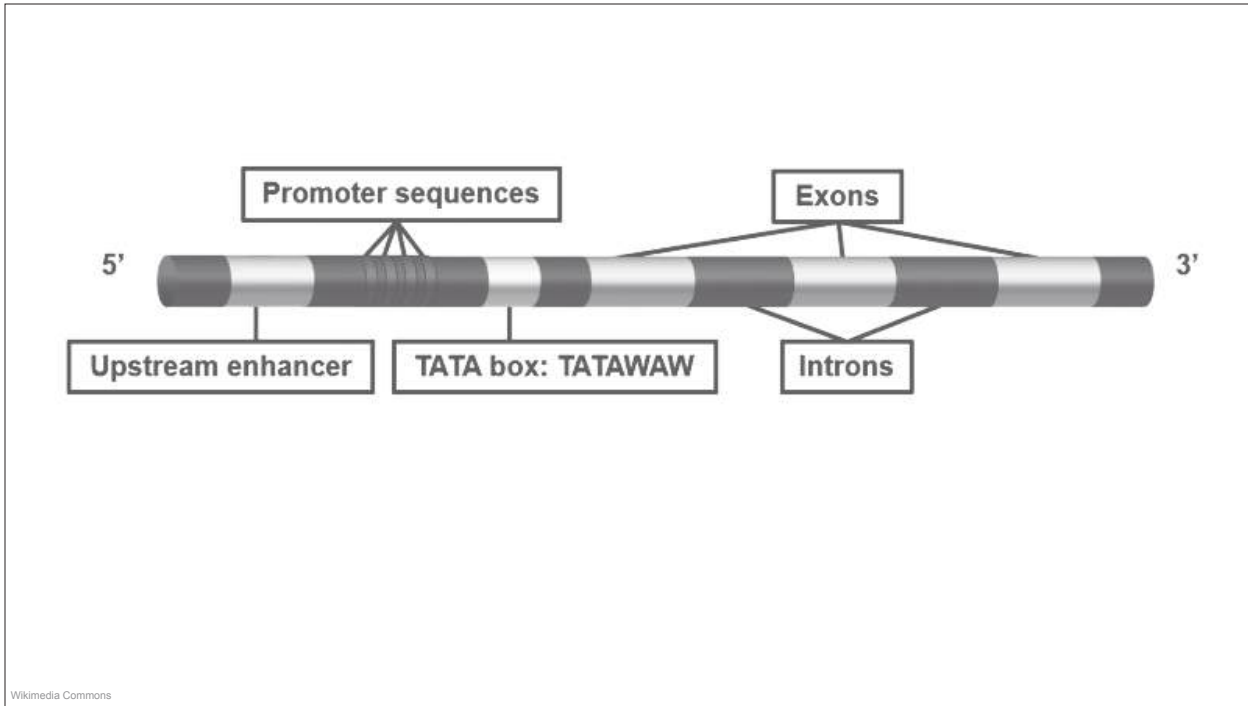


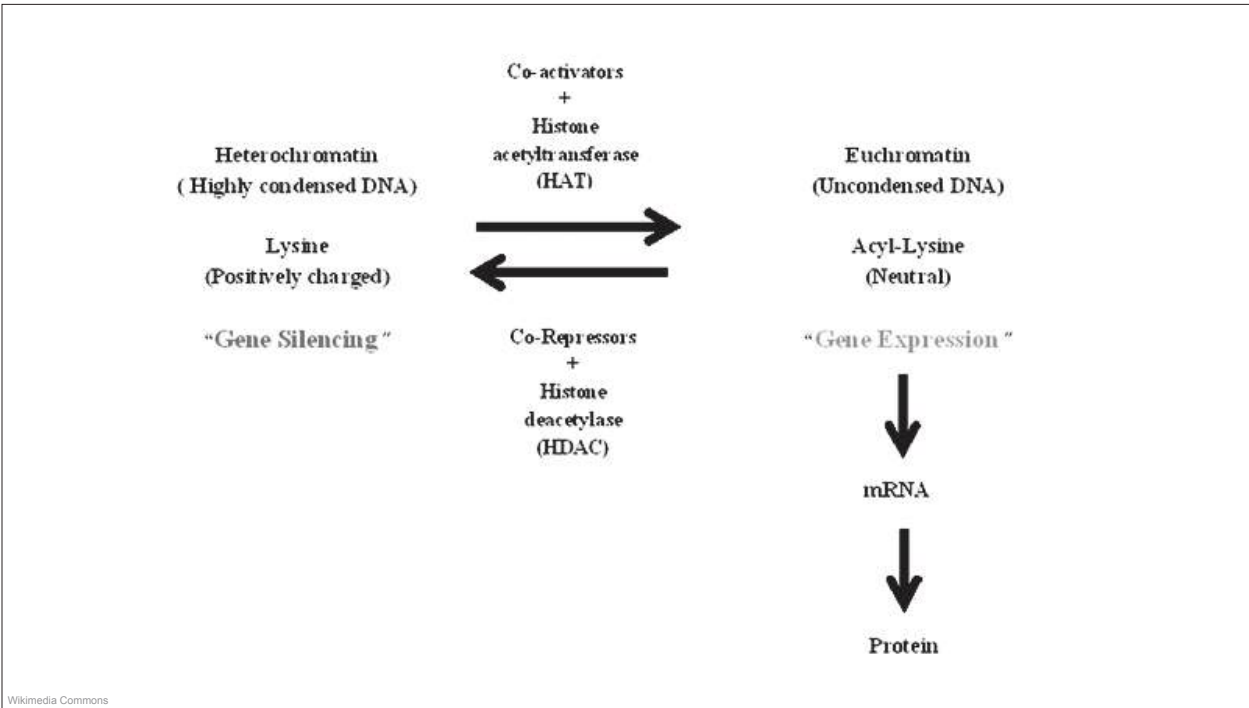
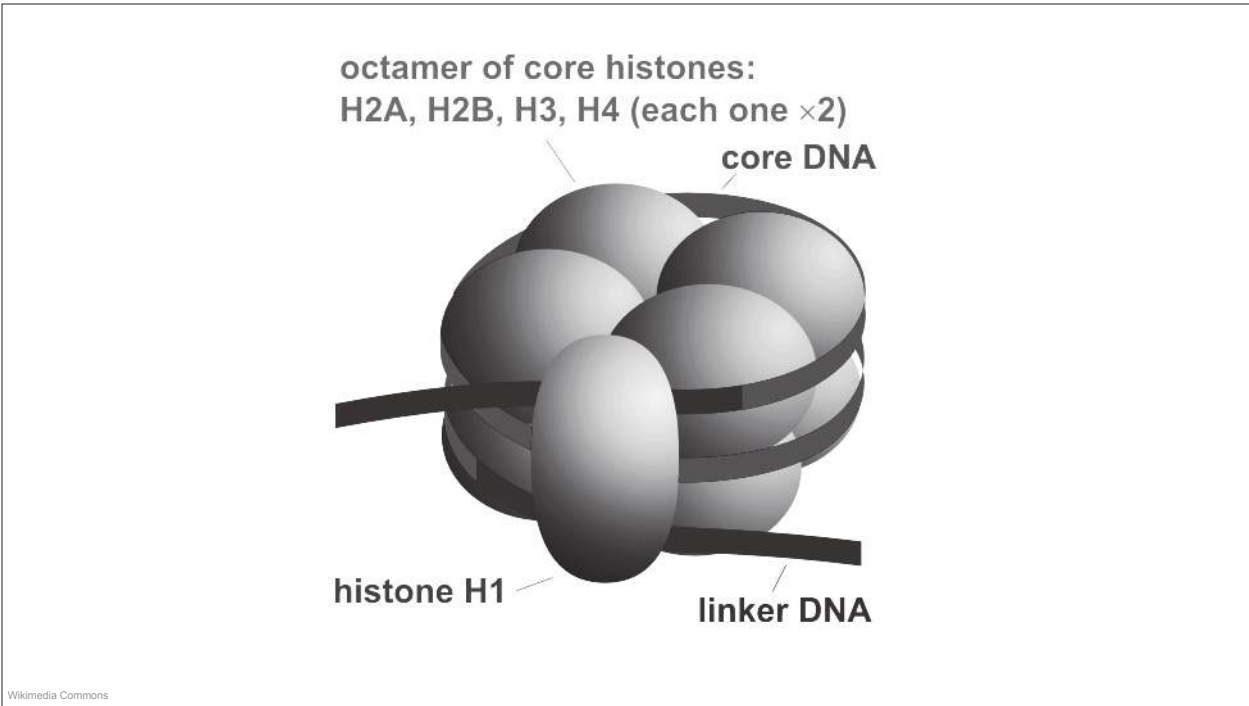


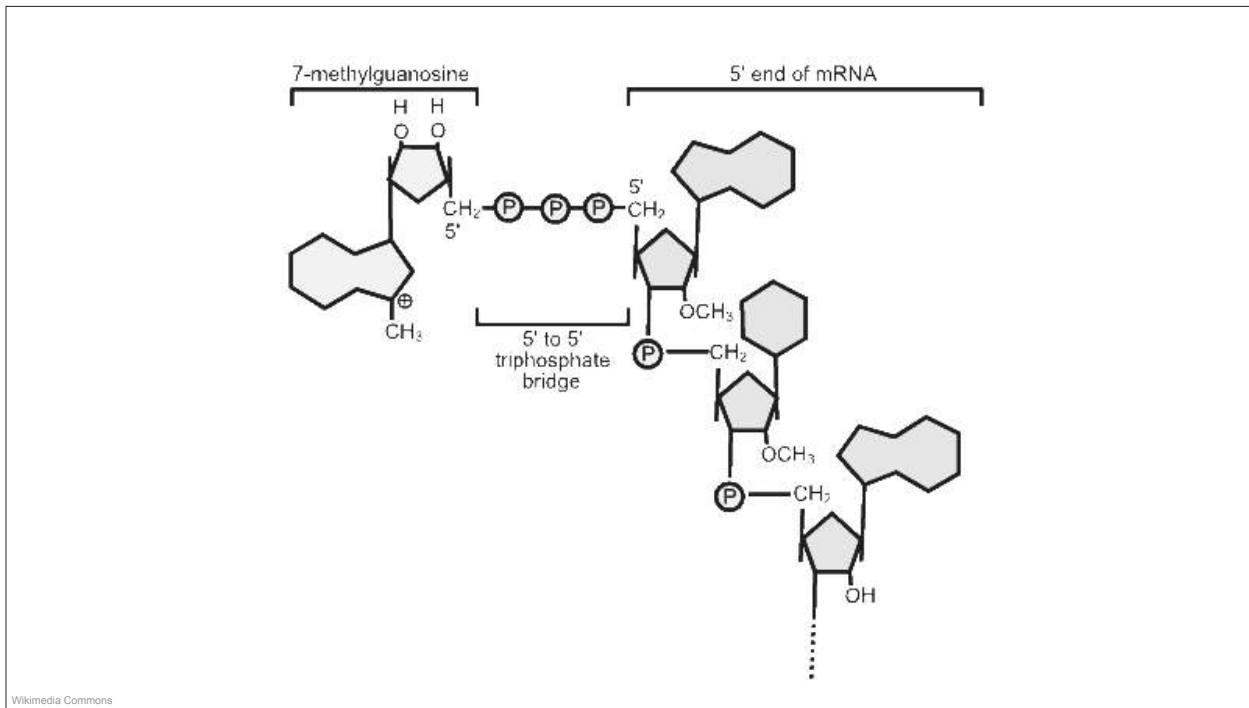
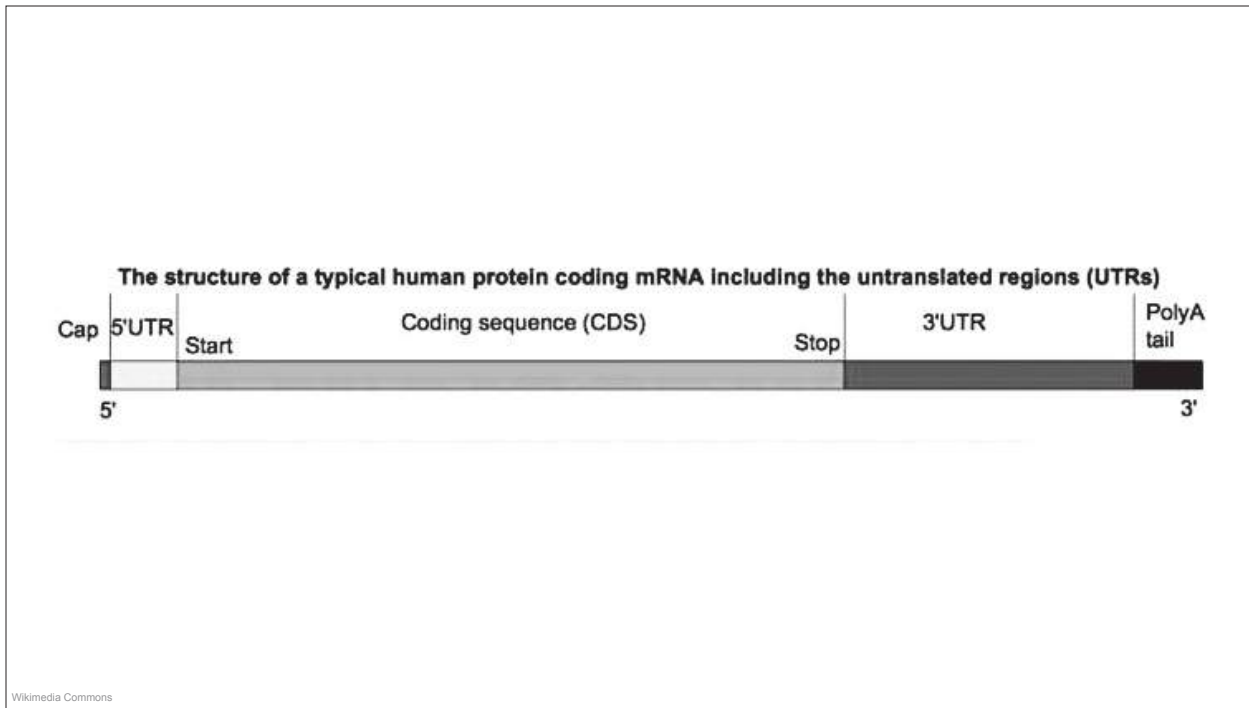
The *lac* Operon and its Control Elements

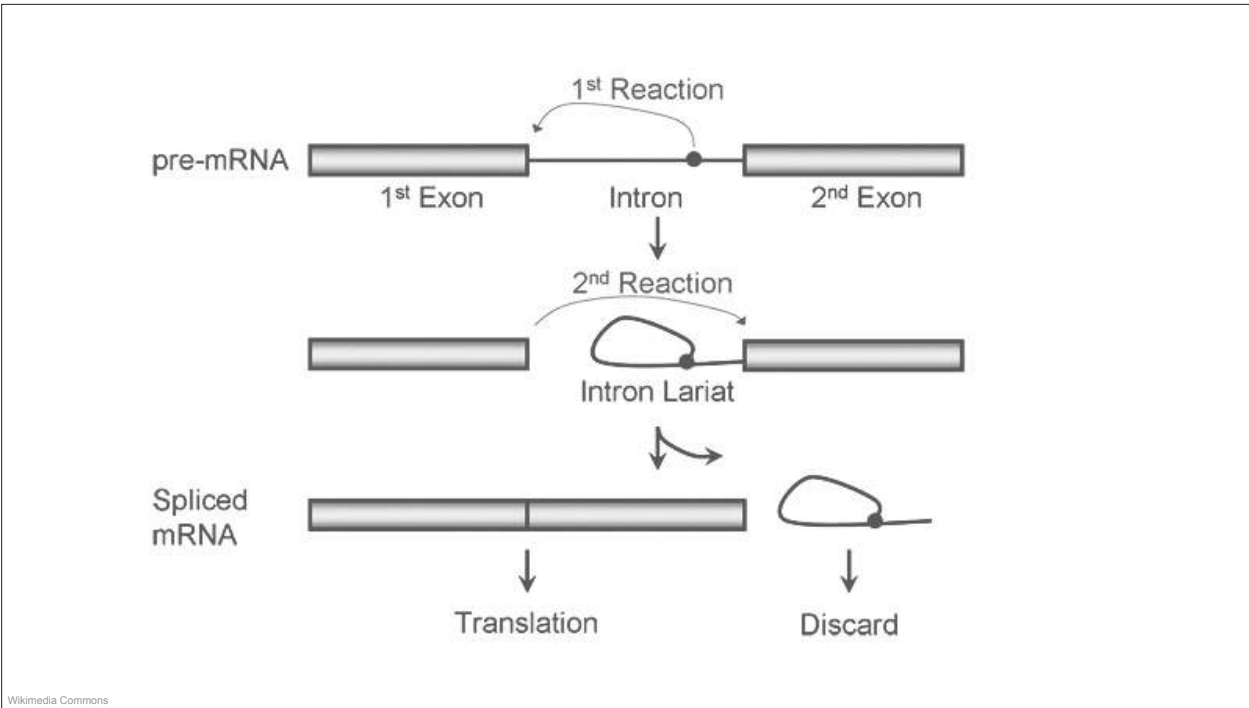
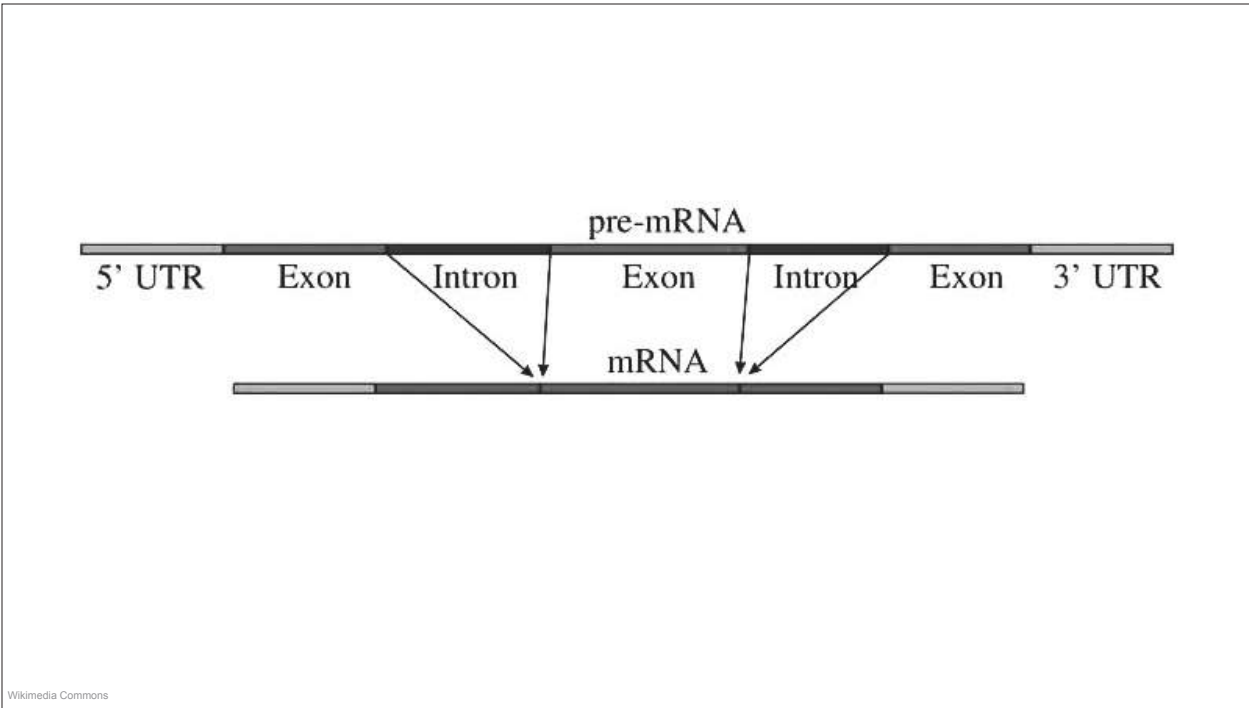


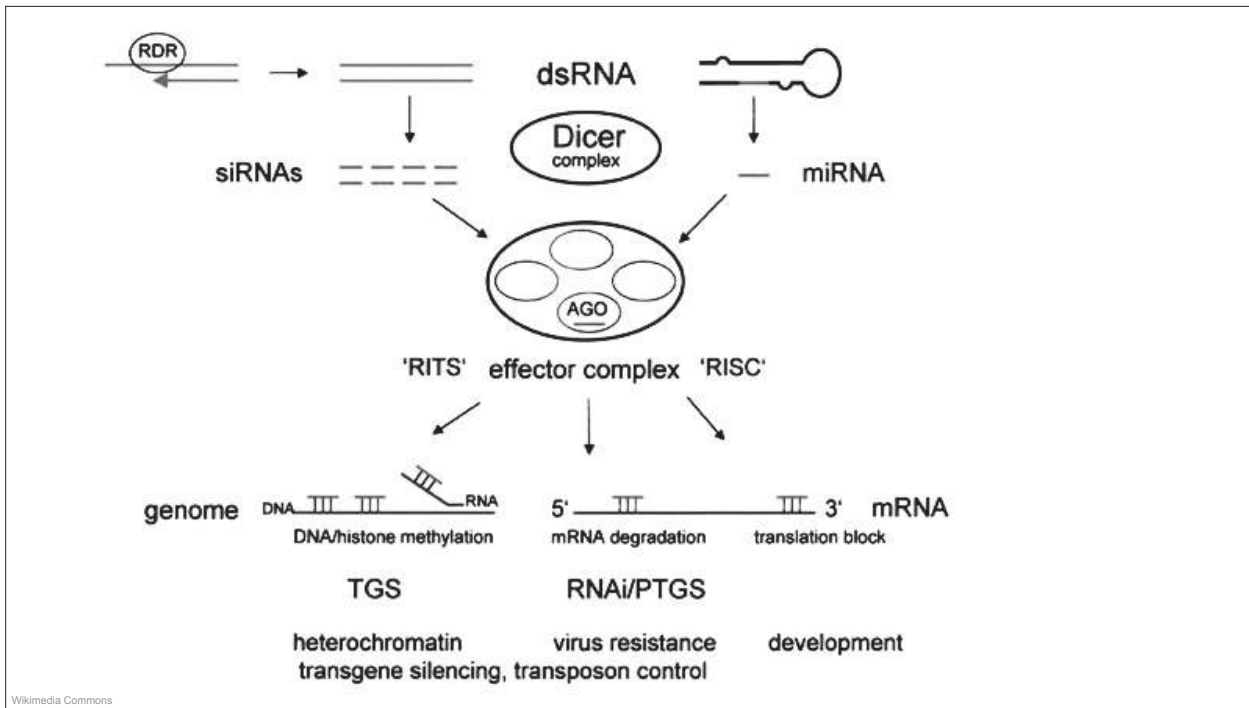
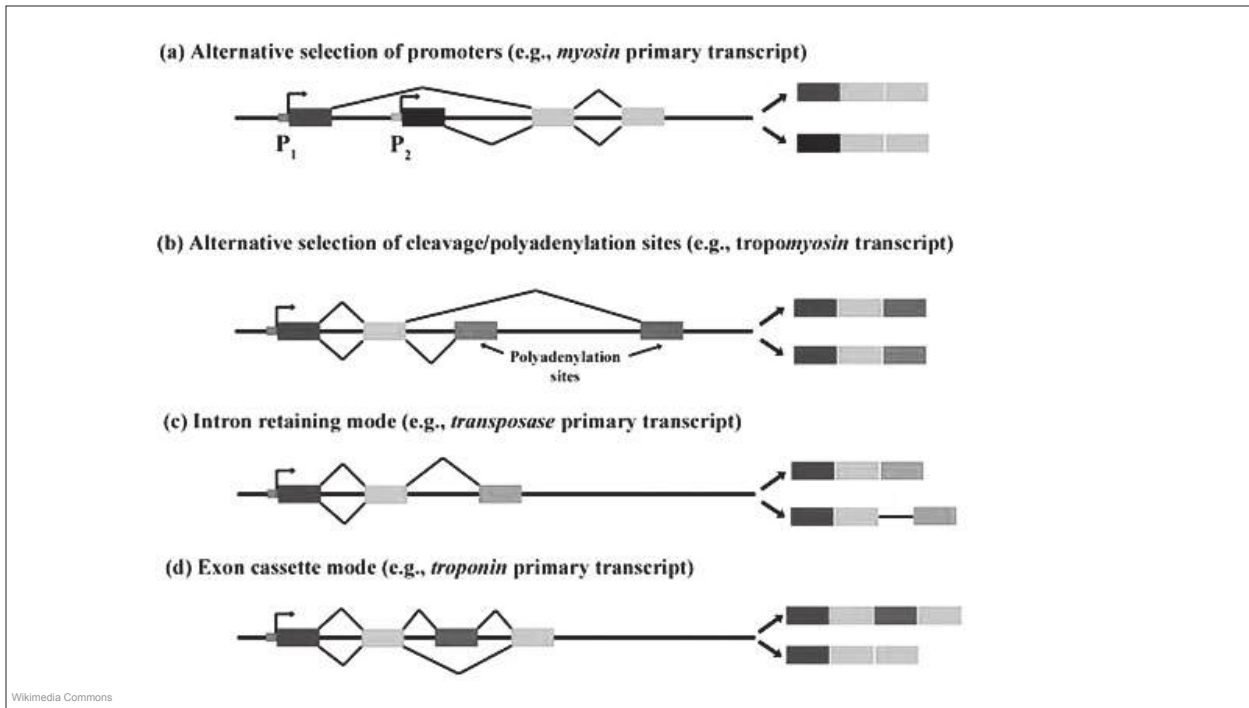
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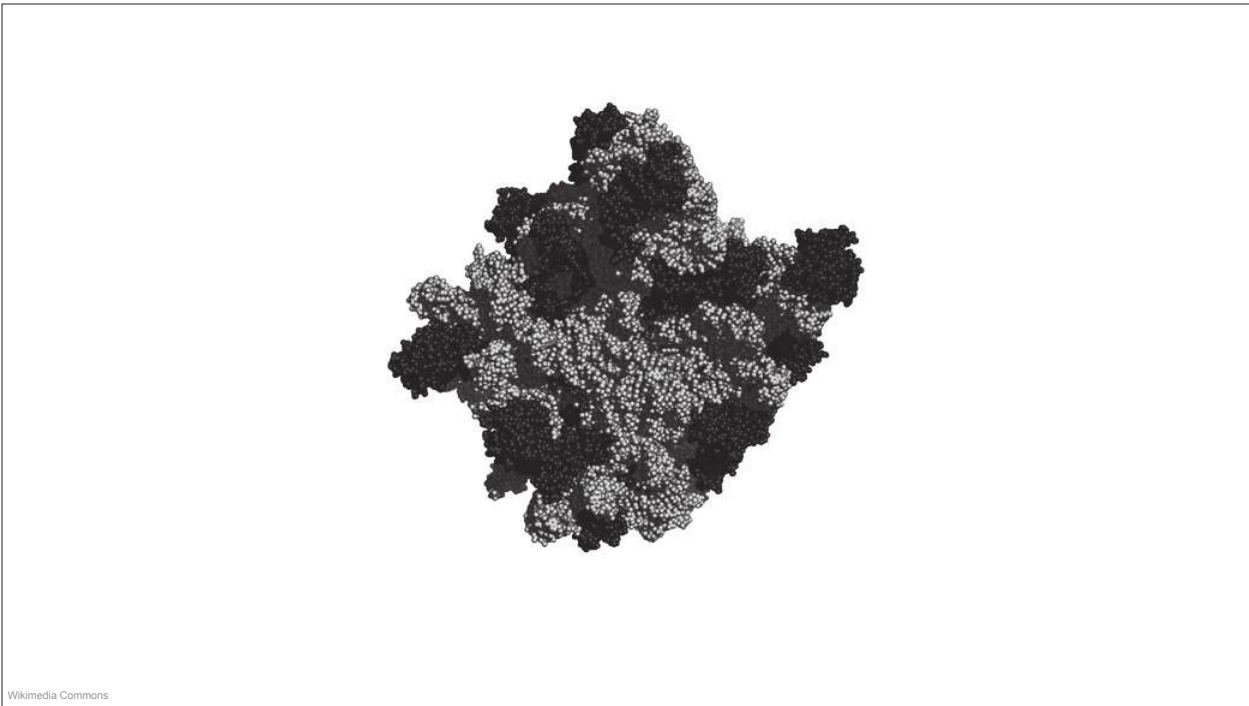






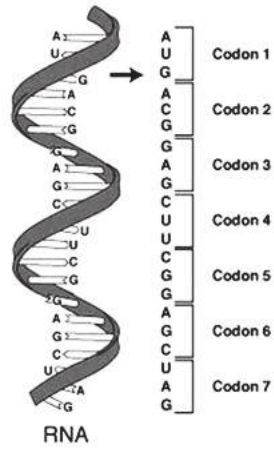






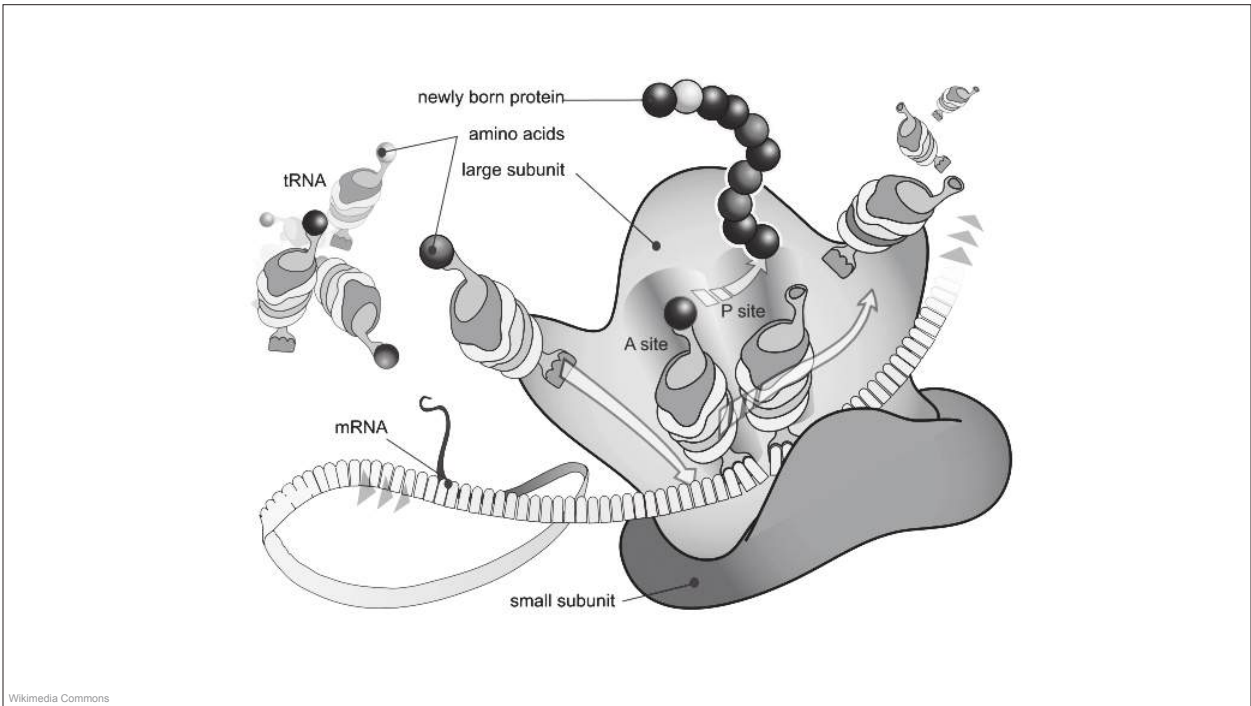
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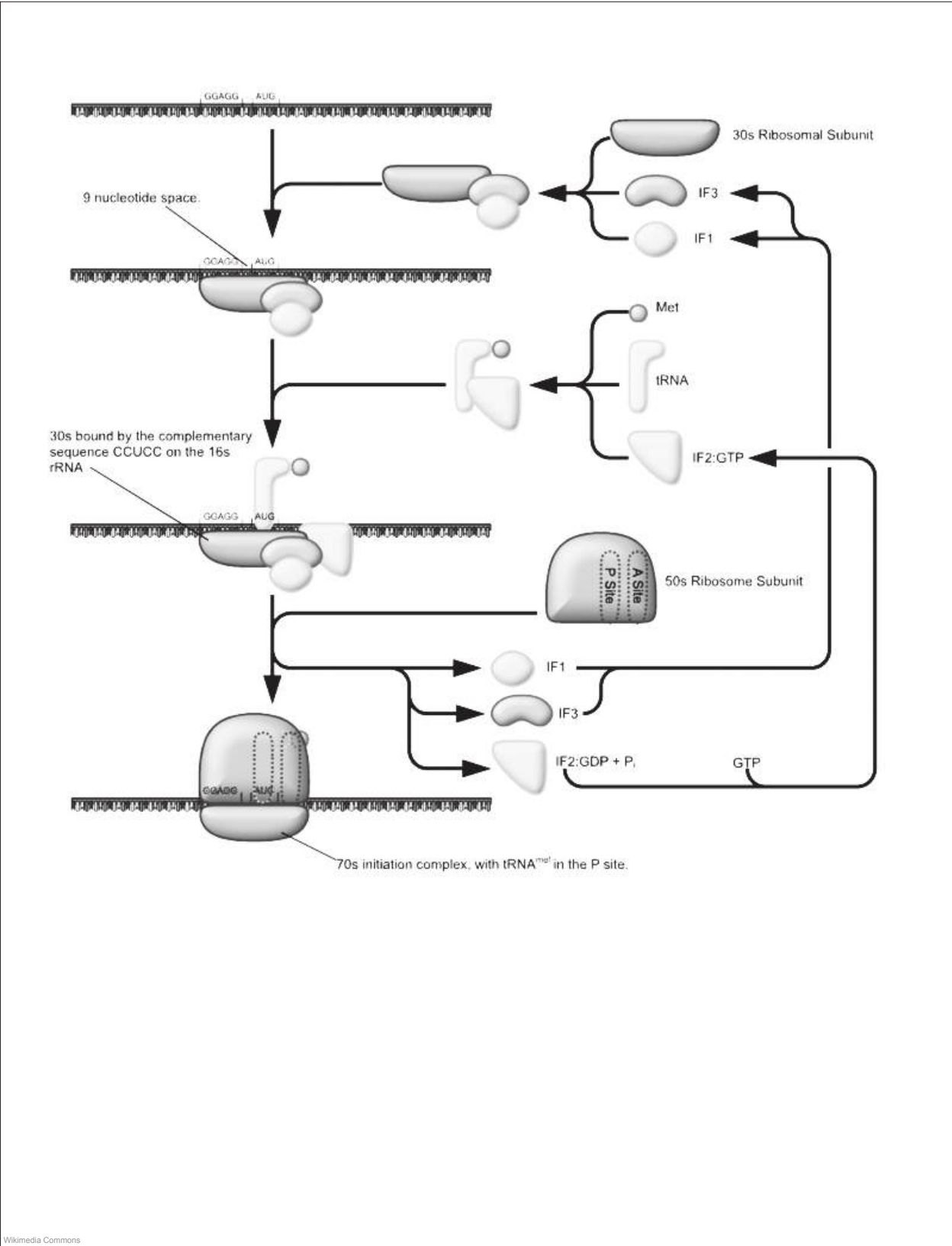
		Second Base				
		U	C	A	G	
First Base	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA } STOP UAG }	UGU } Cys UGC } UGA } STOP UGG } Trp	Third Base
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U
	A	AUU } AUC } Ile AUA } AUG } Met or Start	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	C
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U
						G



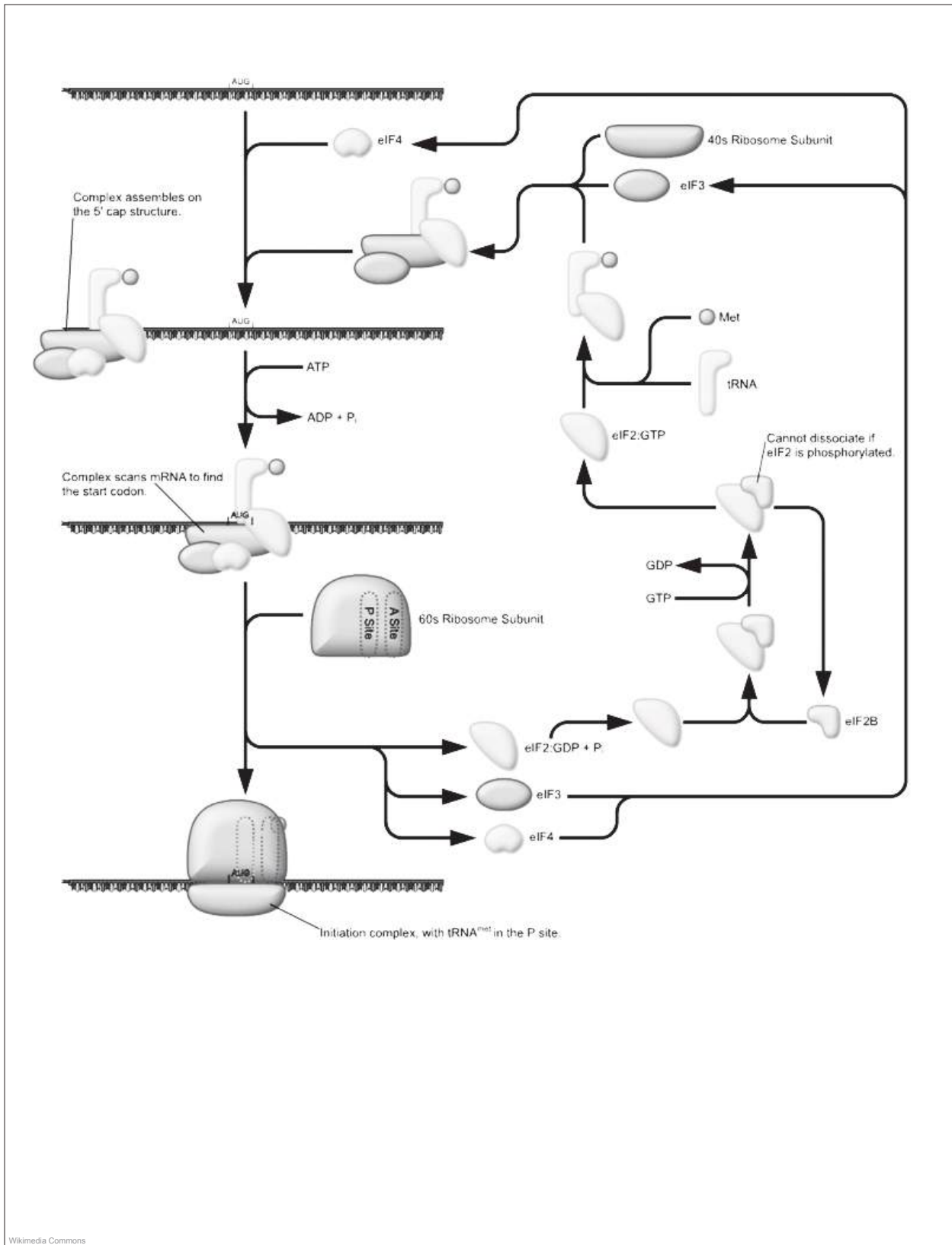
RNA
Ribonucleic acid

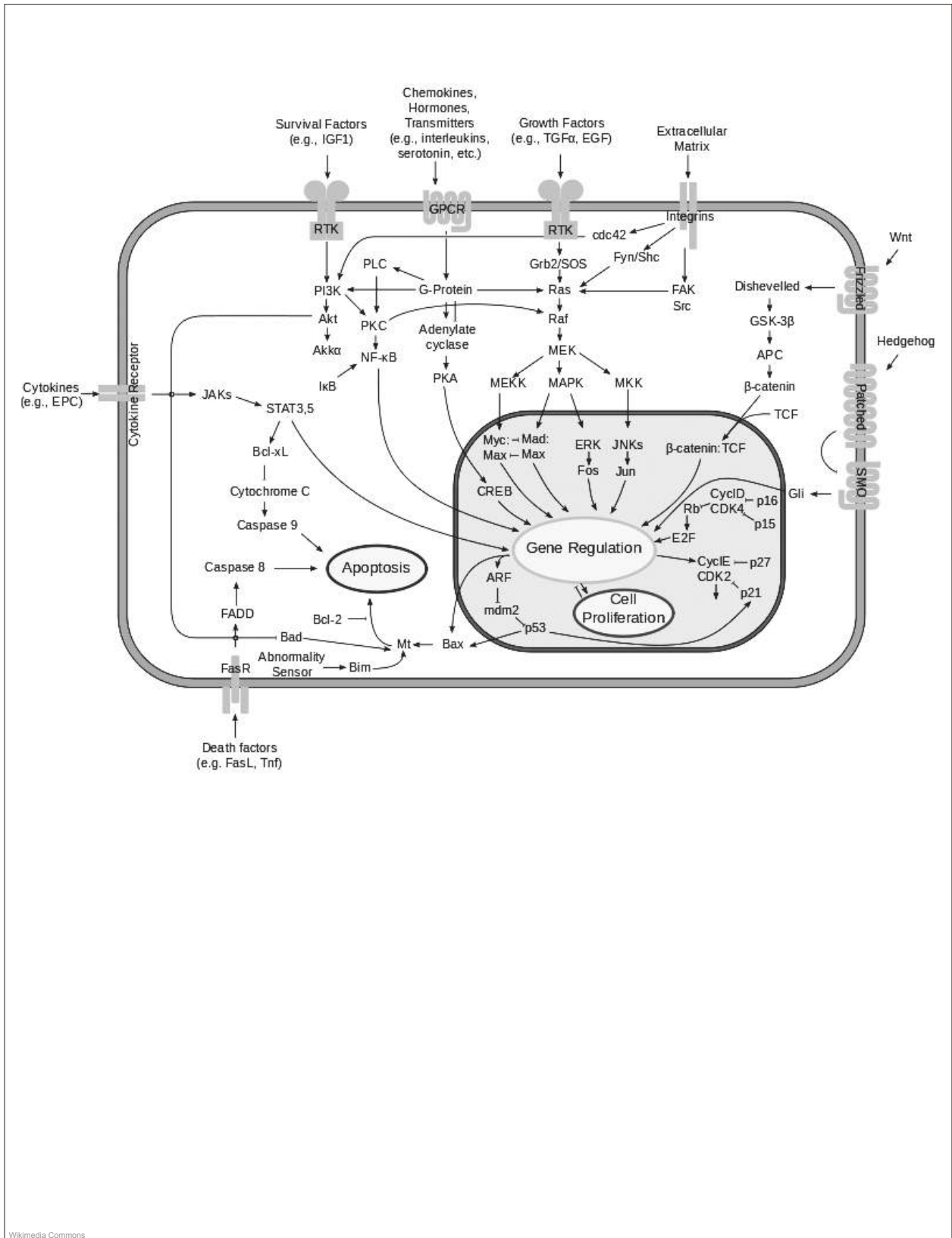
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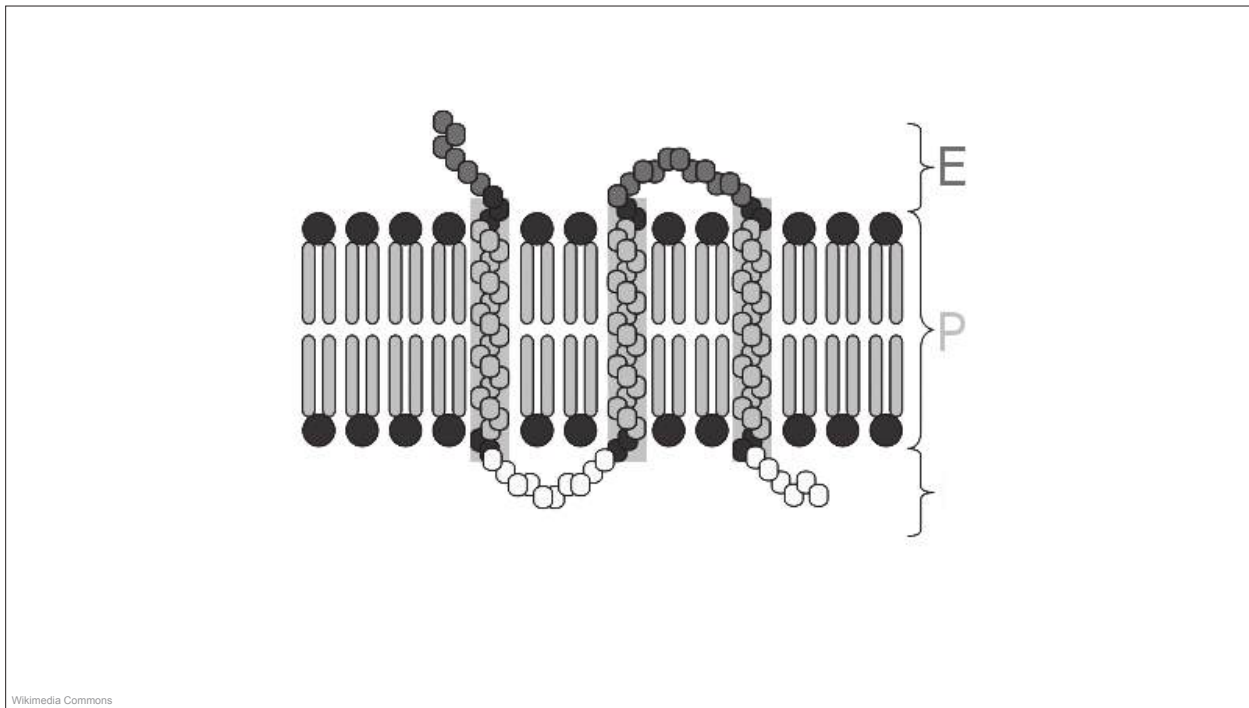
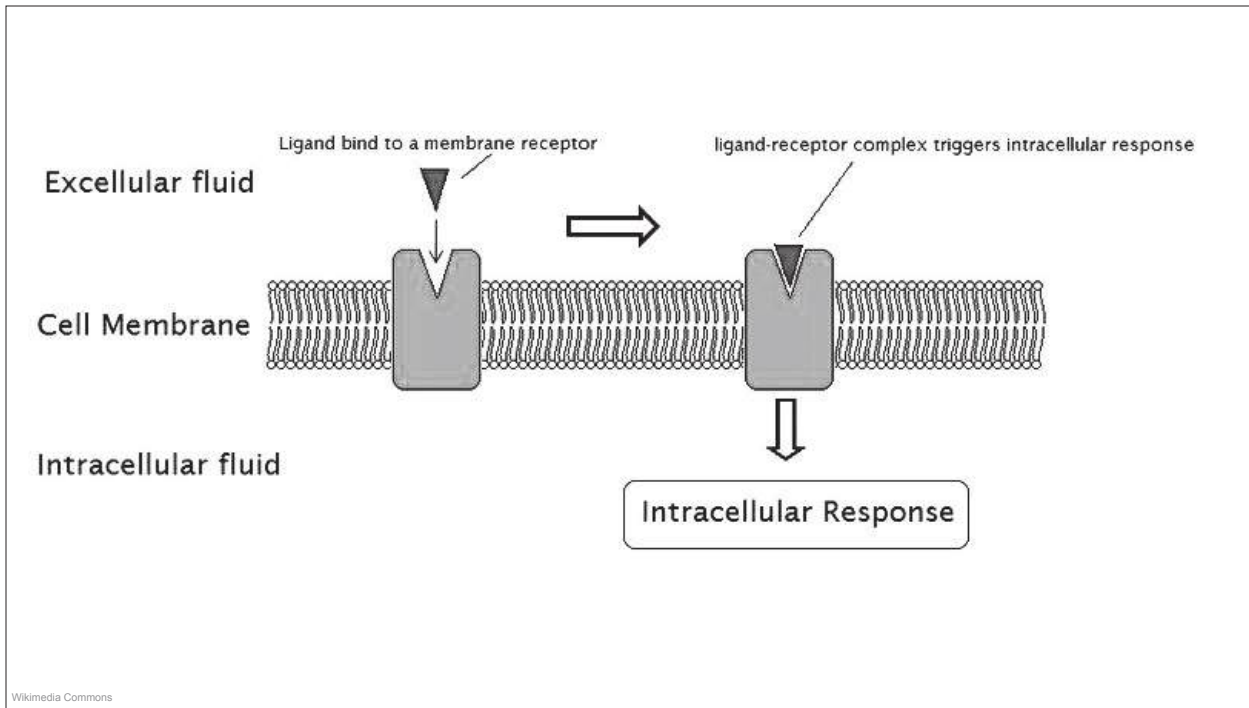


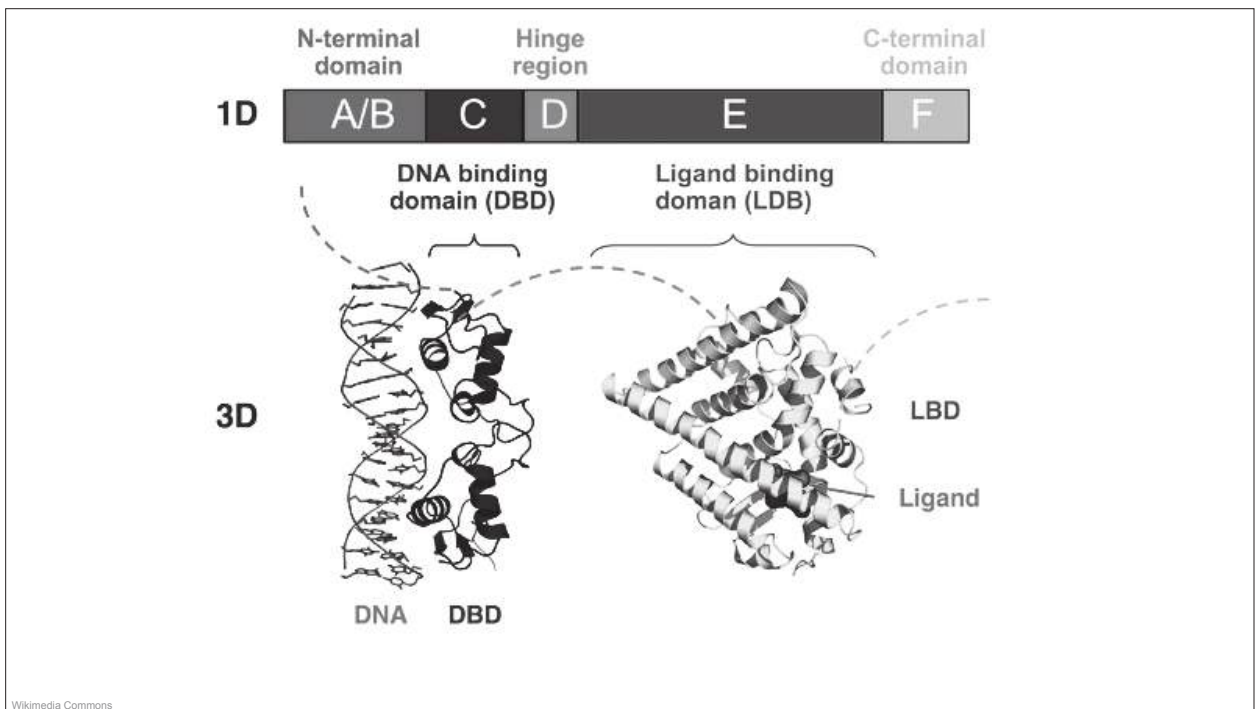
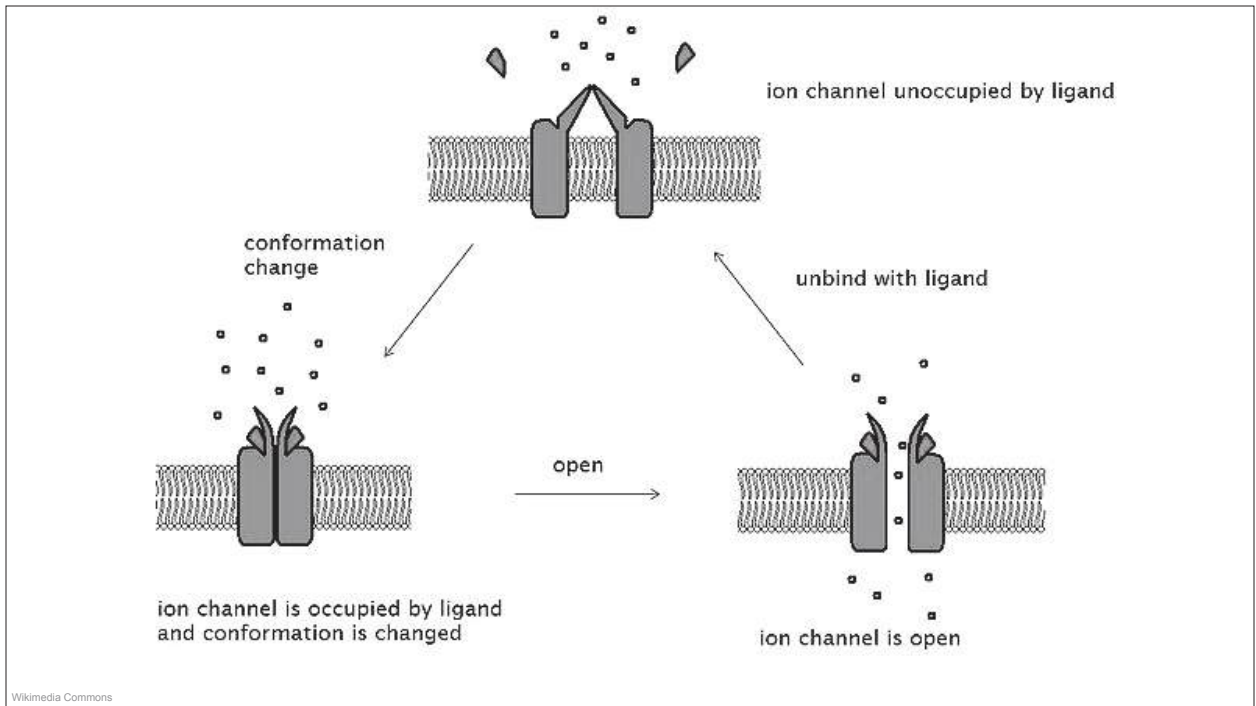
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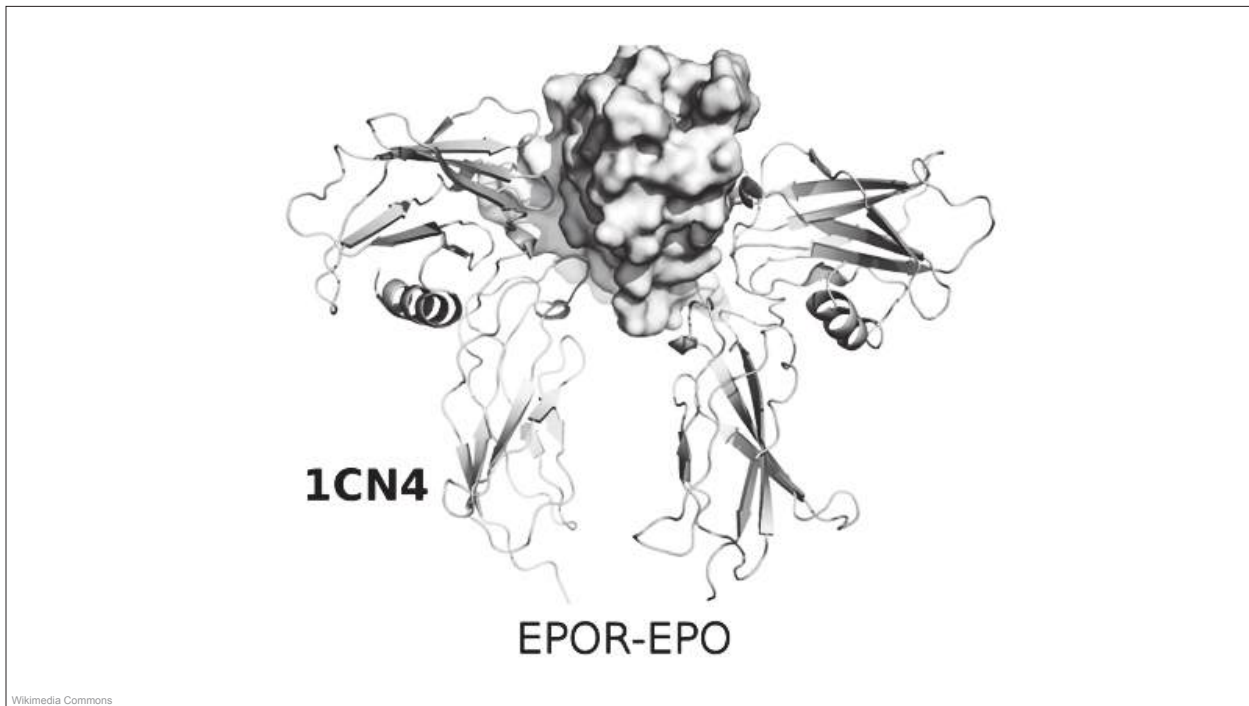
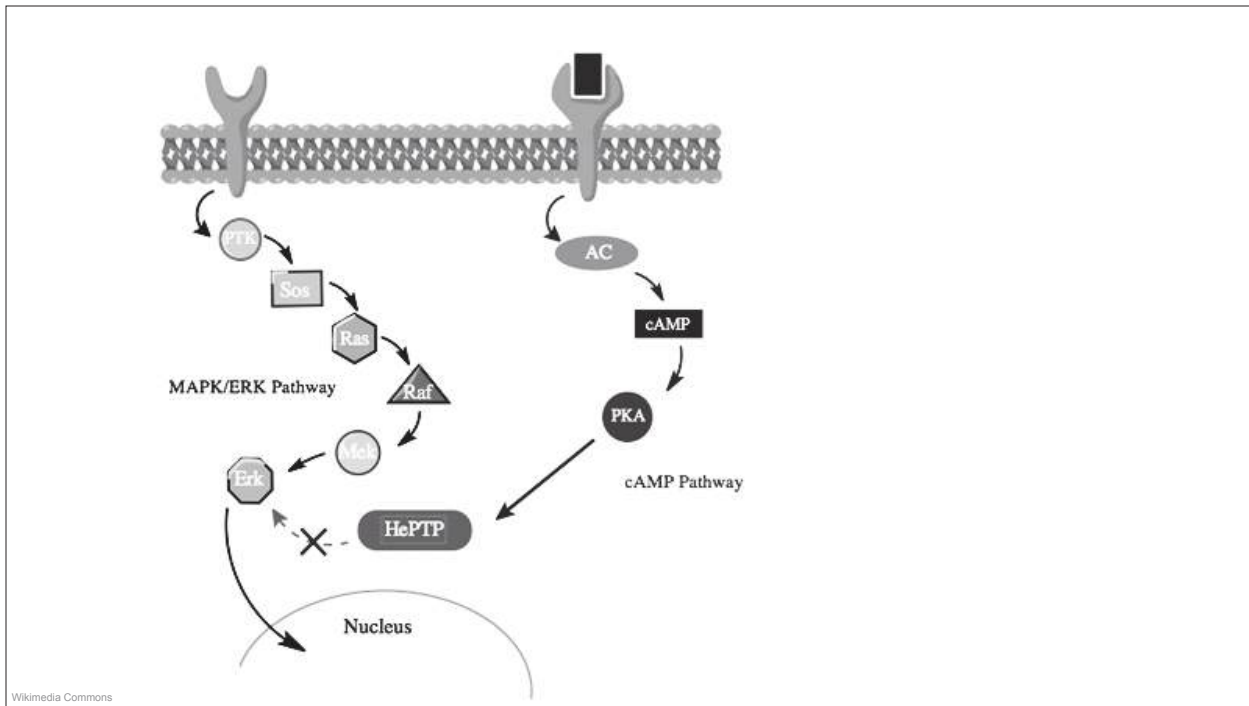


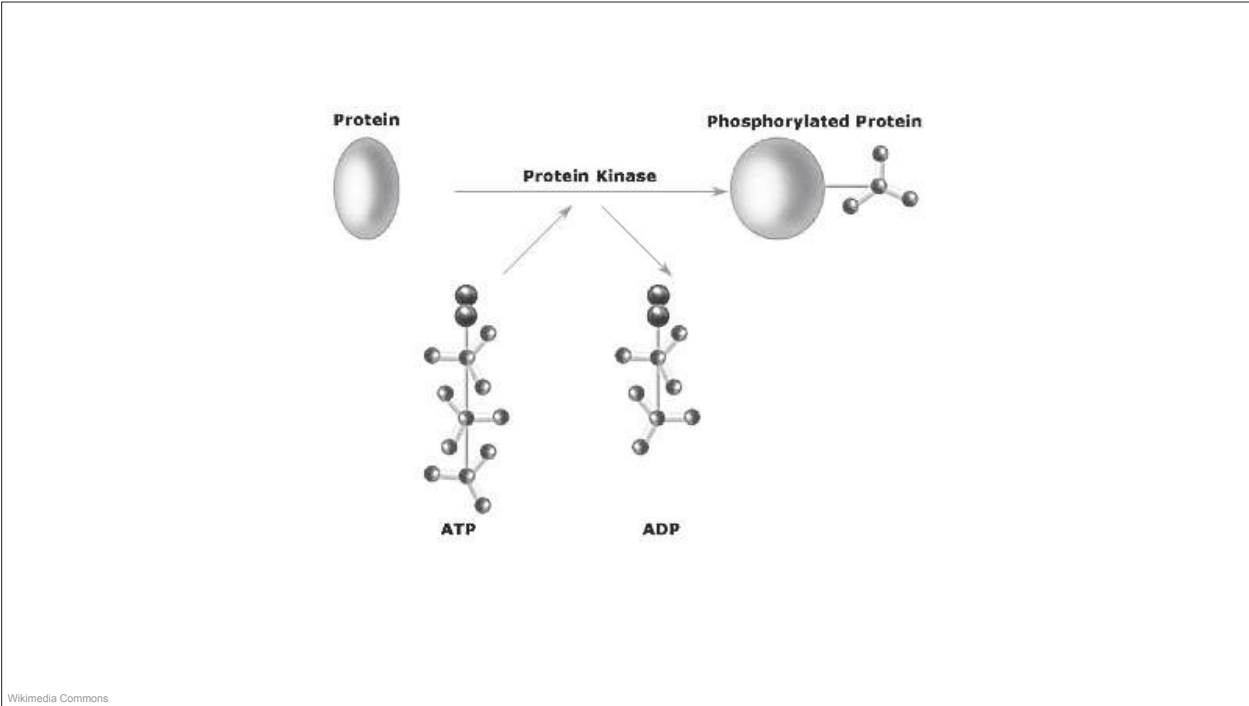
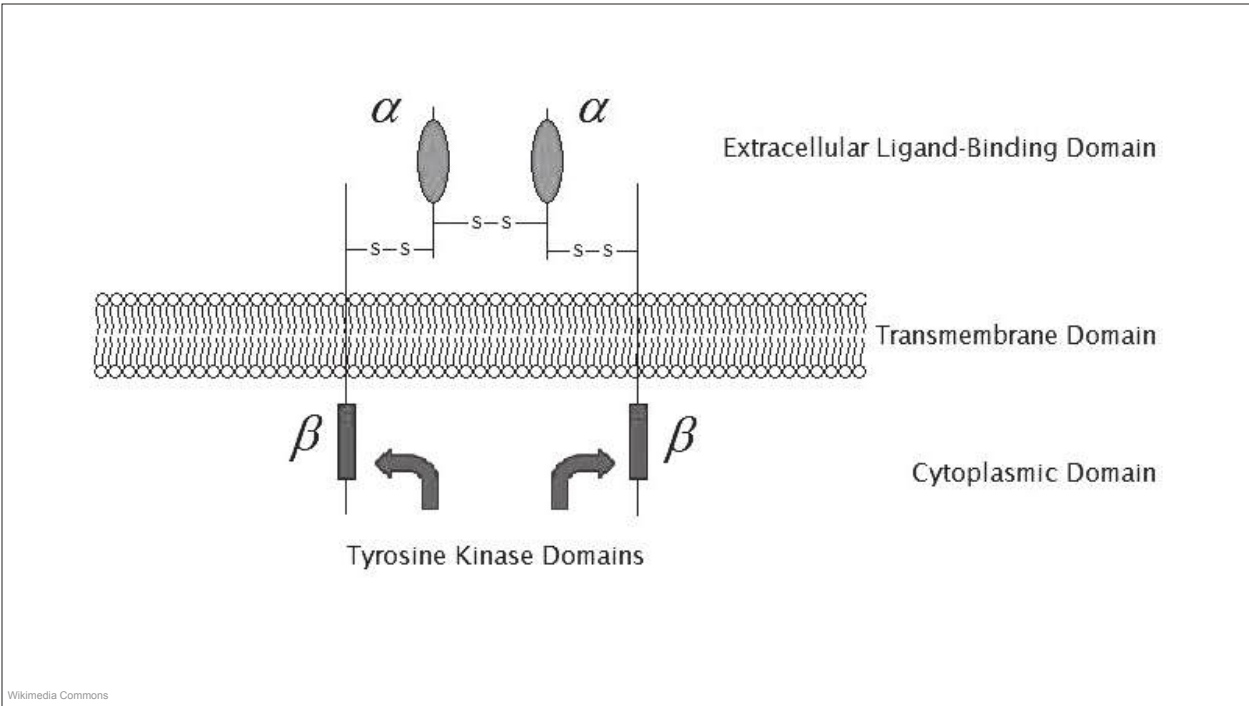
Signal Transduction Pathways



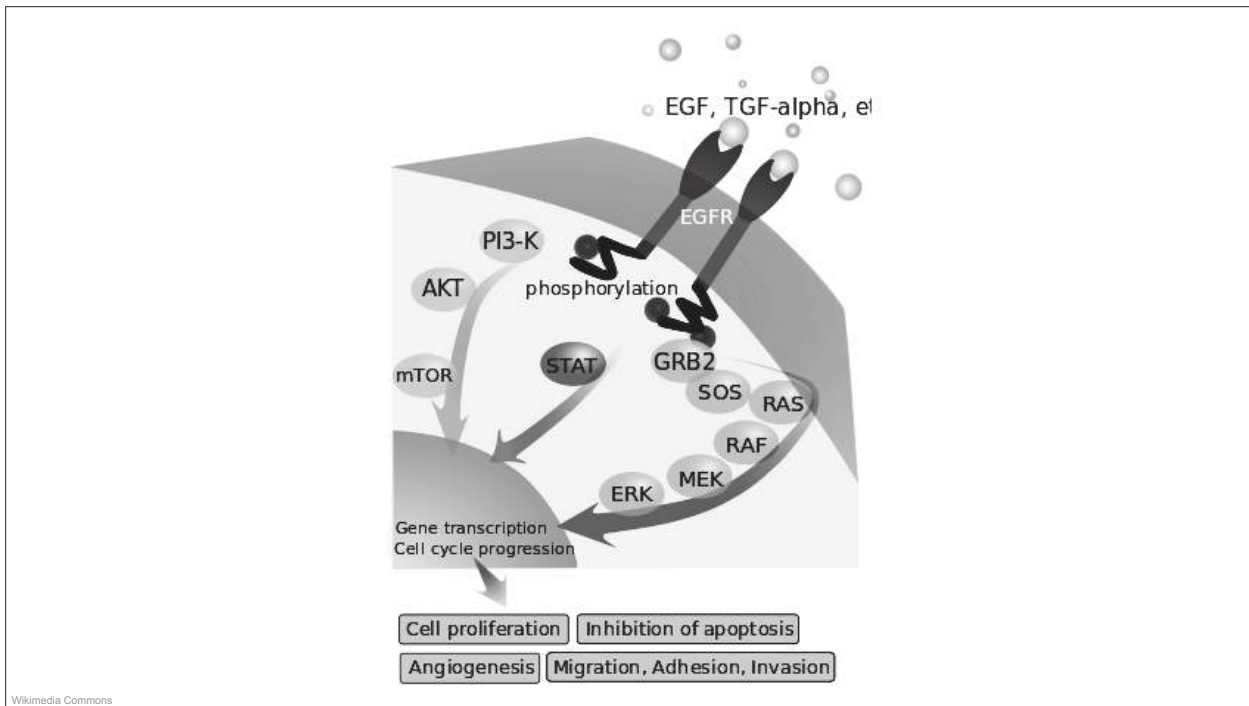
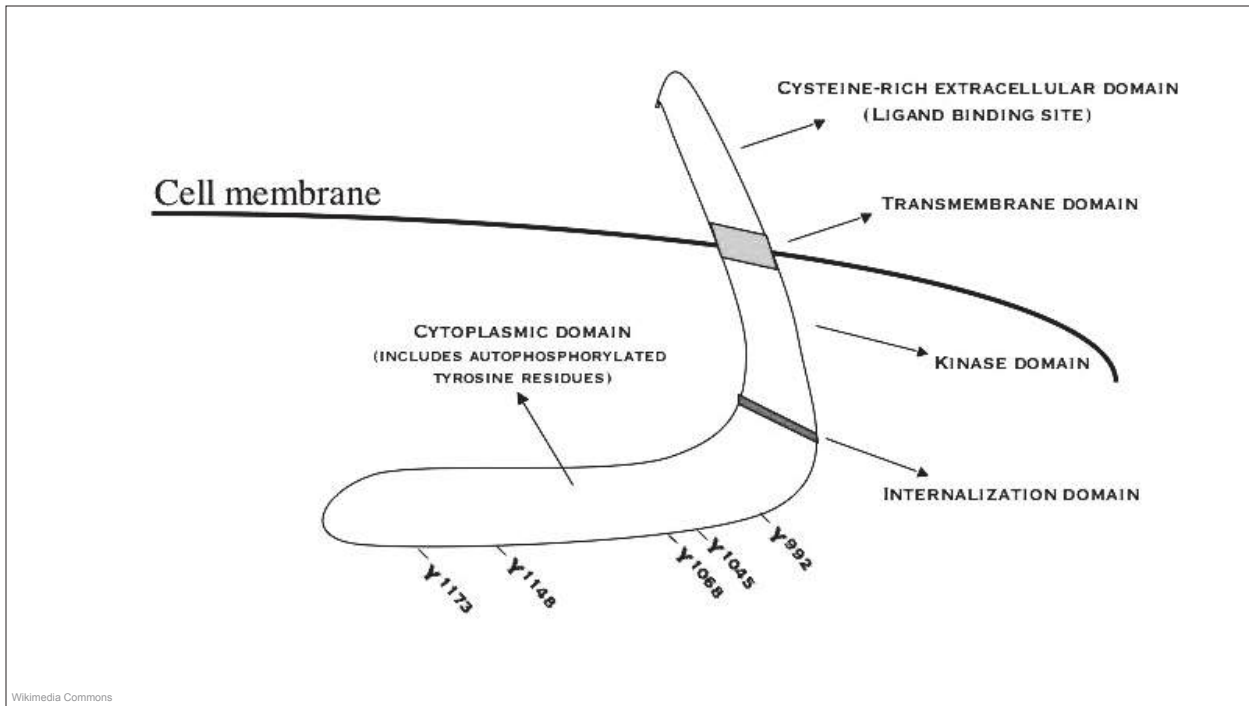


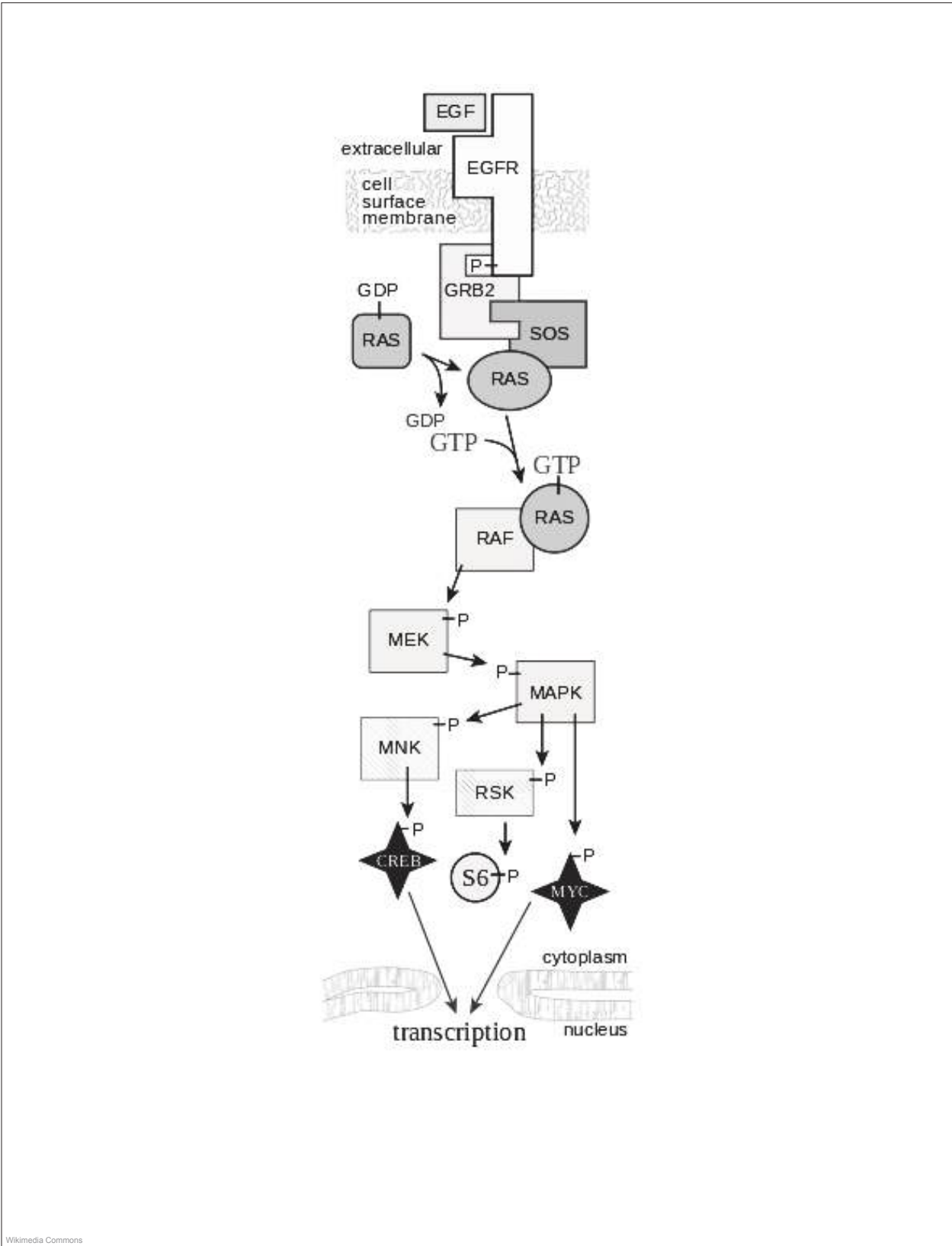
Signal Transduction Pathways





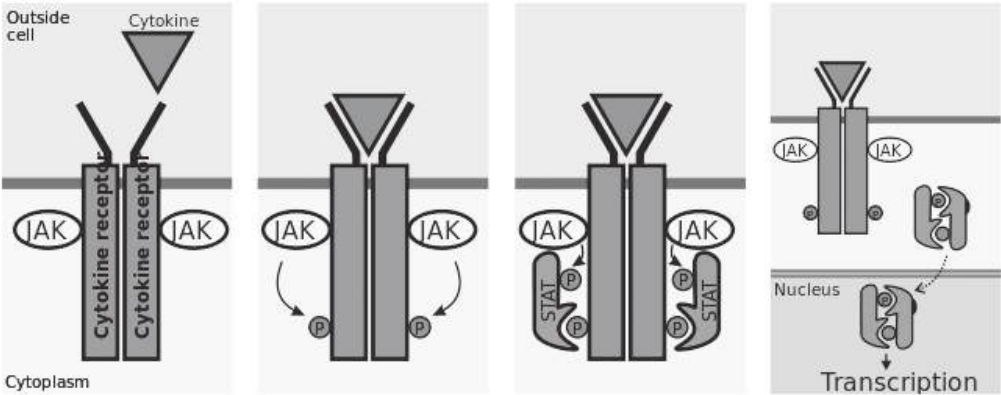
Signal Transduction Pathways





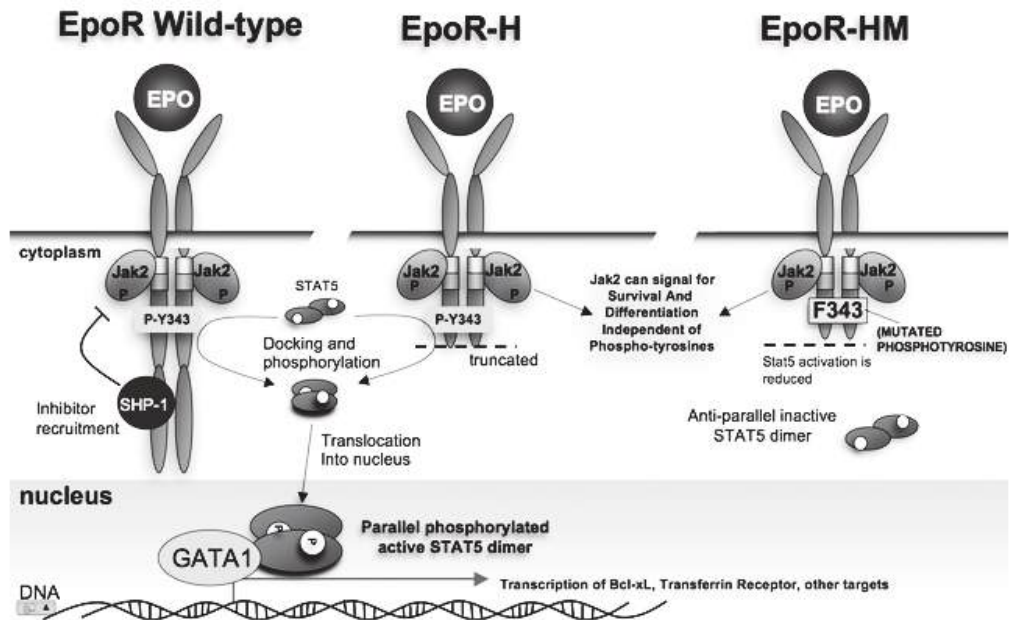
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Signal Transduction Pathways

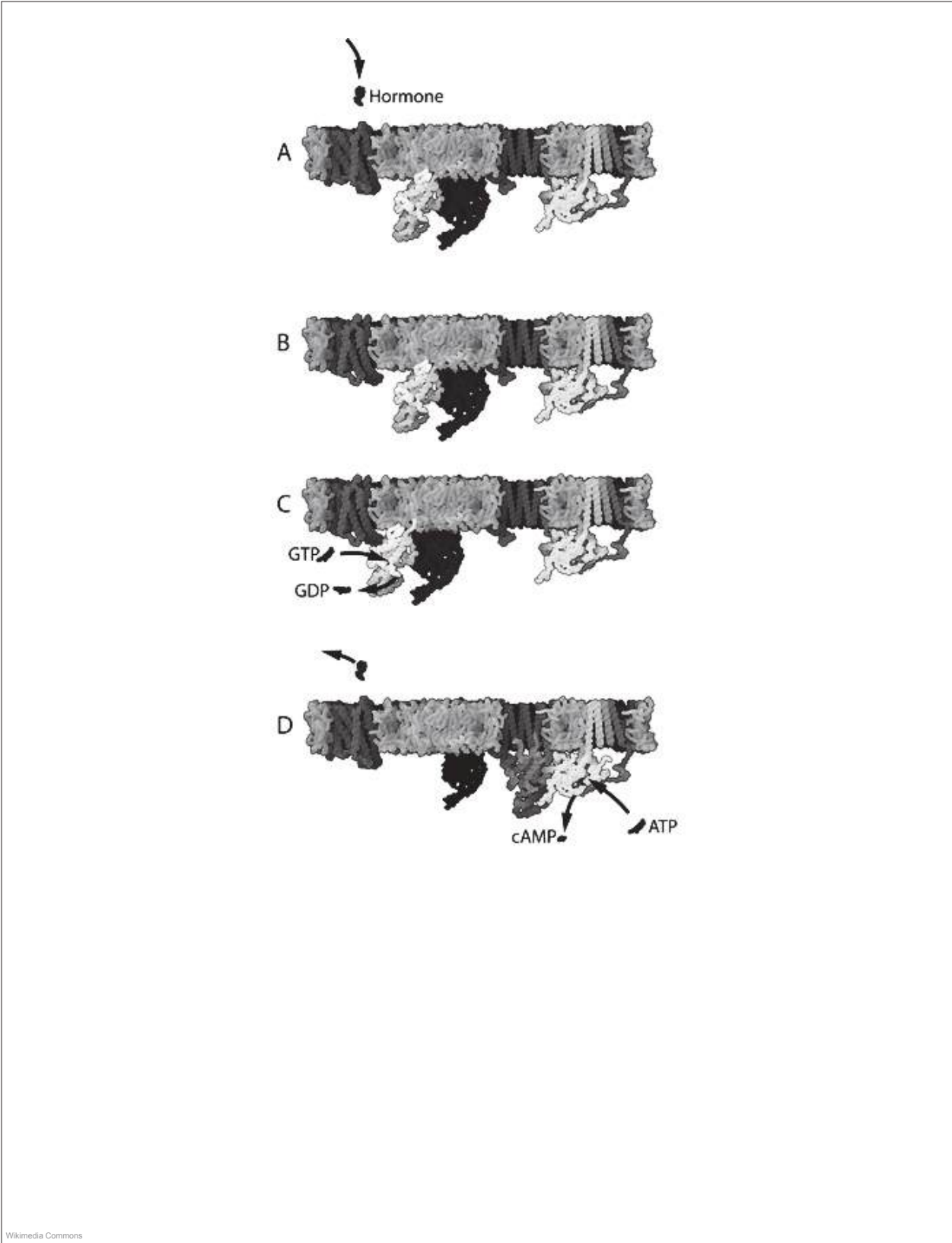


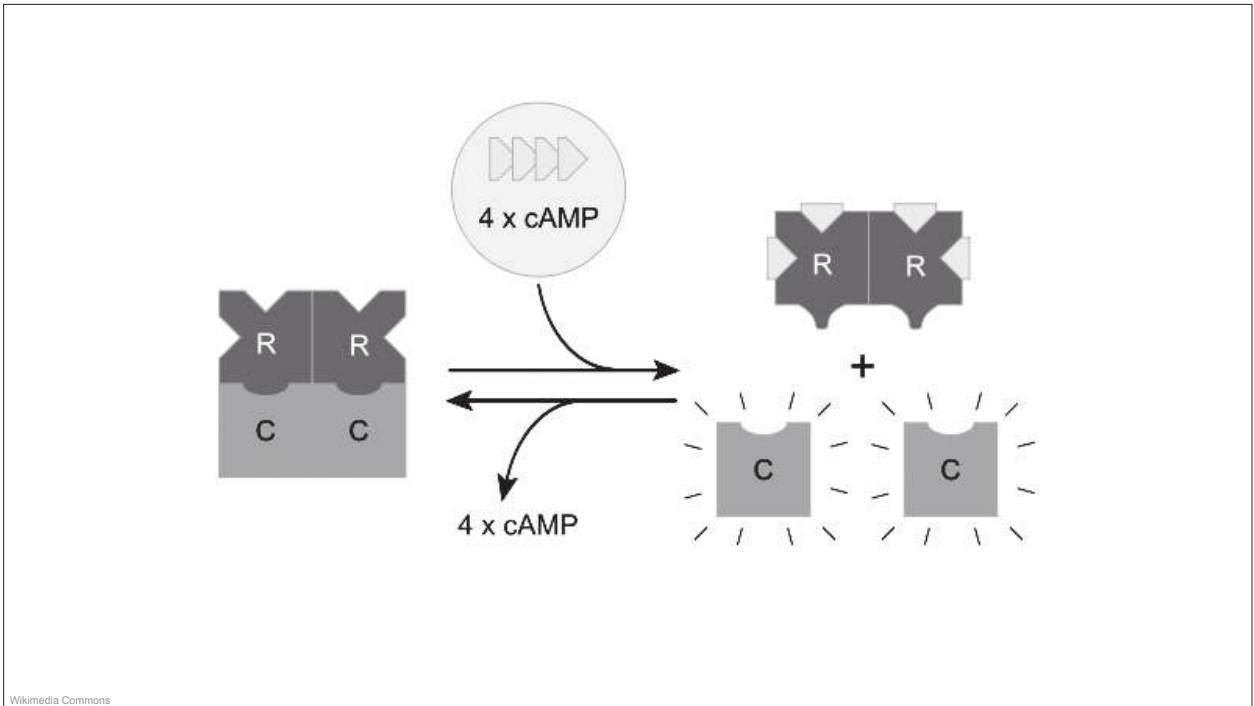
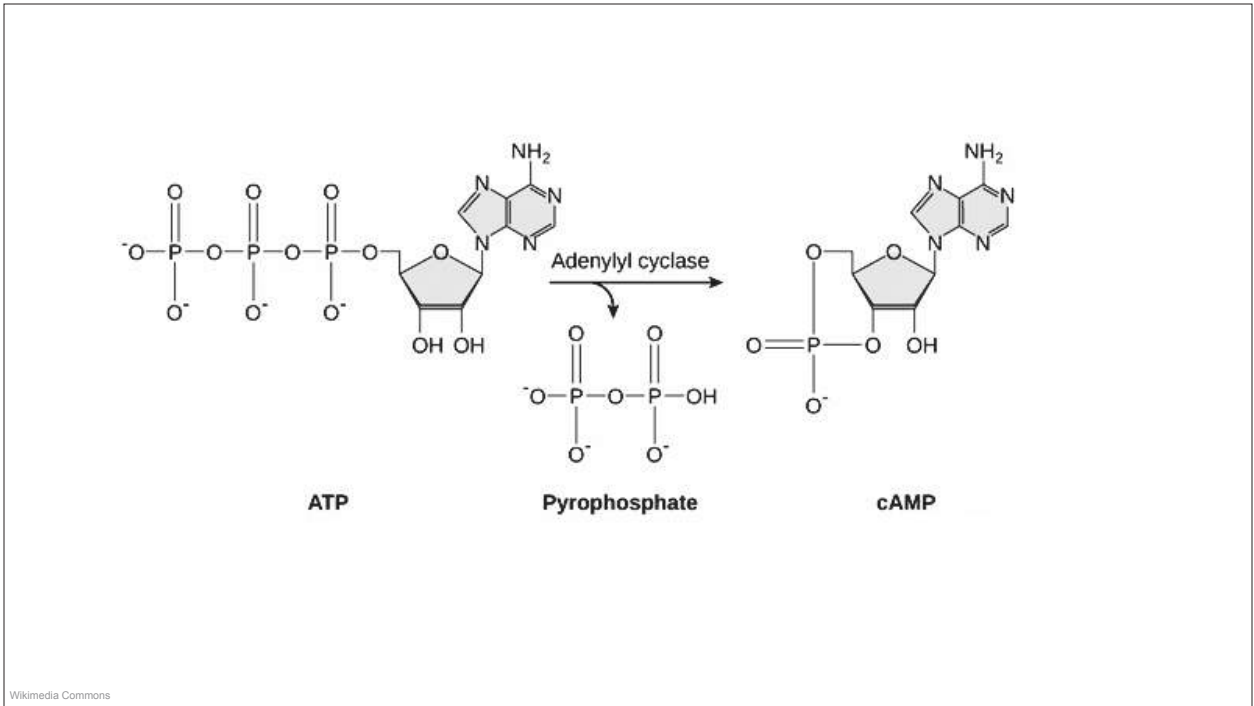
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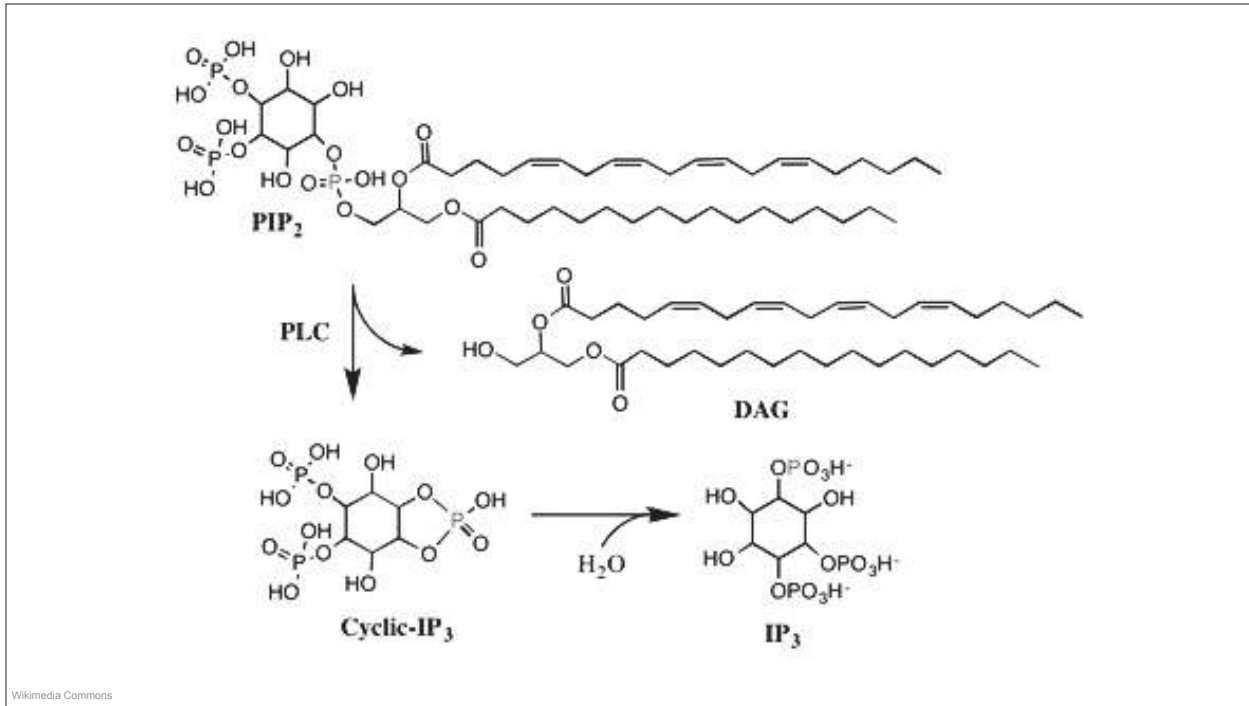
Truncated Epo Receptors



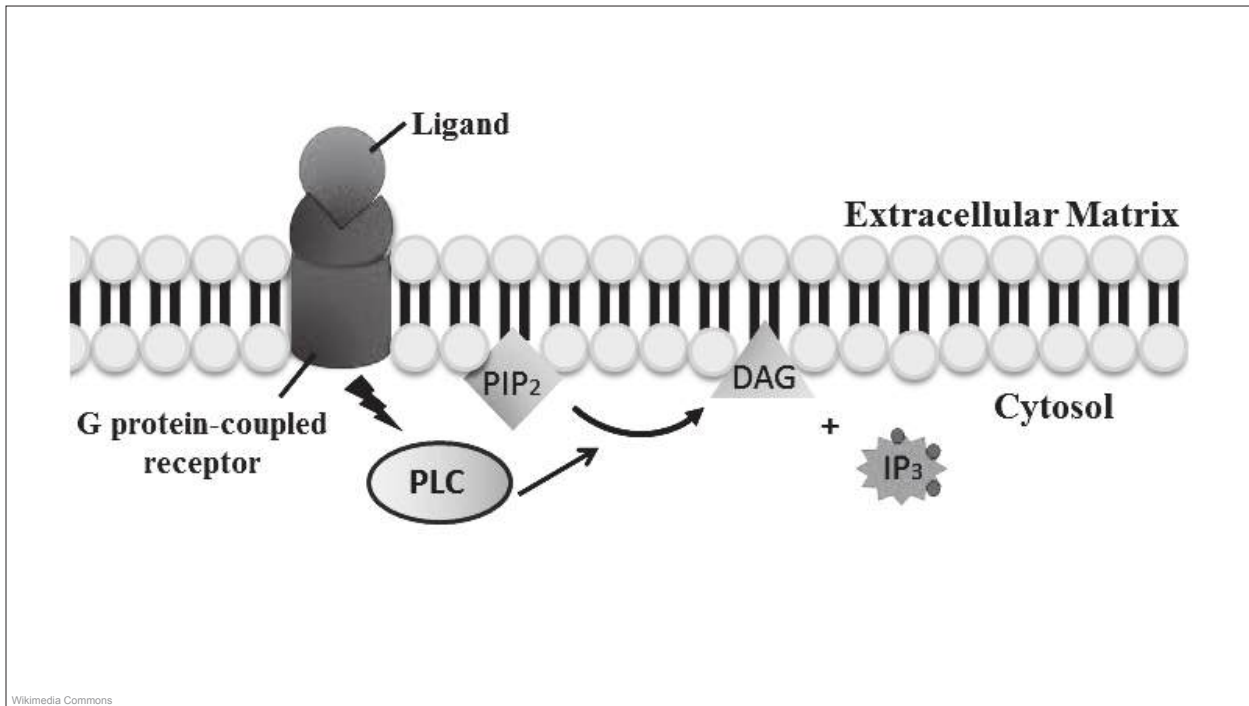
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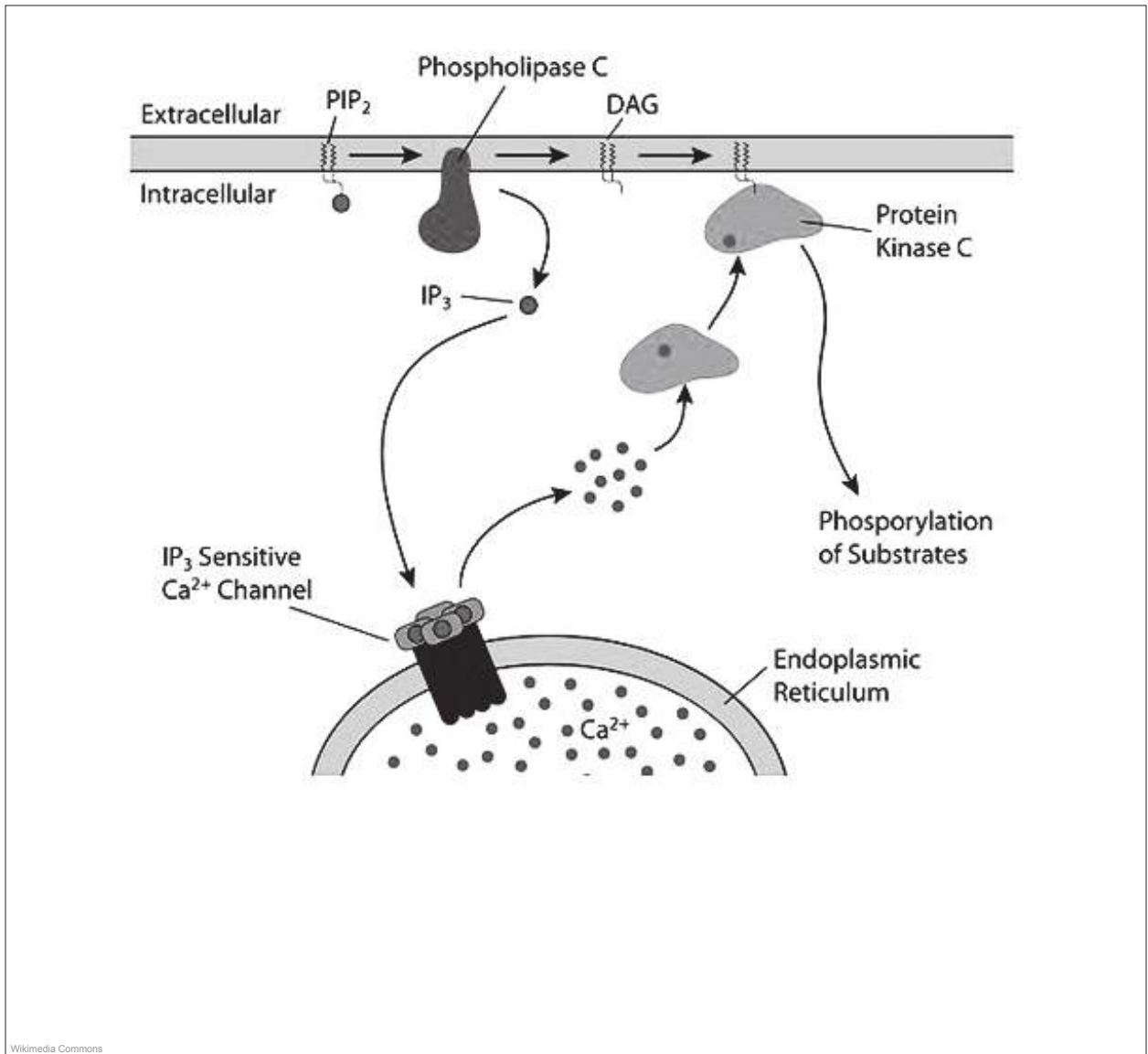


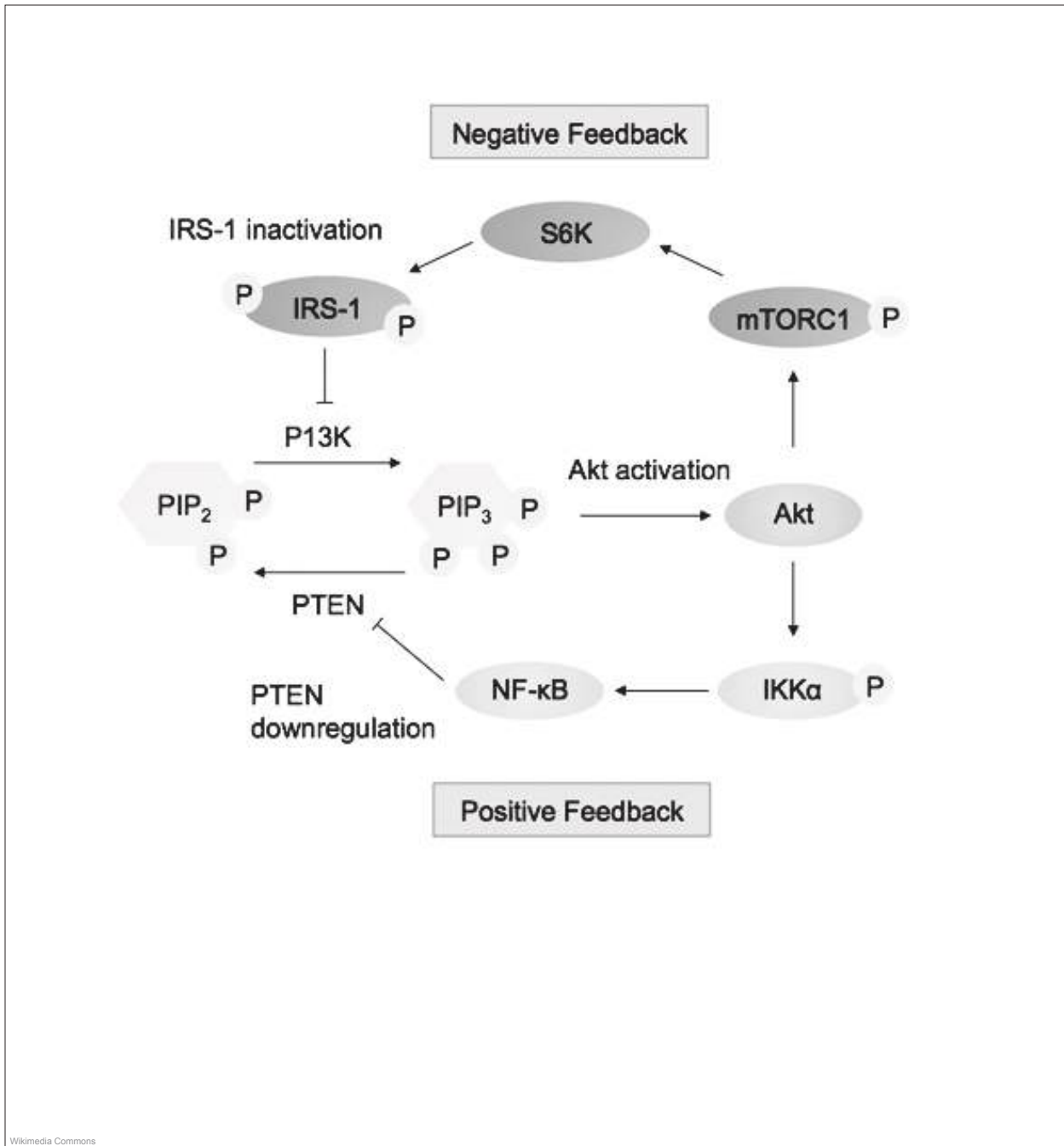


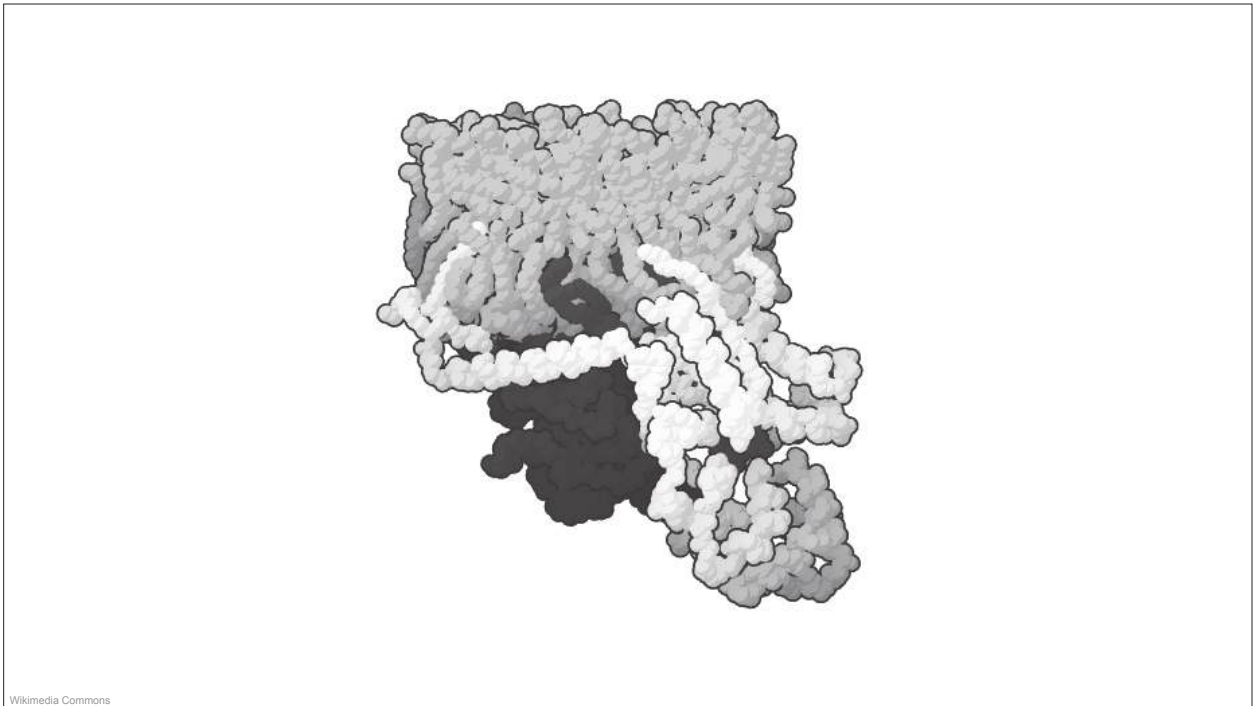
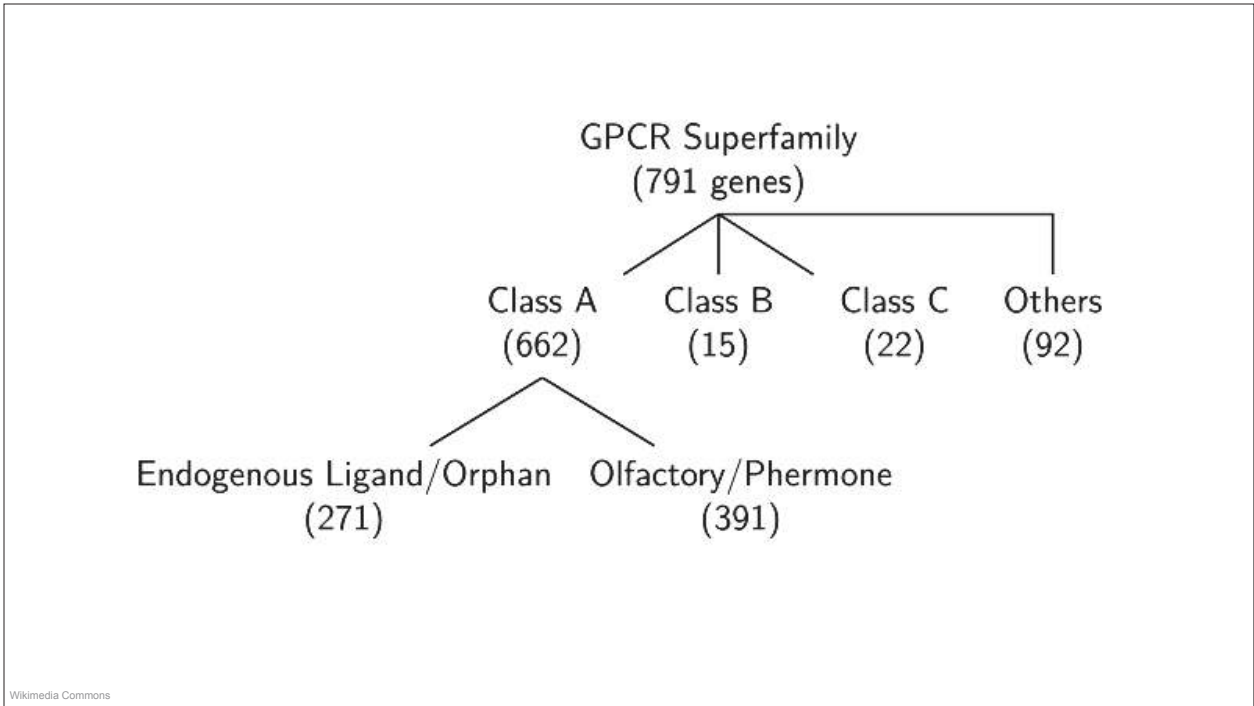
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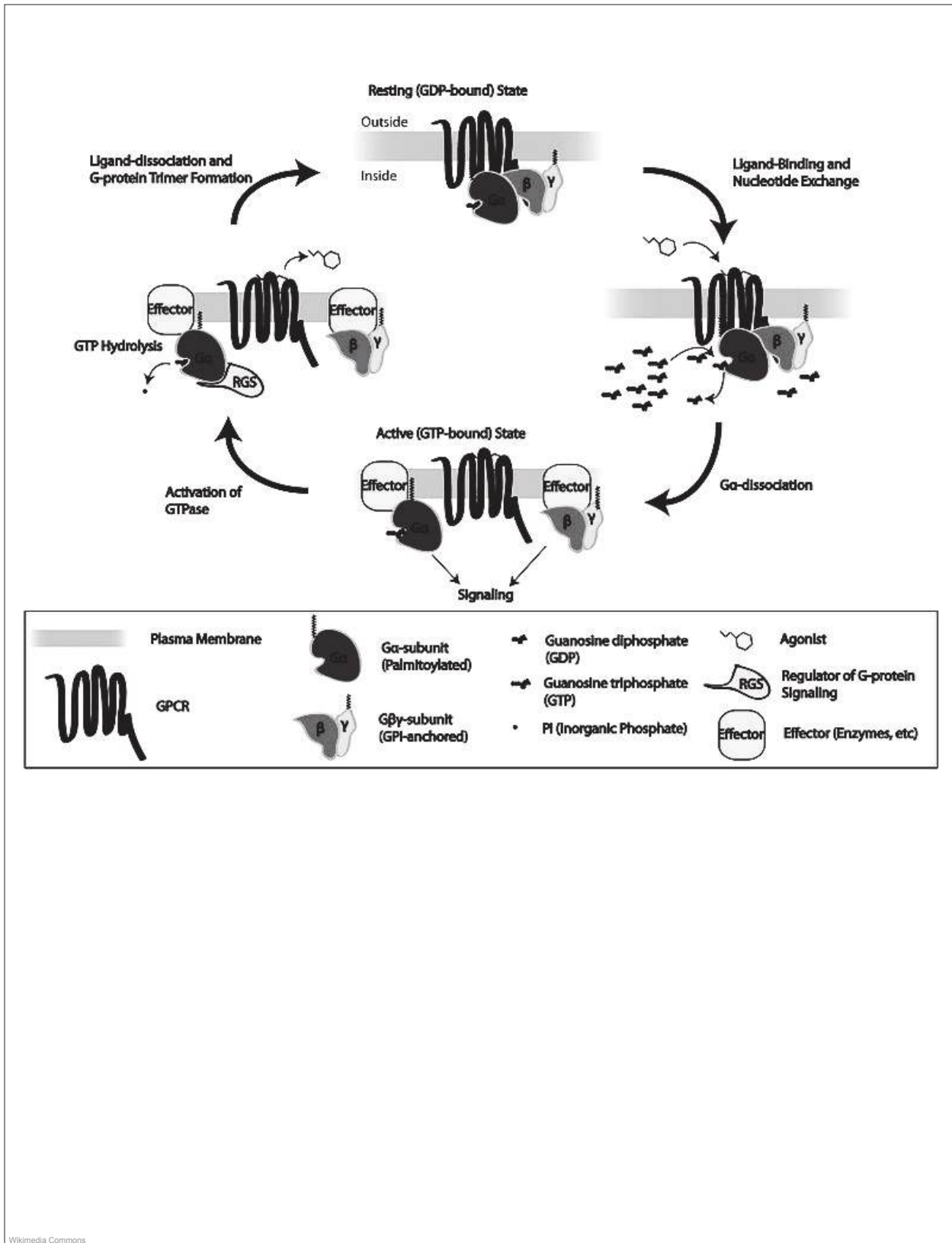
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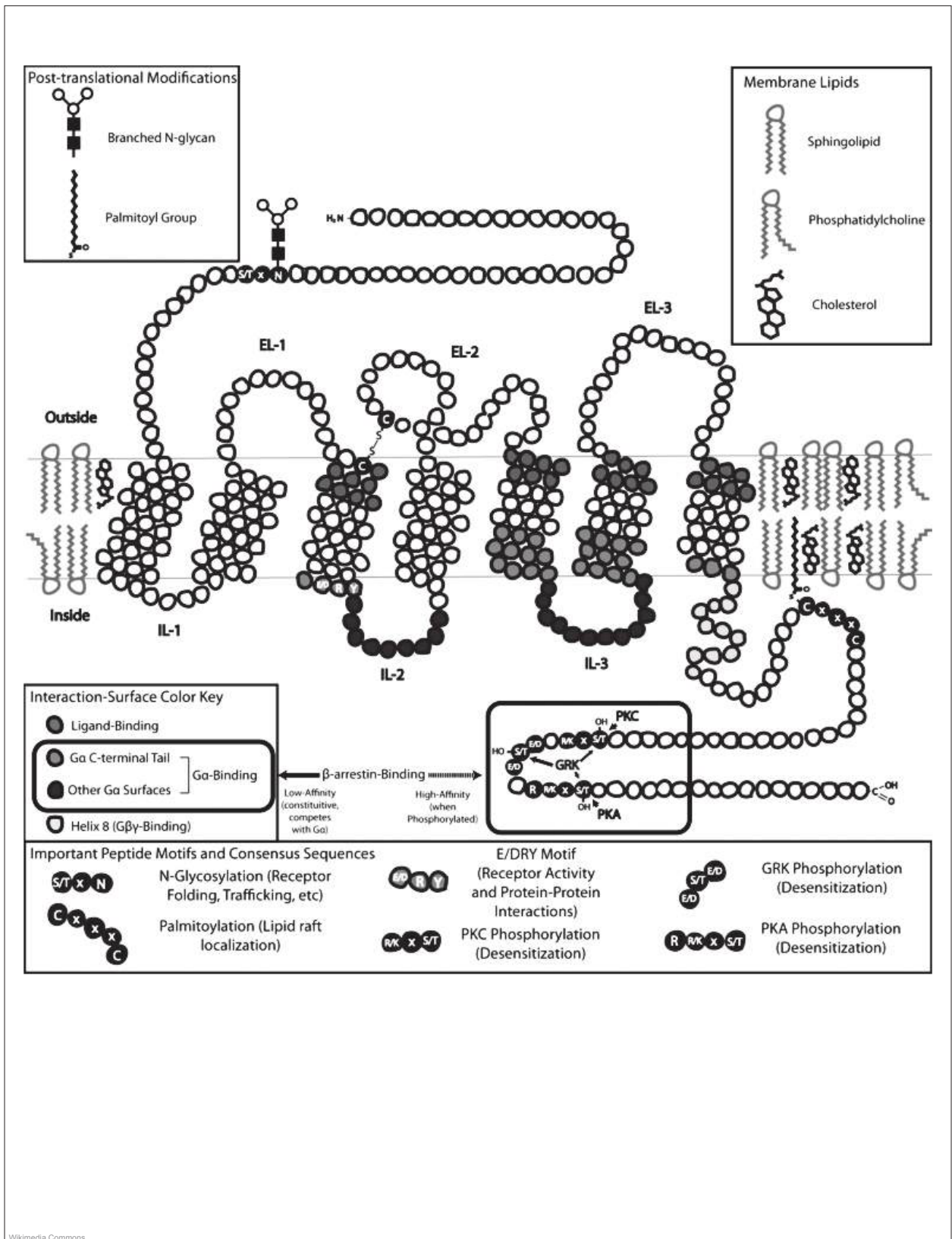


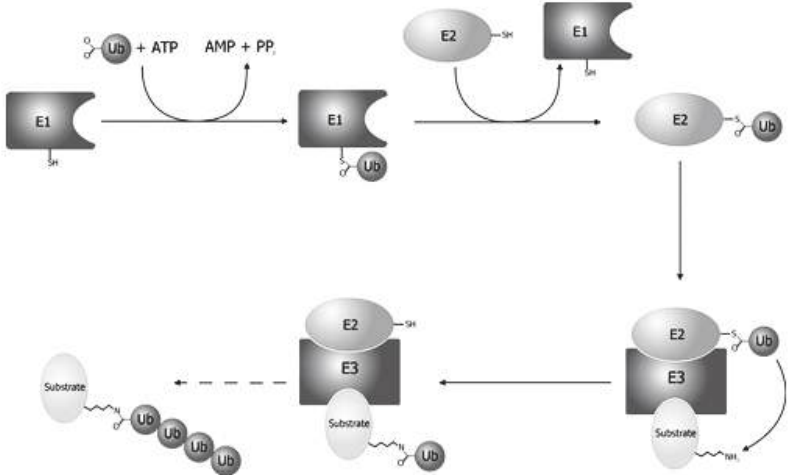




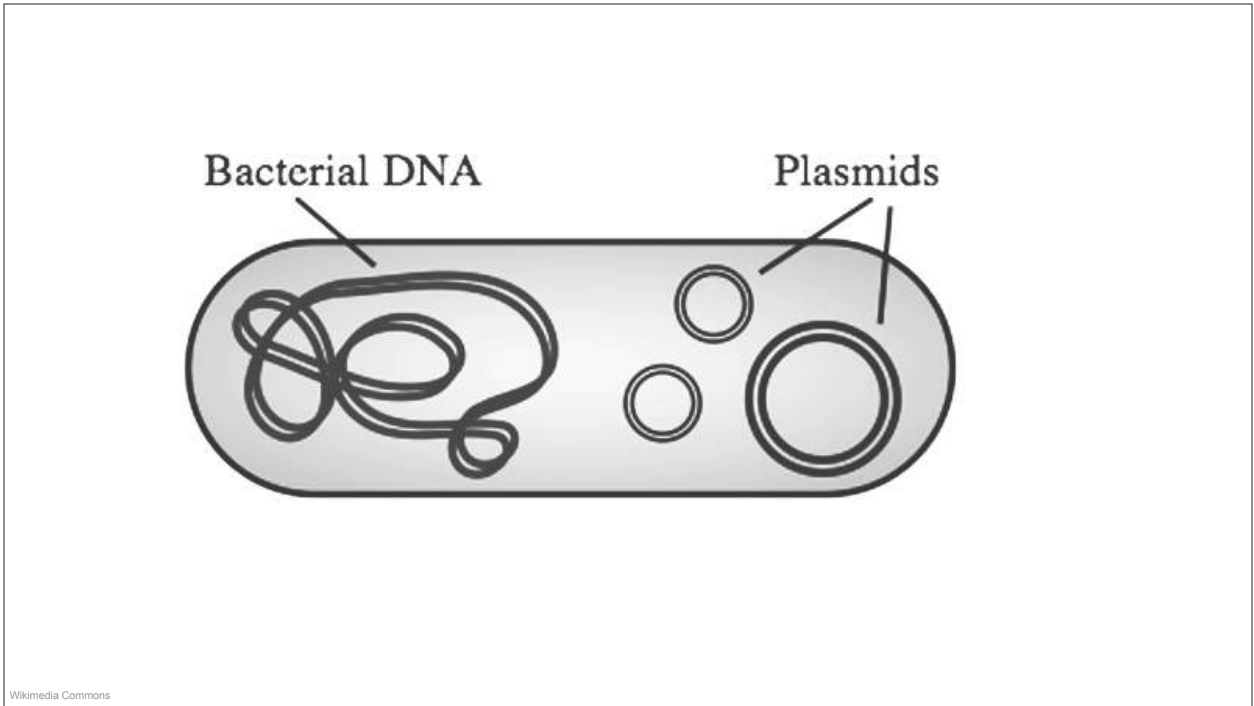
Signal Transduction Pathways



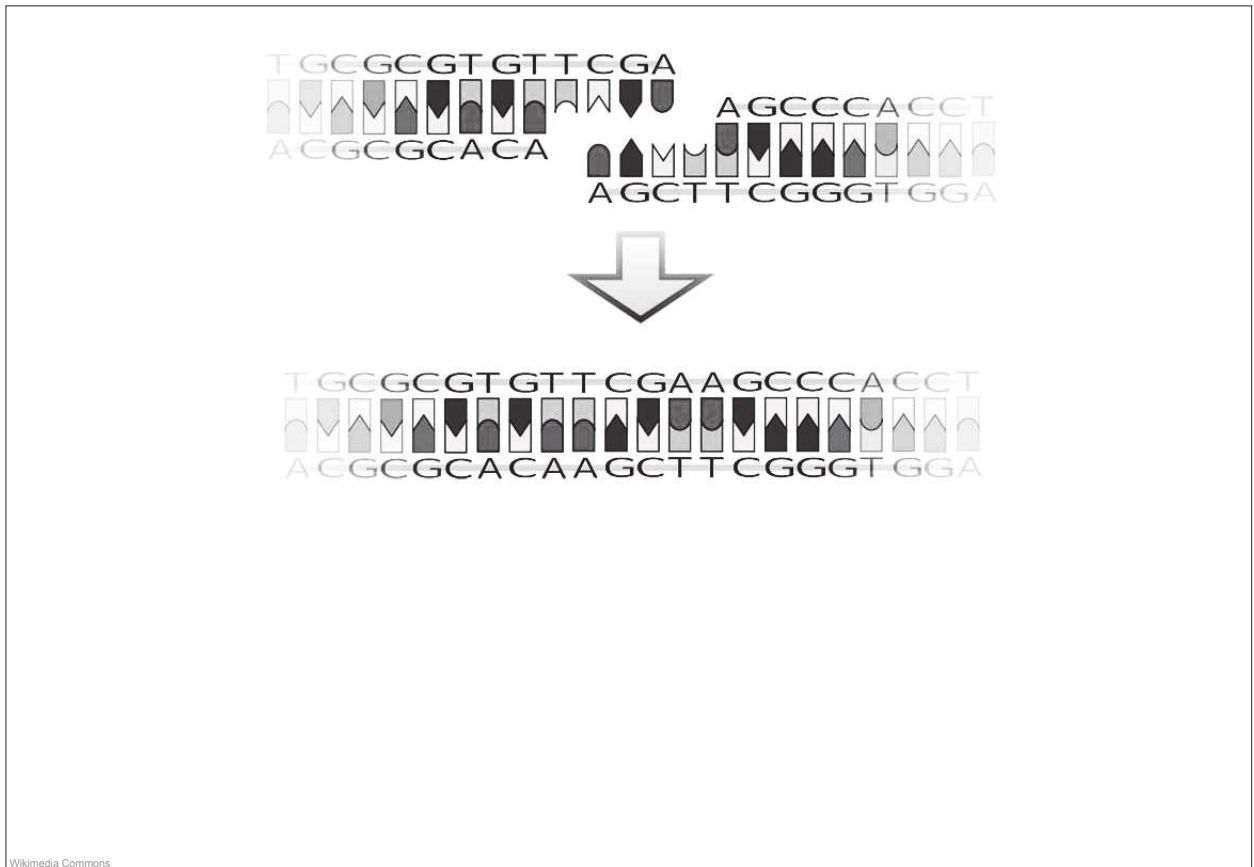




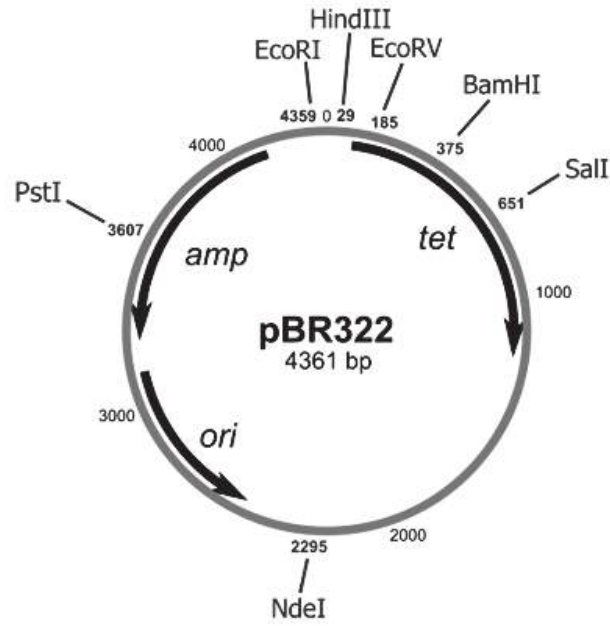
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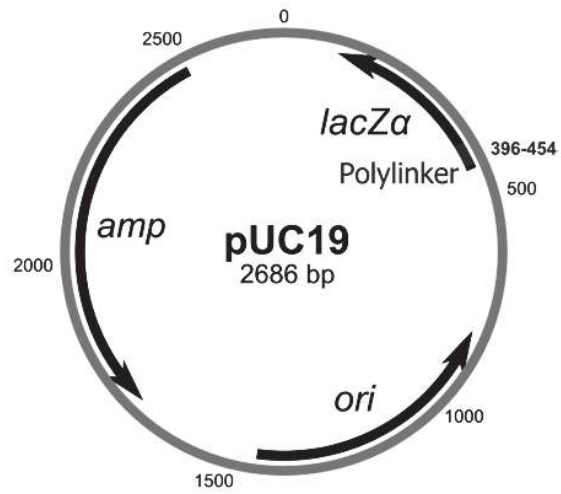
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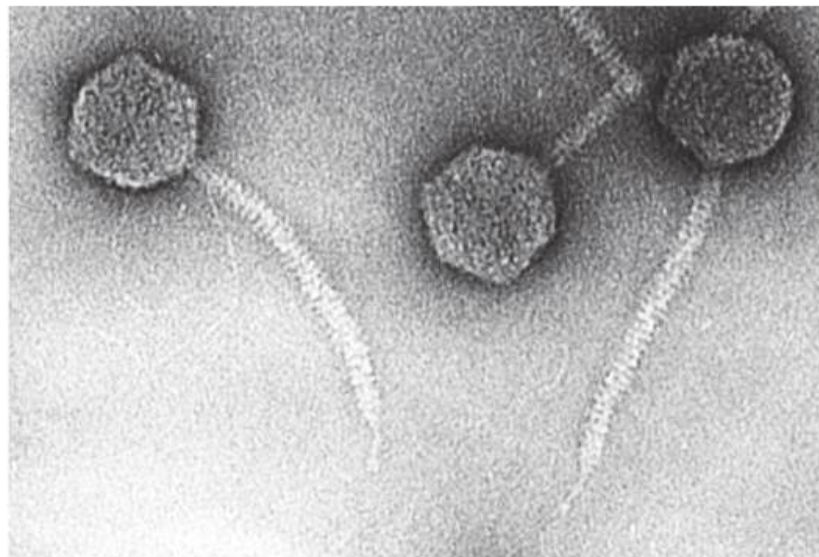
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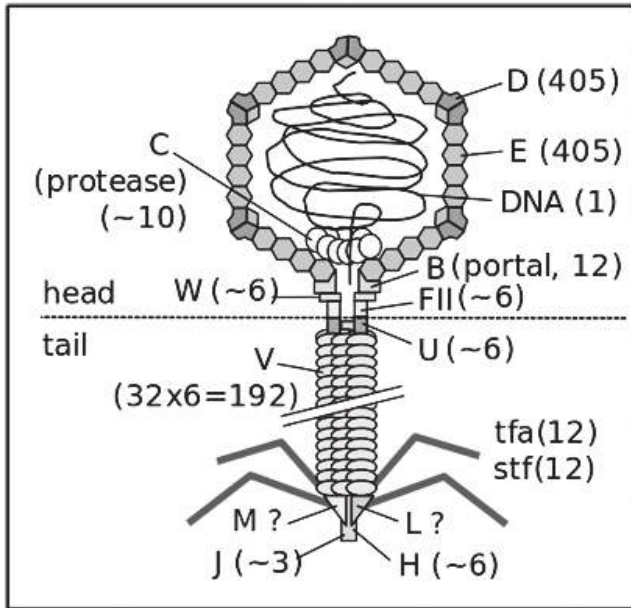
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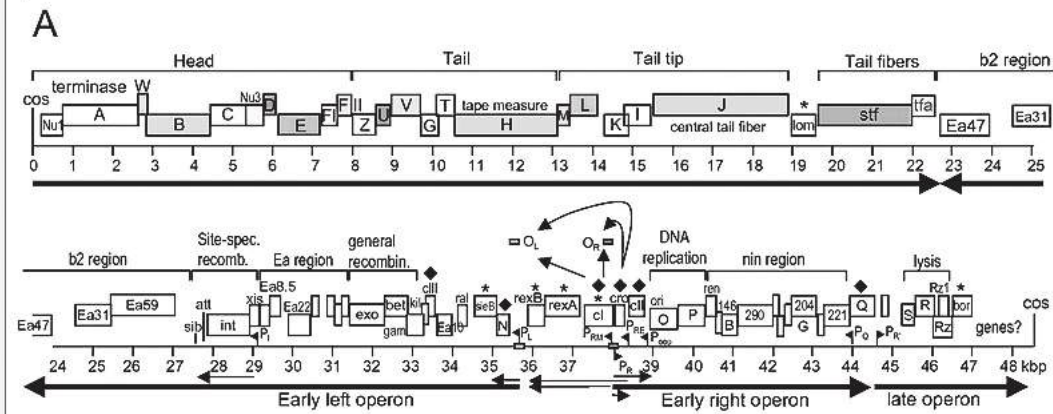


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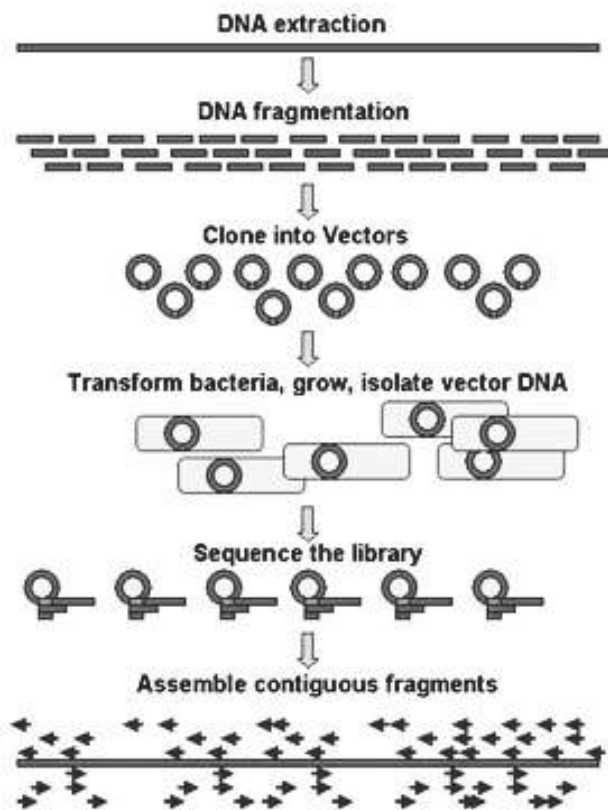
Figure 1.



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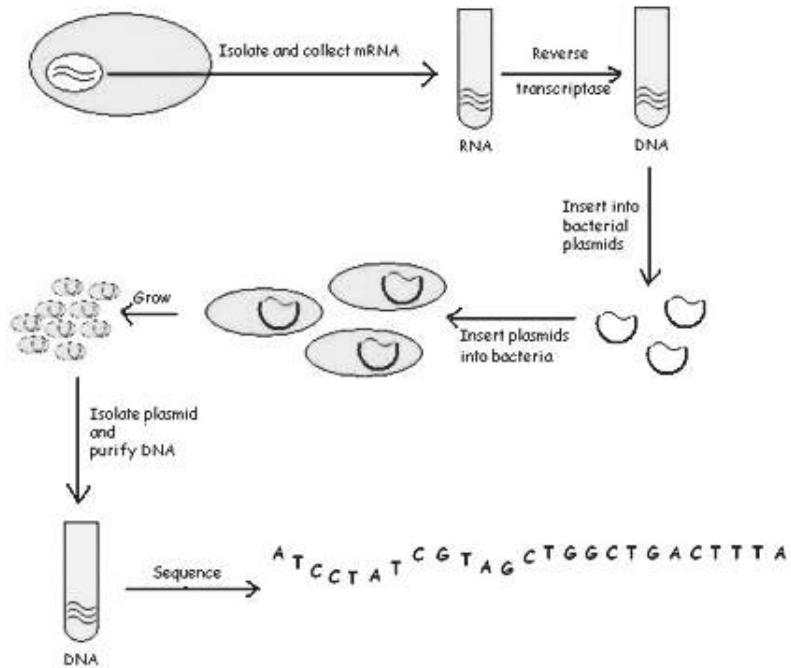


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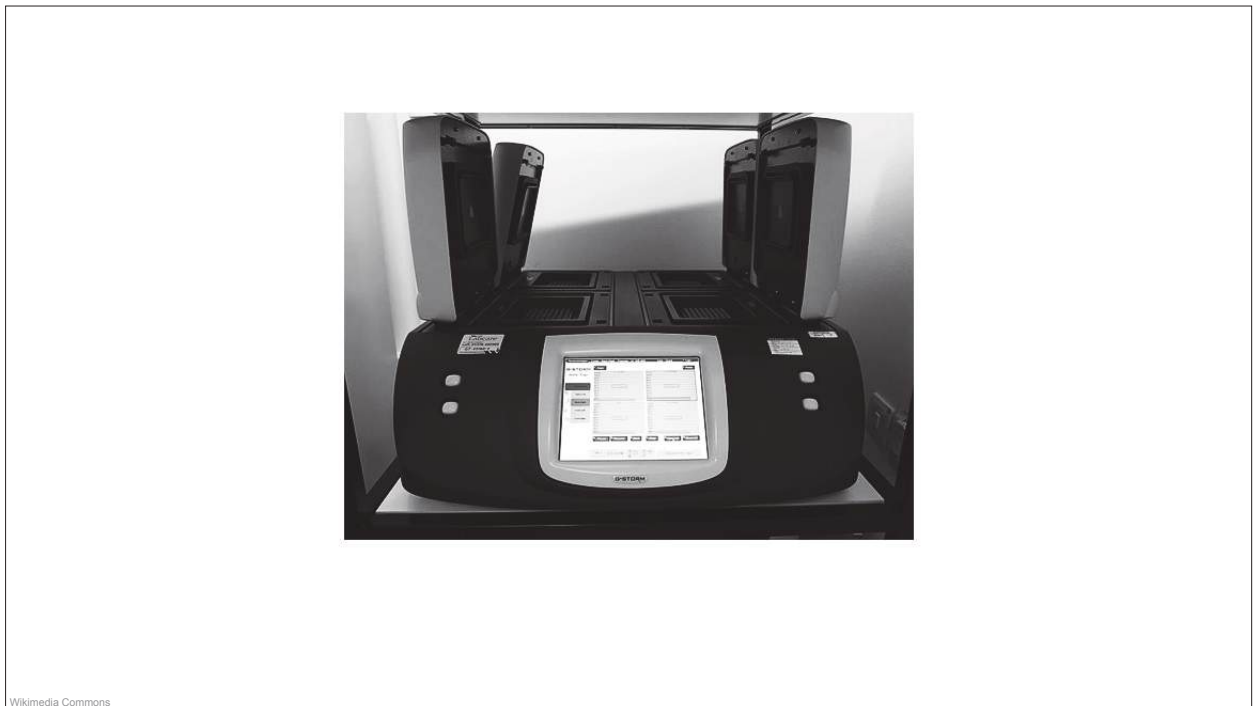
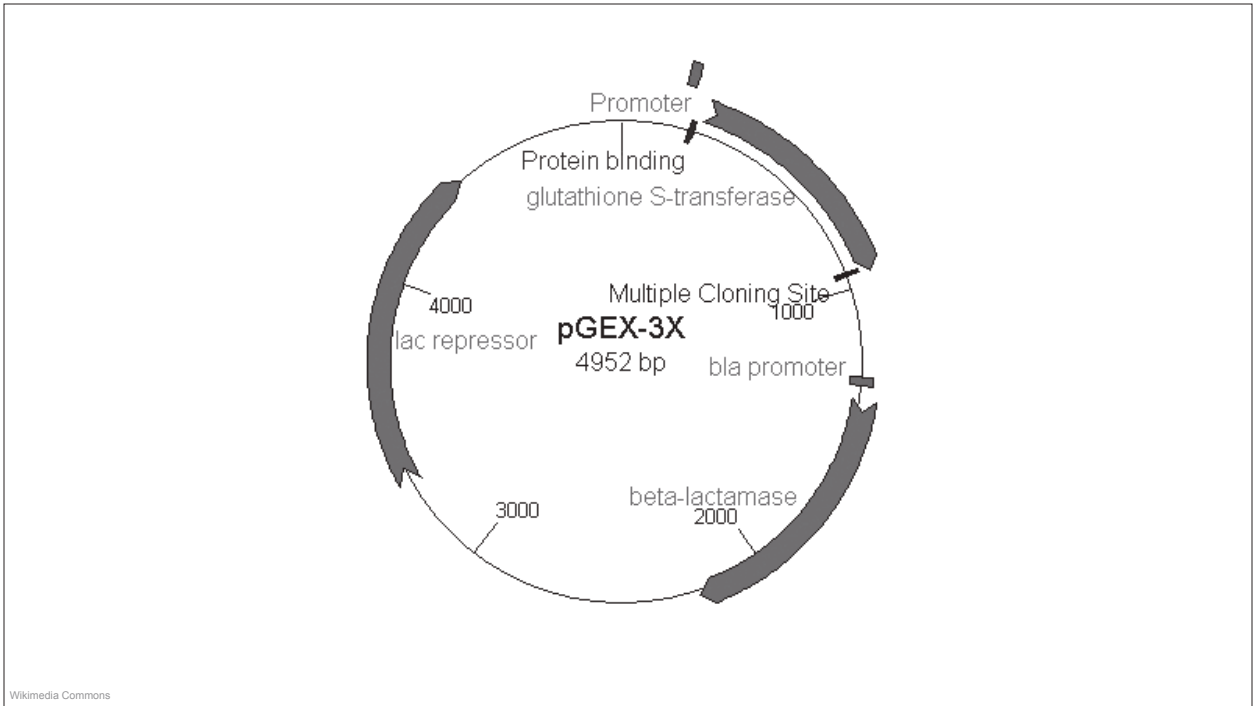


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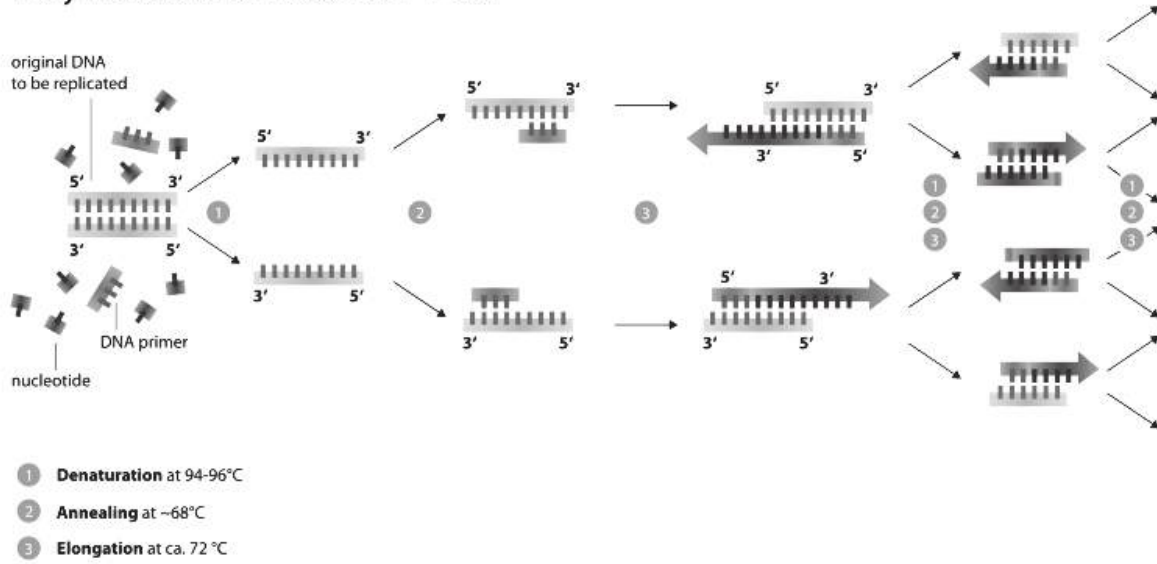
Formation of a cDNA Library



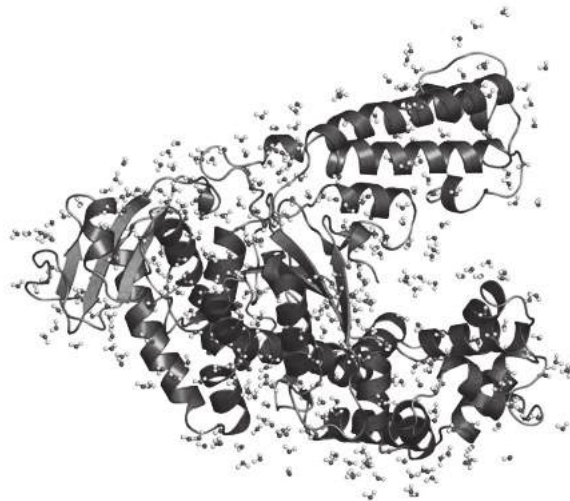
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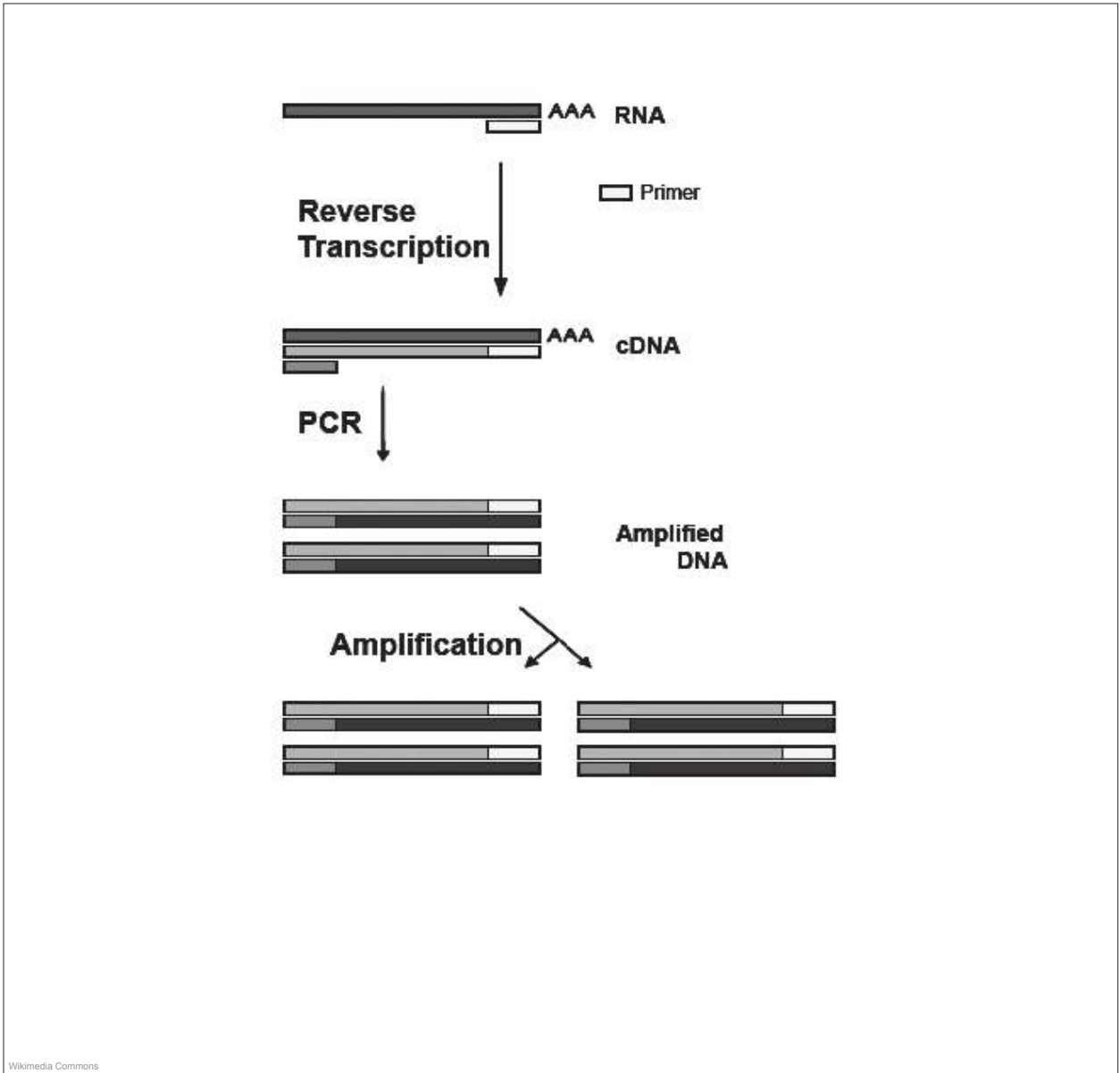
Polymerase chain reaction - PCR

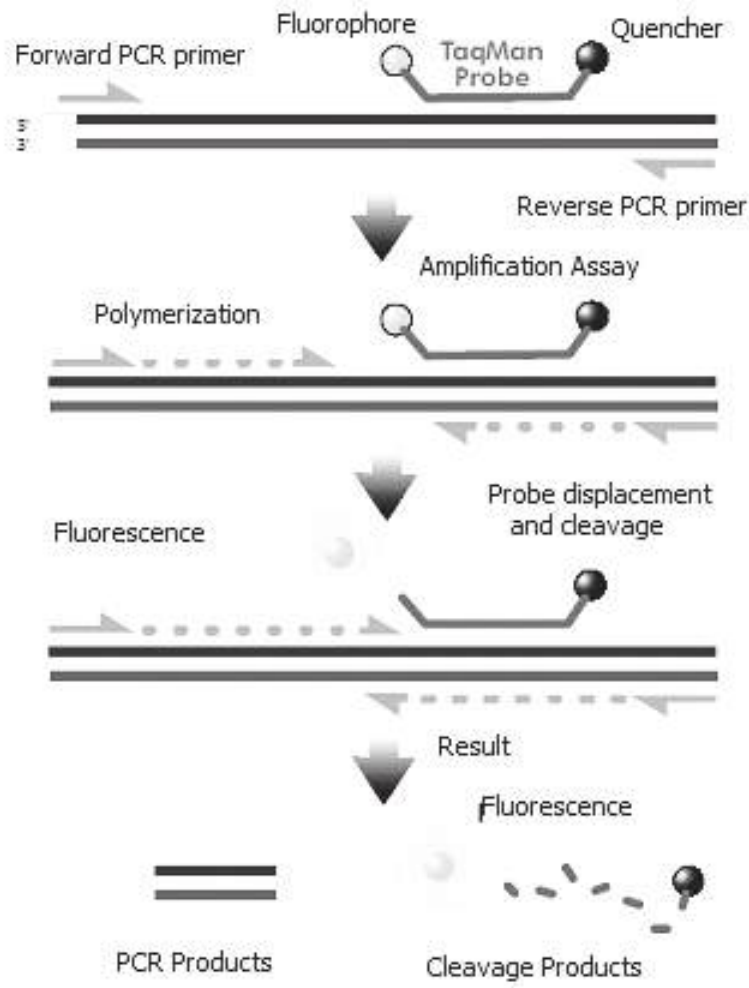


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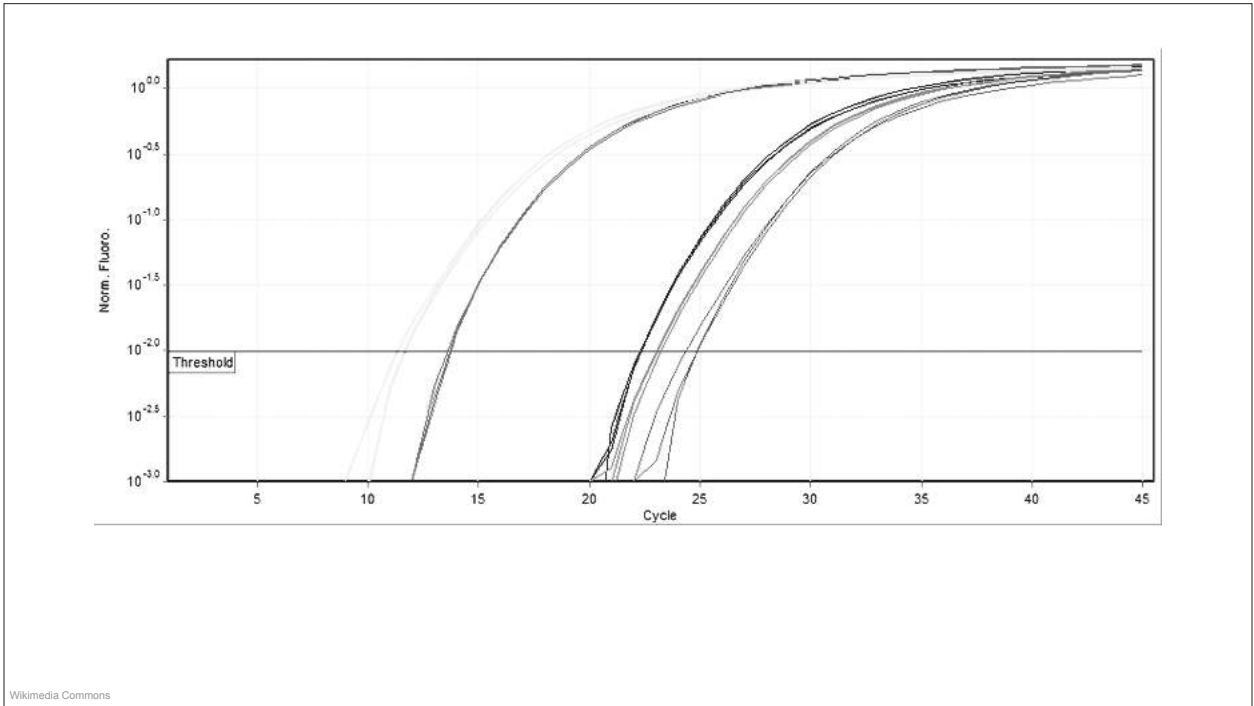


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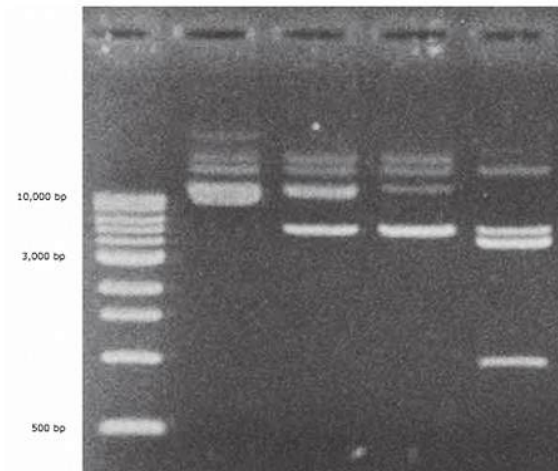


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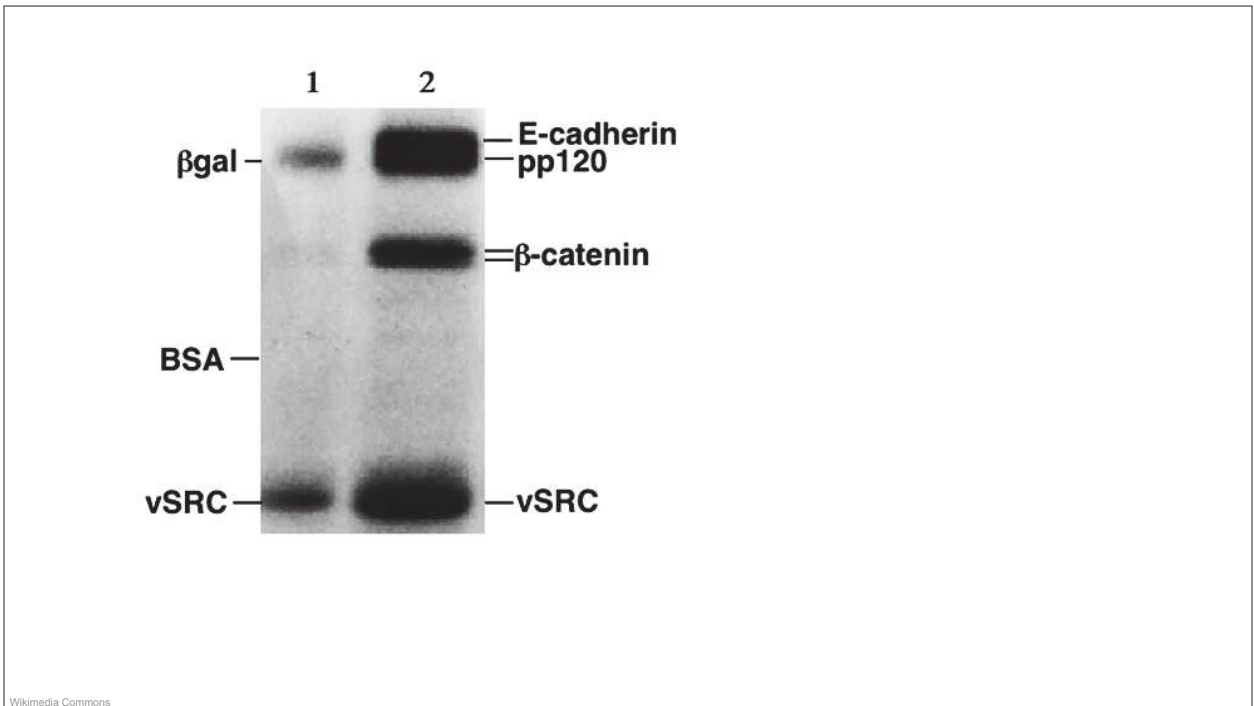
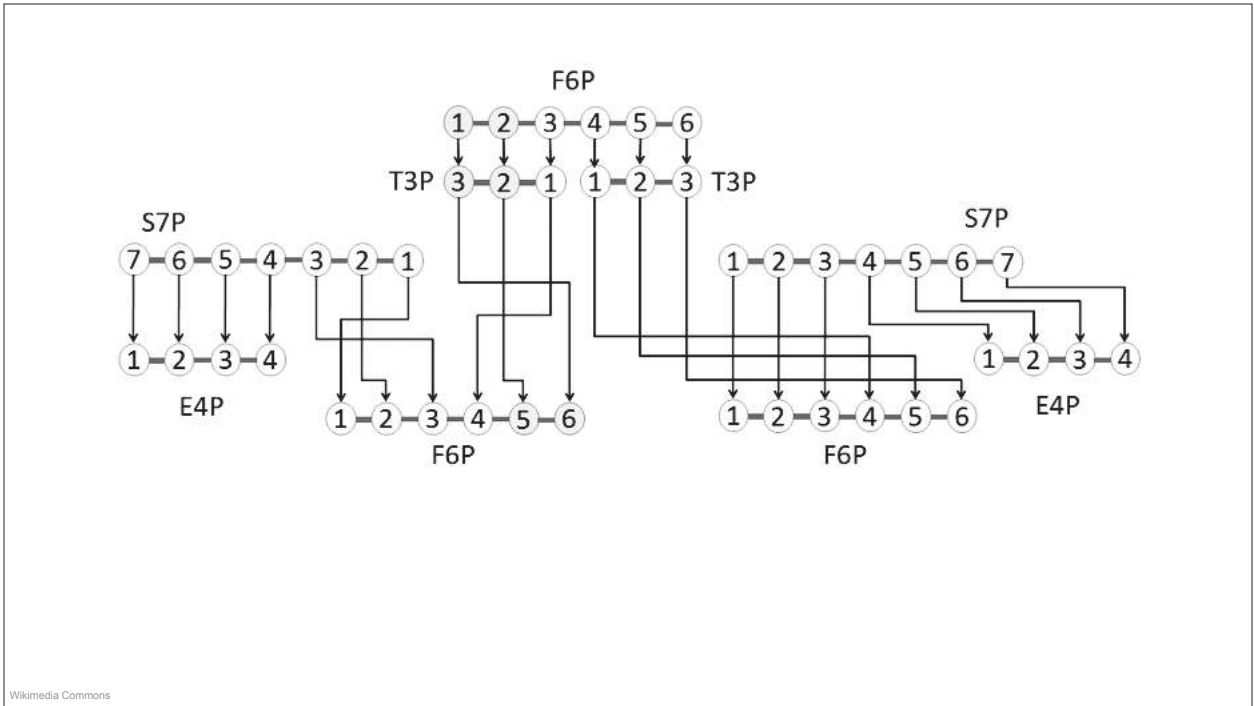




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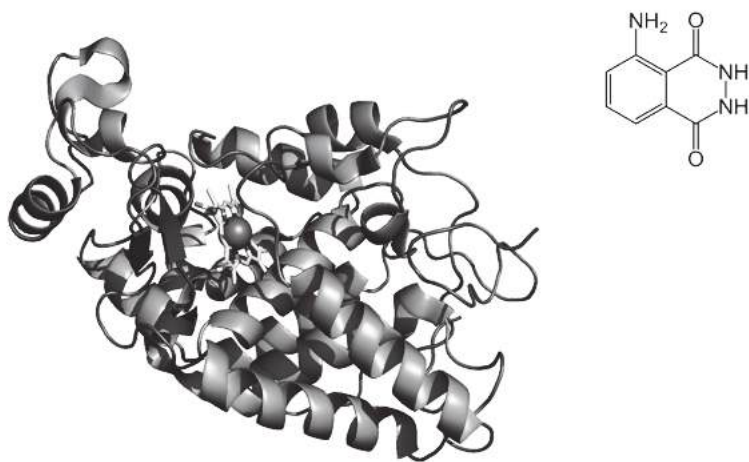


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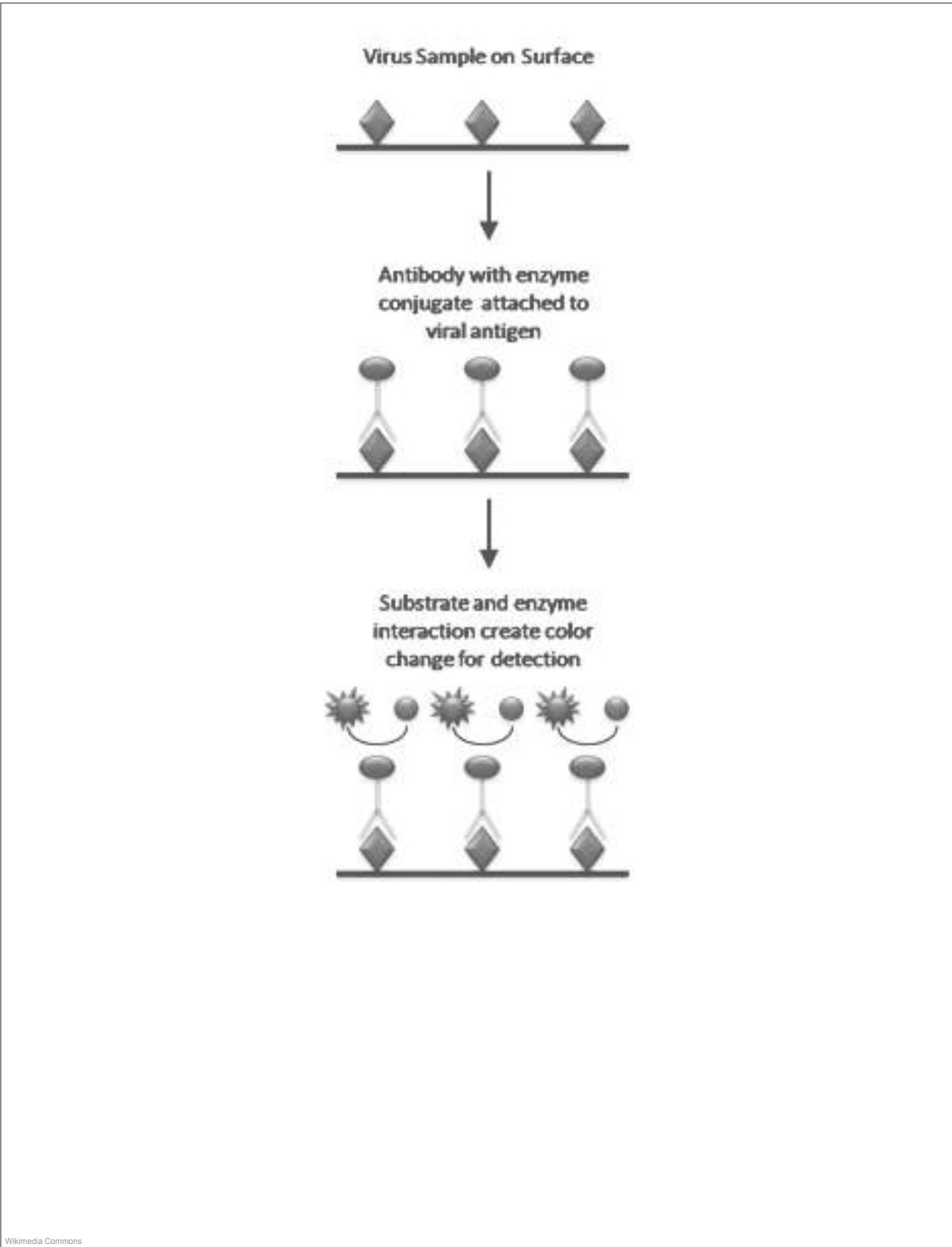




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(1)



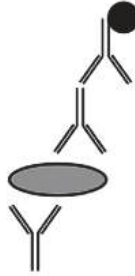
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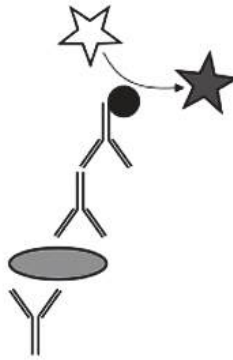
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(4)



(5)



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