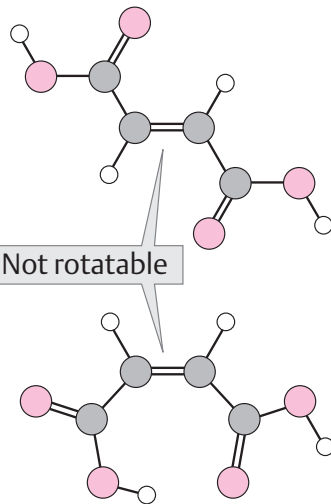


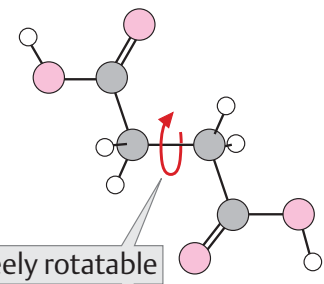
A. *cis-trans* isomers

Fumaric acid
Fp. 287 °C
pK_a 3.0, 4.5

Maleic acid
Fp. 130 °C
pK_a 1.9, 6.5

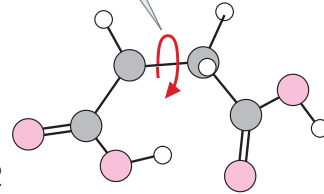
B. Conformers

Succinic acid
Conformation 1

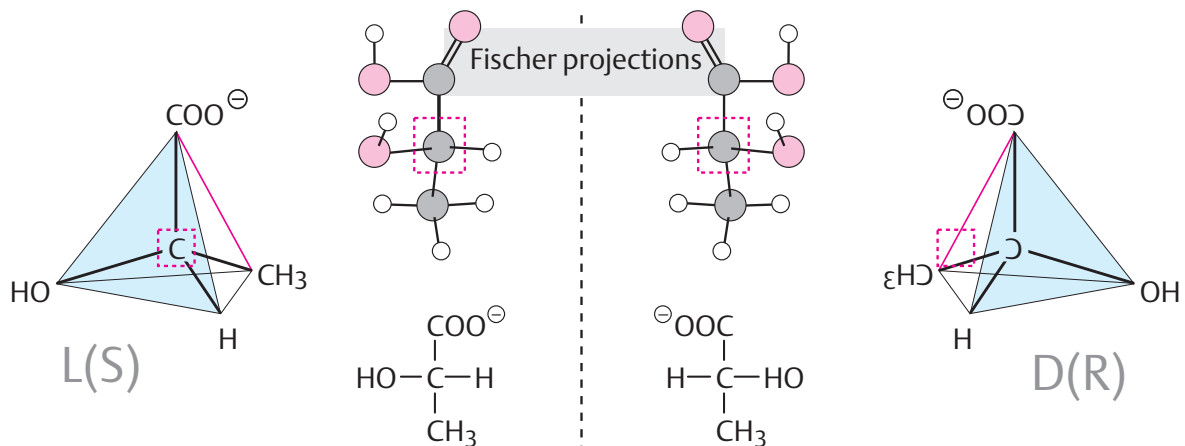


Freely rotatable

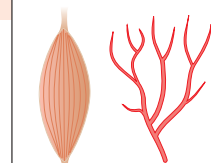
Succinic acid
Conformation 2



C. Optical isomers



	L-lactic acid
Fp.	53 °C
pK _a value	3.7
Specific rotation	+ 2.5°



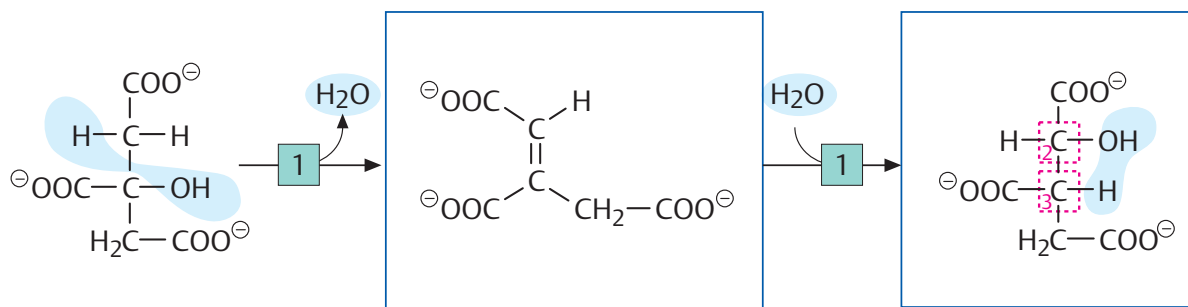
In muscle, blood

	D-lactic acid	
Fp.	53 °C	Fp.
pK _a value	3.7	pK _a value
Specific rotation	-2.5°	Specific rotation



In milk products

D. The aconitase reaction



Citrate (prochiral)

cis-Aconitate (intermediate product)

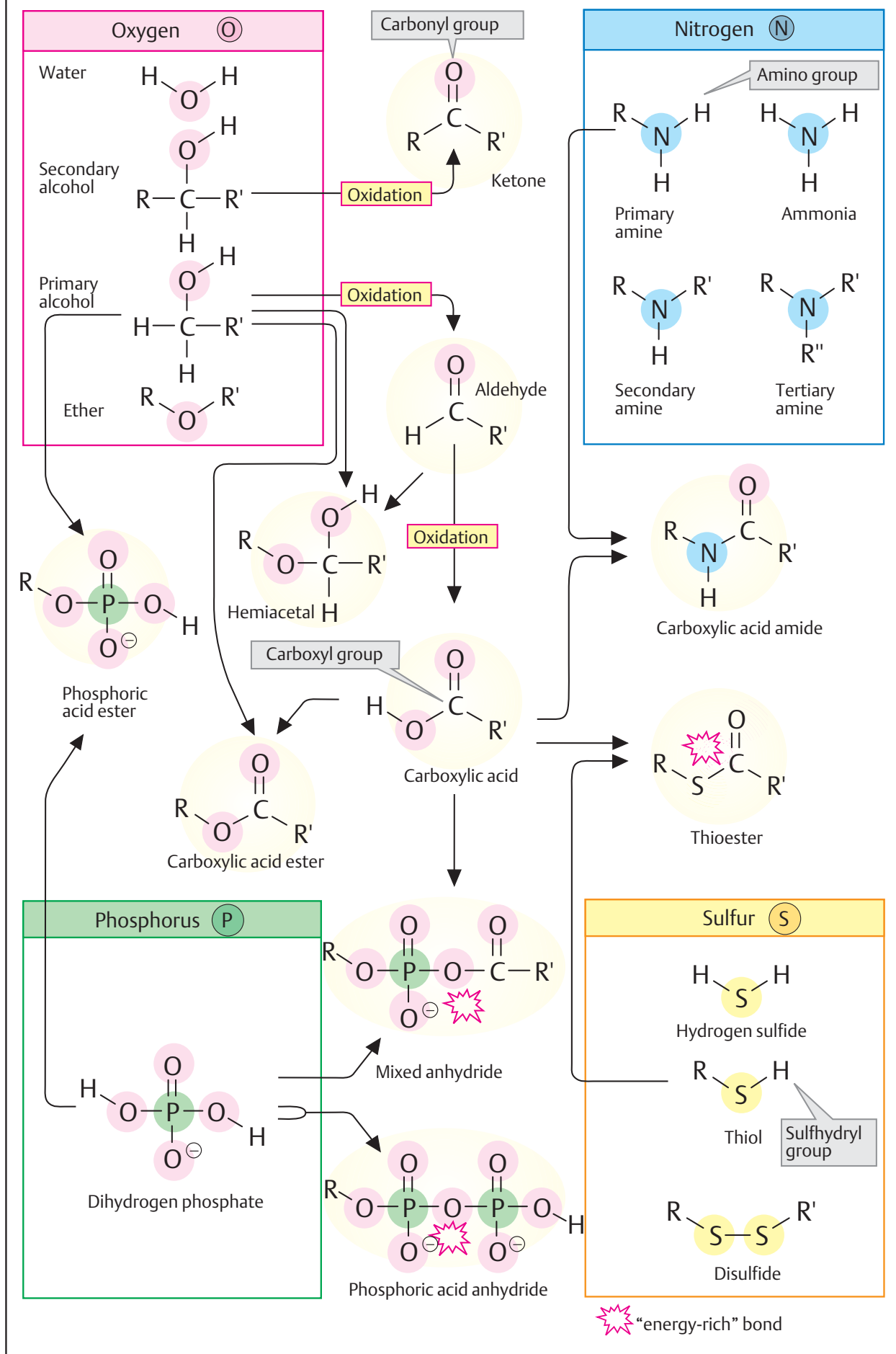
(2R,3S)-Isocitrate

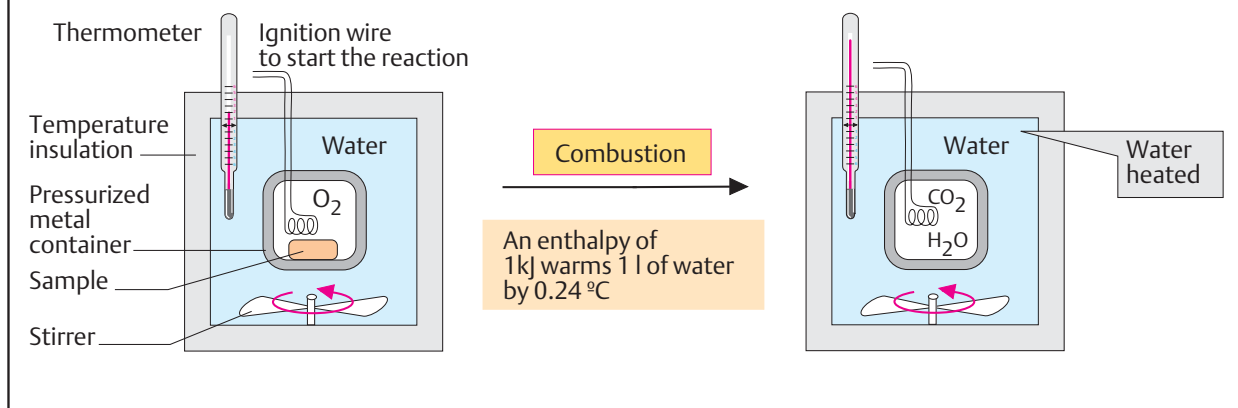
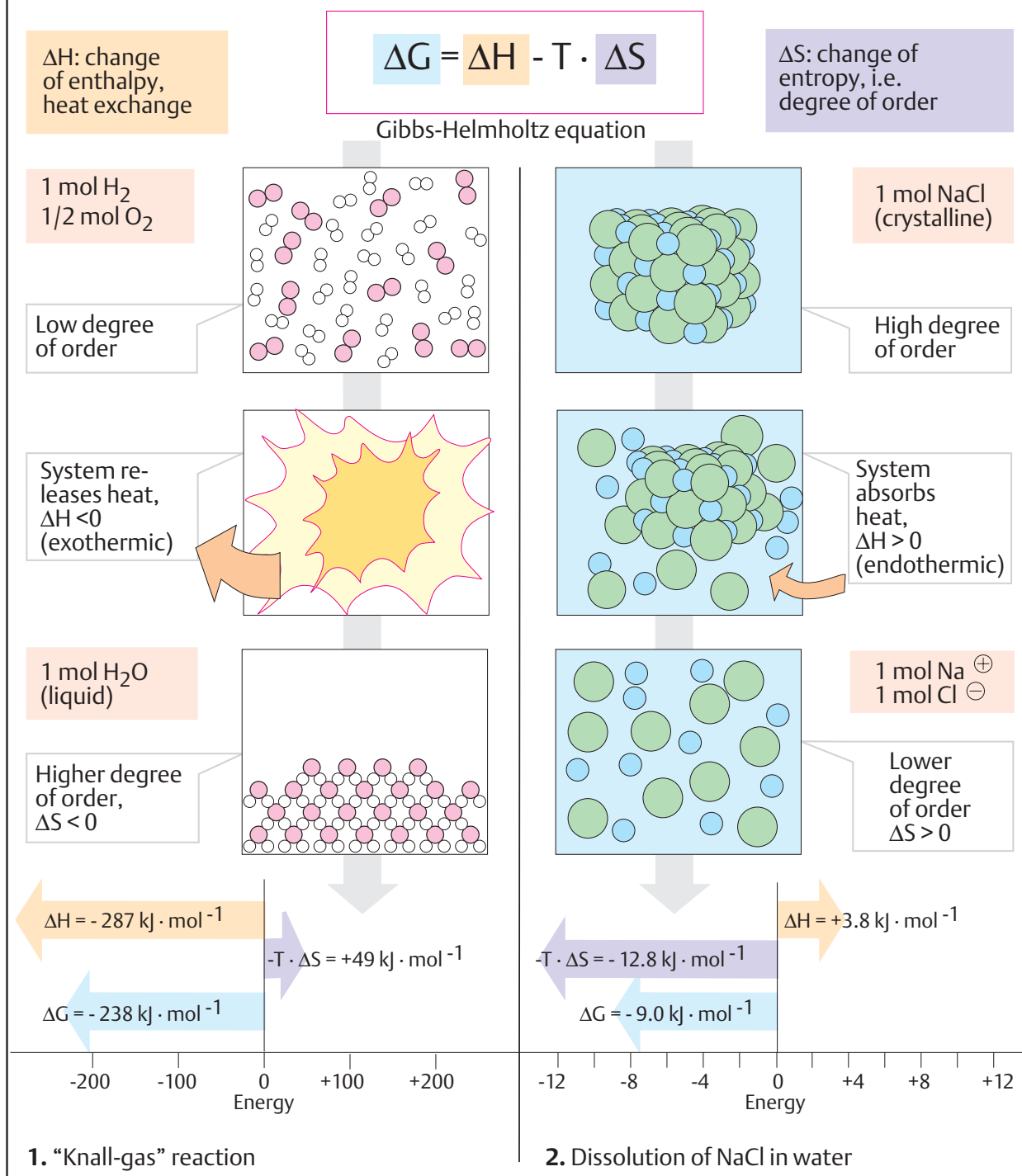
trans-Aconitate occurs in plants



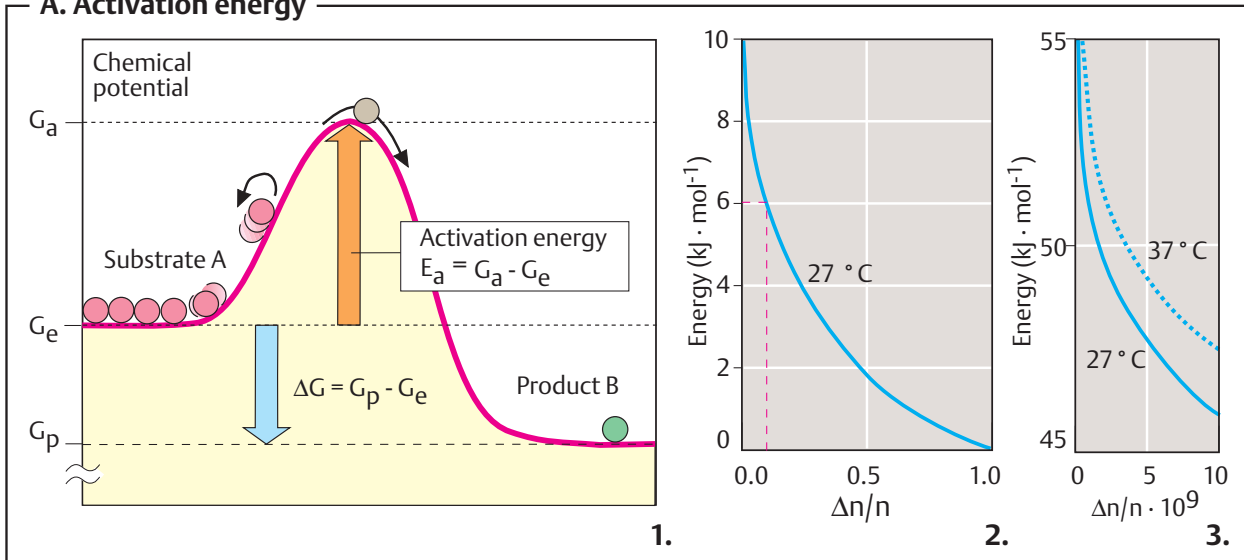
1 Aconitase 4.2.1.3

A. Important classes of compounds

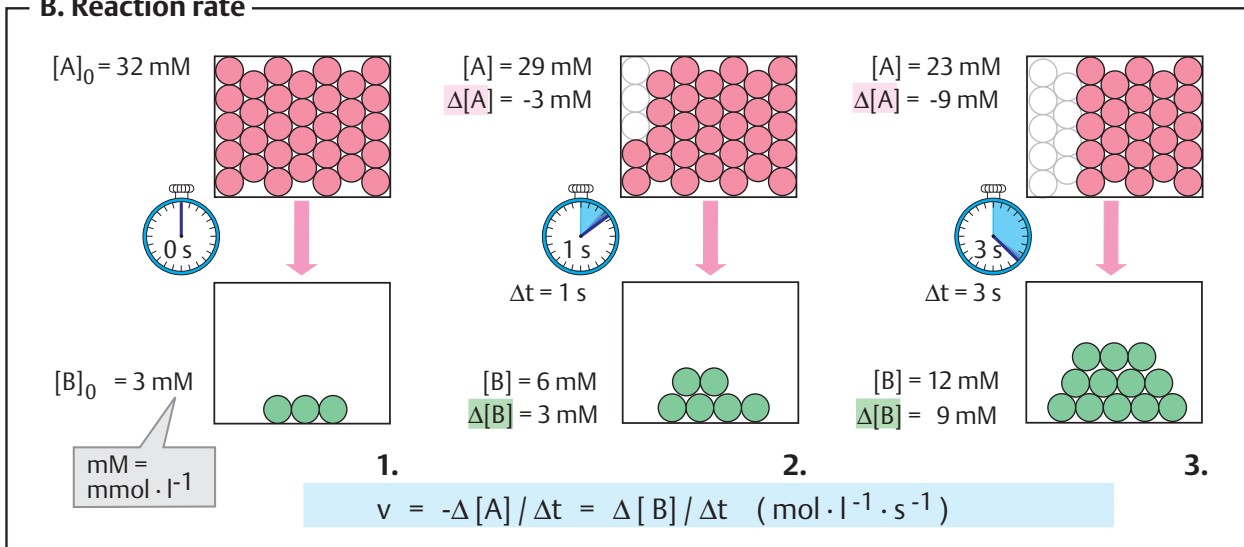


A. Heat of reaction and calorimetry

B. Enthalpy and entropy


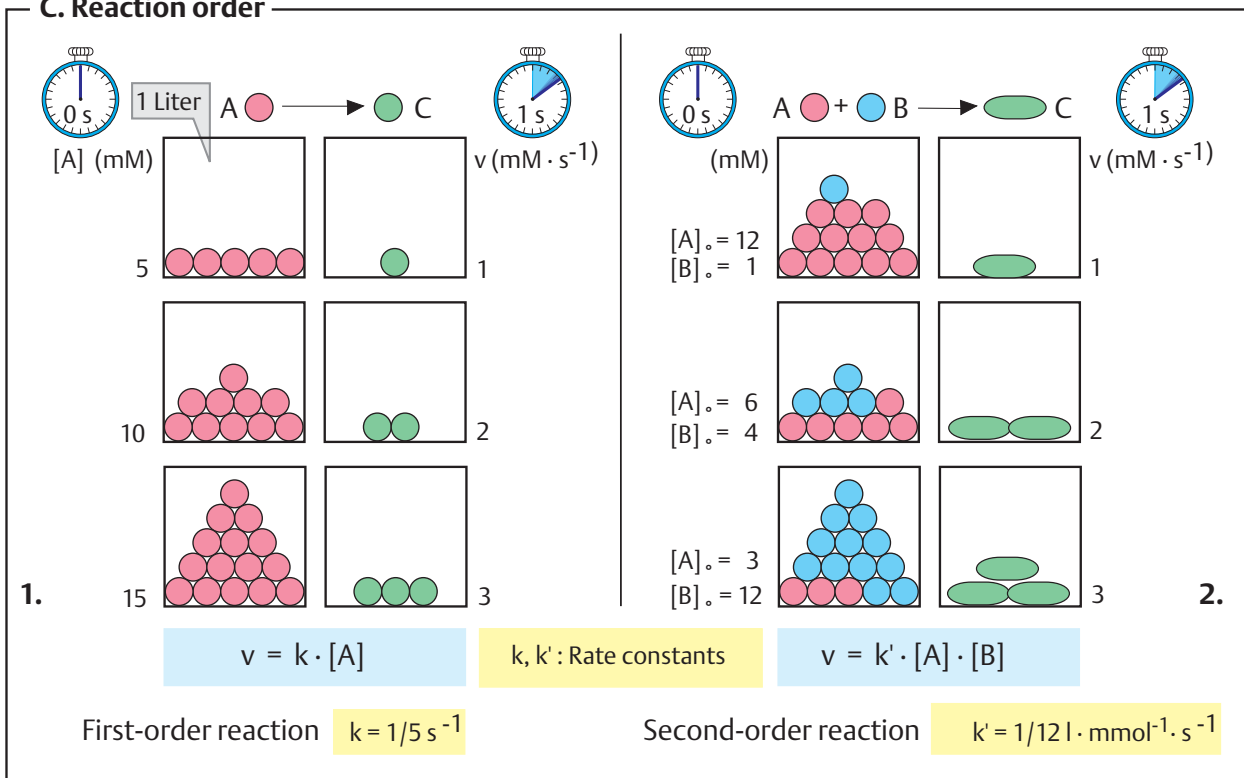
A. Activation energy



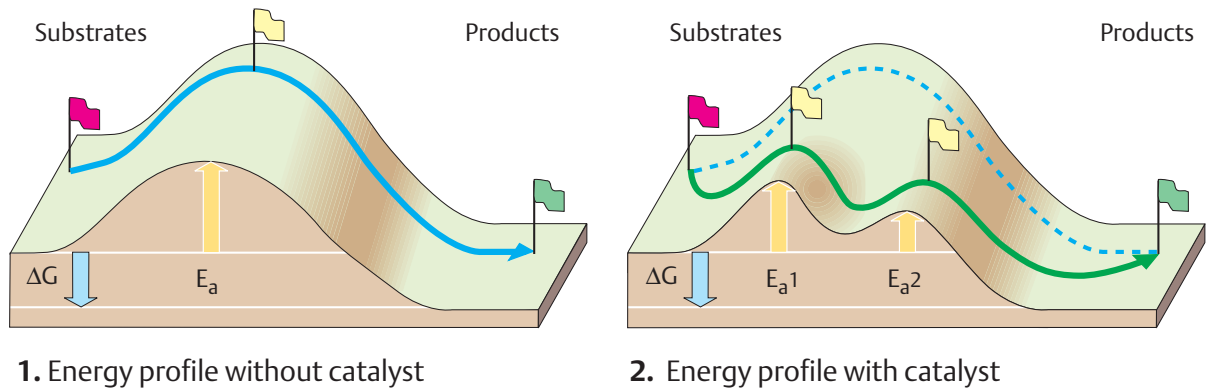
B. Reaction rate



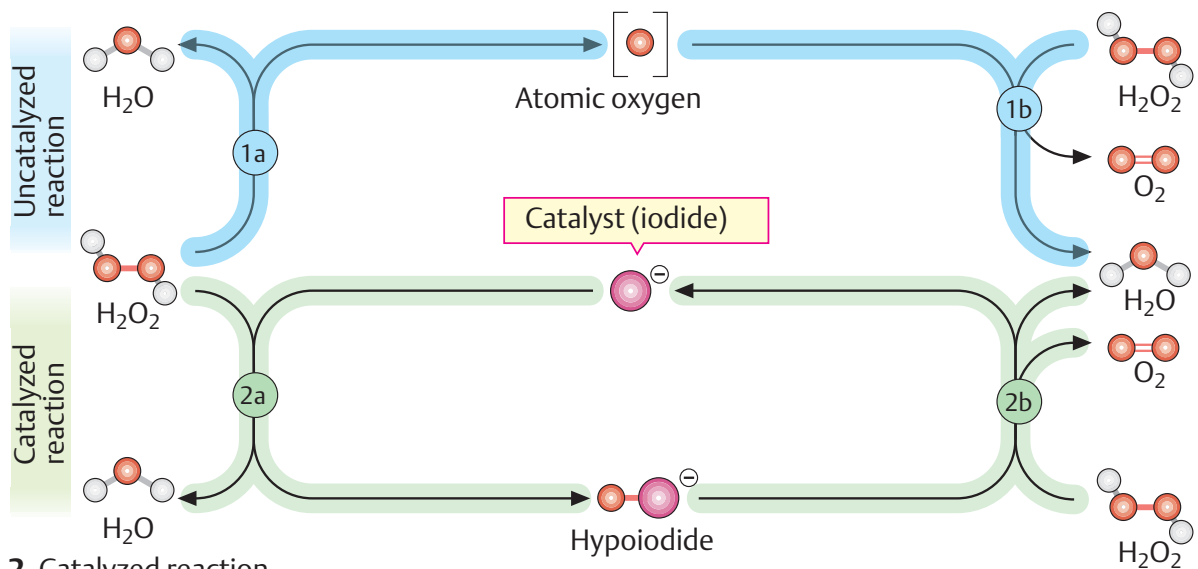
C. Reaction order



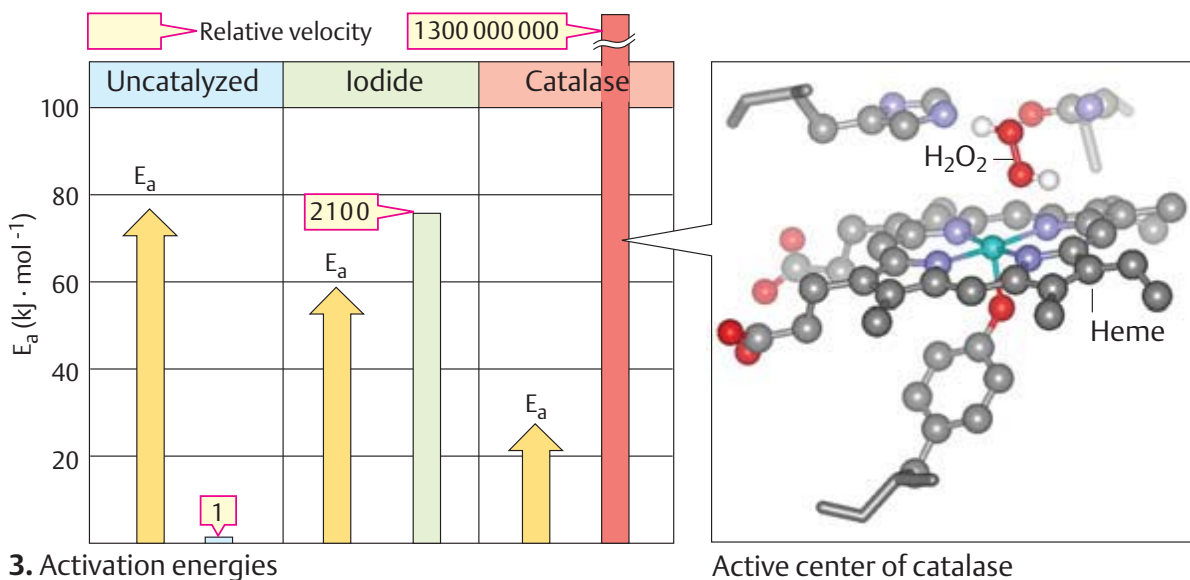
A. Catalysis: principle

B. Catalysis of H_2O_2 – breakdown by iodide

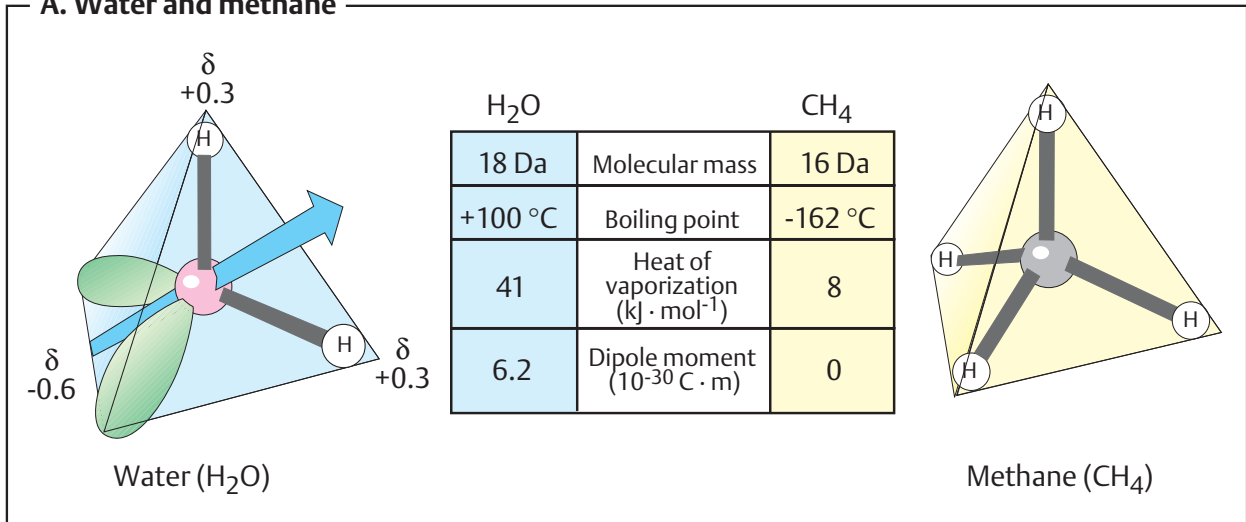
1. Breakdown of hydrogen peroxide



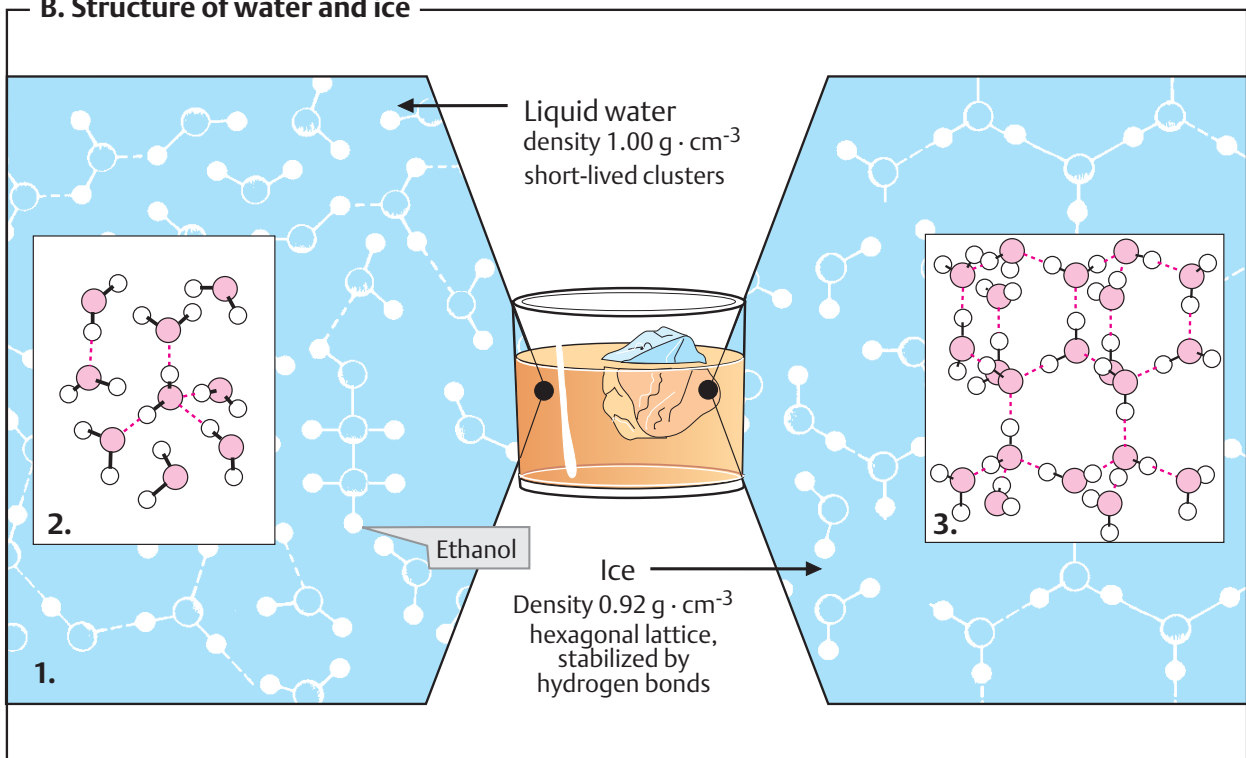
2. Catalyzed reaction



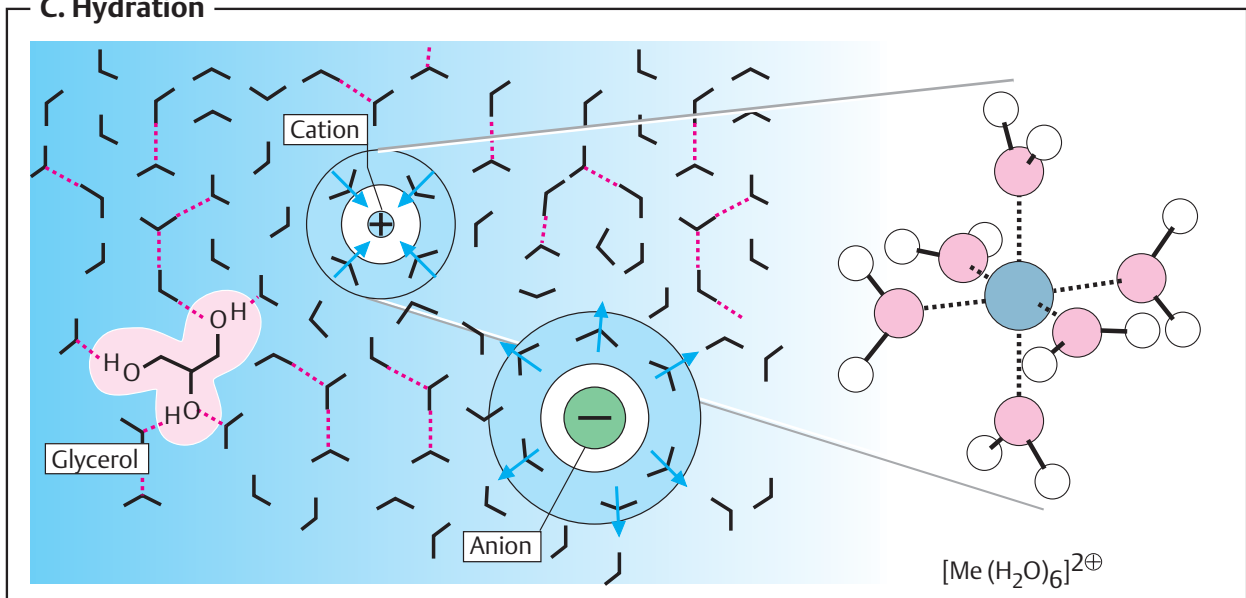
A. Water and methane



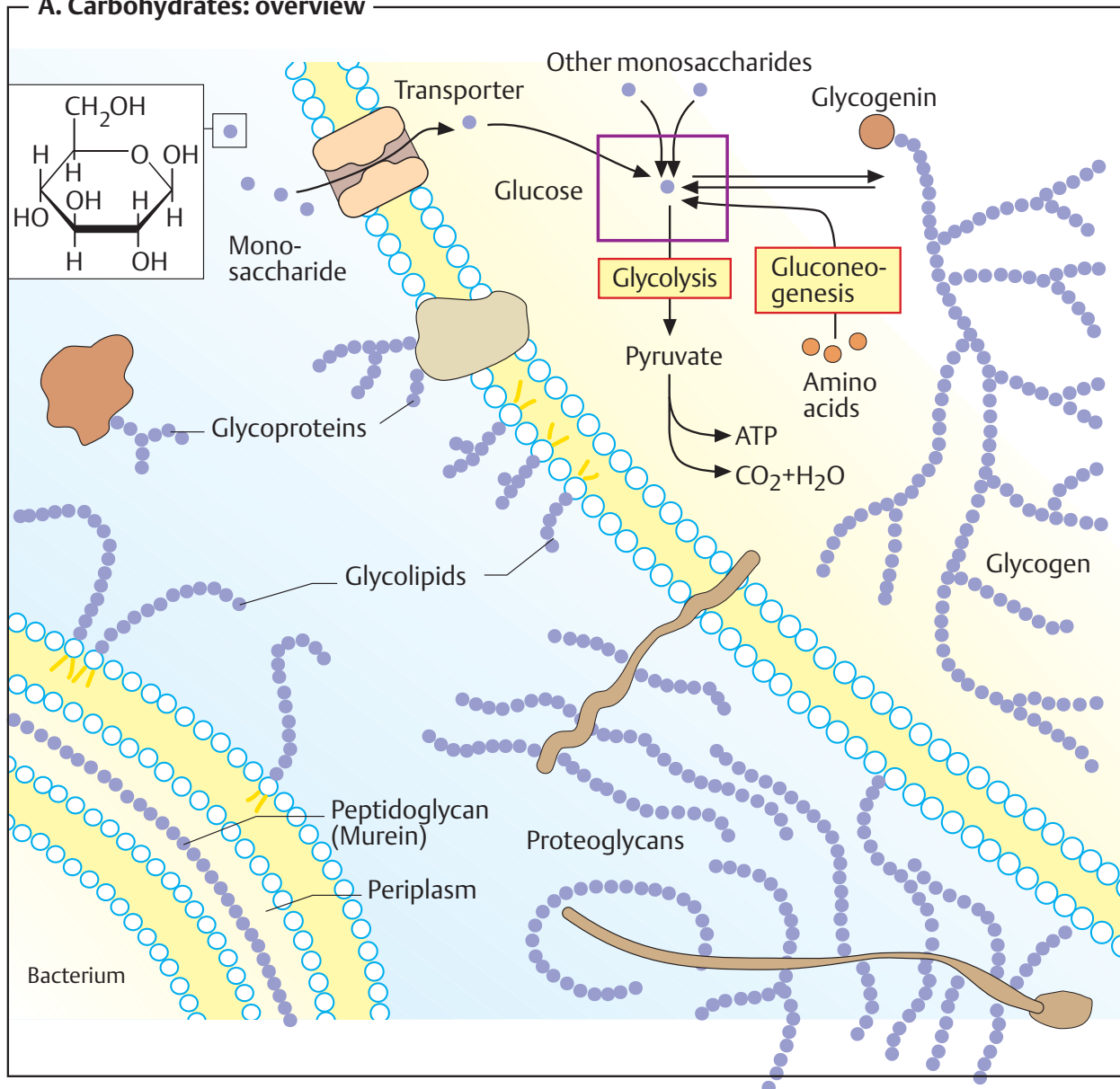
B. Structure of water and ice



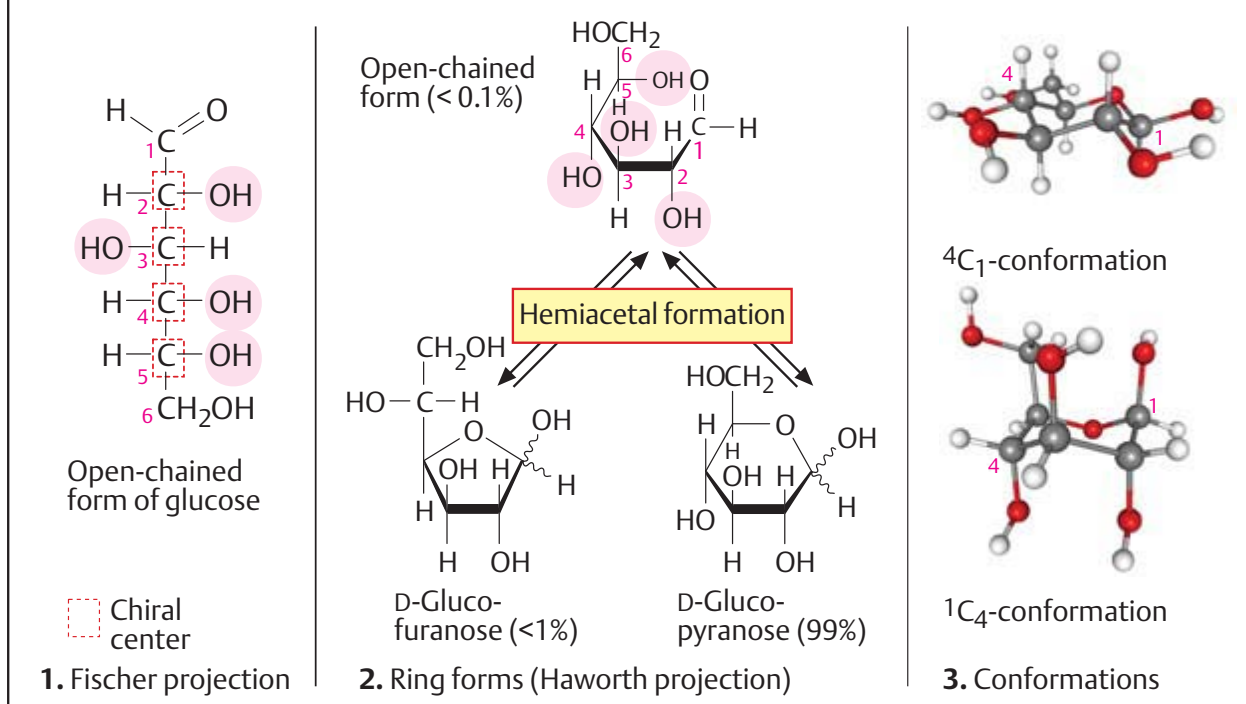
C. Hydration



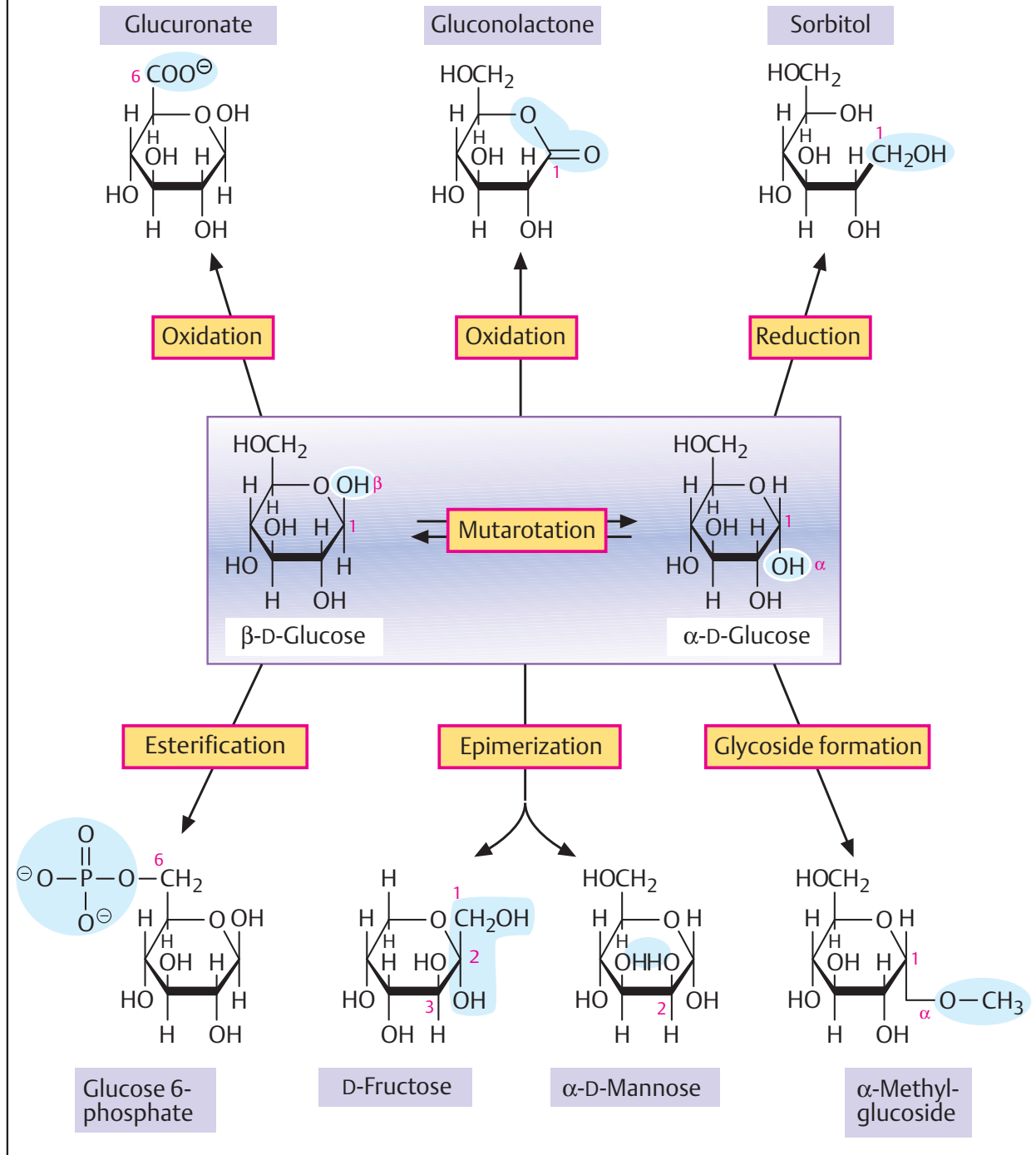
A. Carbohydrates: overview



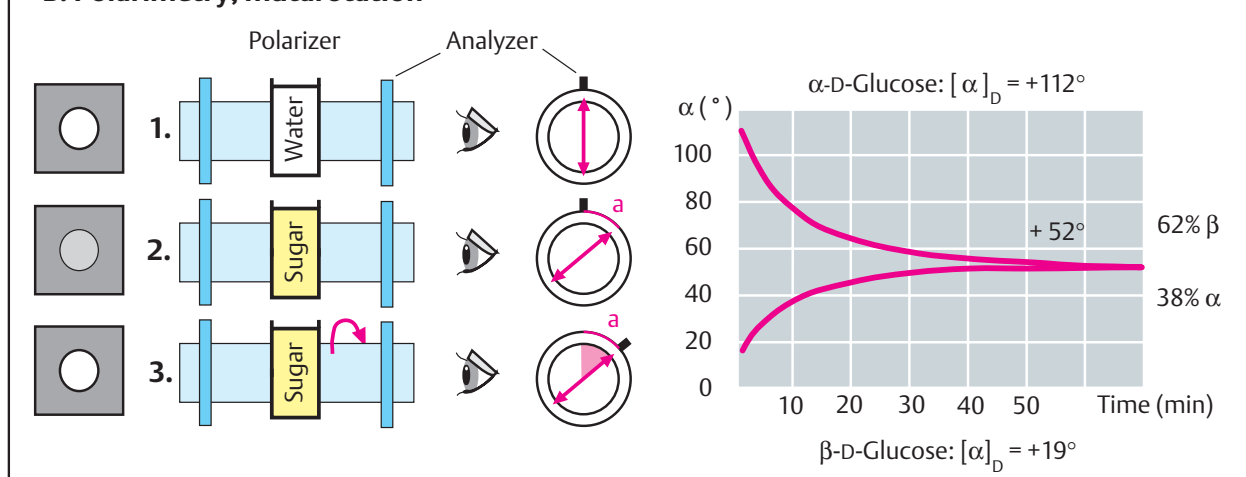
B. Monosaccharides: structure



A. Reactions of the monosaccharides



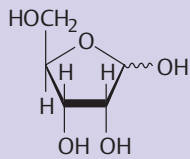
B. Polarimetry, mutarotation



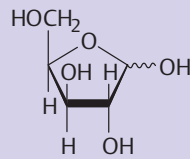
A. Important monosaccharides

① Aldoses

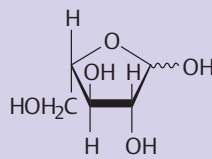
D-Ribose (Rib)



D-Xylose (Xyl)

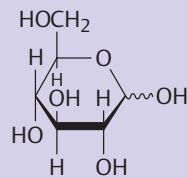


L-Arabinose (Ara)

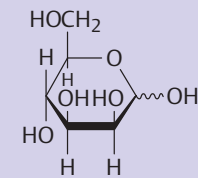


Pentoses

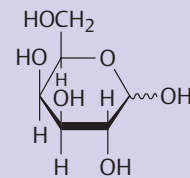
D-Glucose (Glc)



D-Mannose (Man)



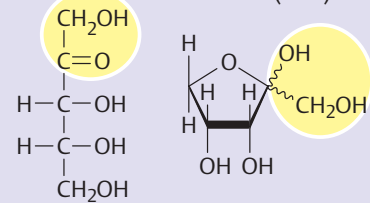
D-Galactose (Gal)



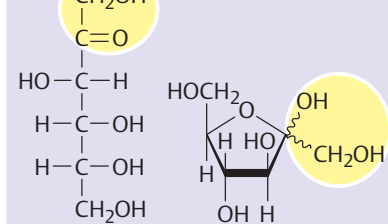
Hexoses

② Ketoses

D-Ribulose (Rub)

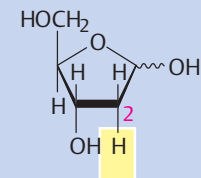


D-Fructose (Fru)

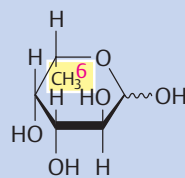


③ Deoxyaldoses

2-Deoxy-D-ribose (dRib)

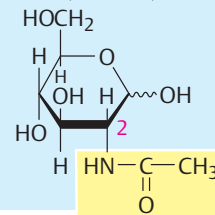


L-Fucose (Fuc)

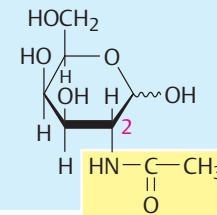


④ Acetylated amino sugars

N-Acetyl-D-glucosamine (GlcNAc)

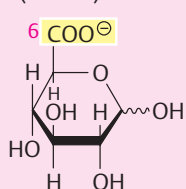


N-Acetyl-D-galactosamine (GalNAc)

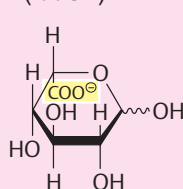


⑤ Acidic monosaccharides

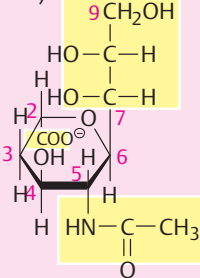
D-Glucuronic acid (GlcUA)



L-Iduronic acid (IduUA)

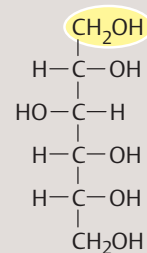


N-Acetylneuraminic acid (NeuAc)

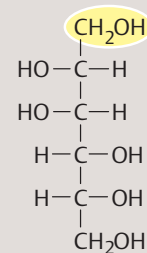


⑥ Sugar alcohols (alditols)

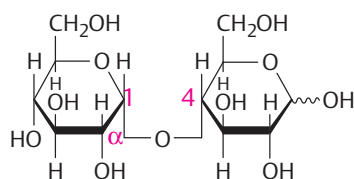
D-Sorbitol



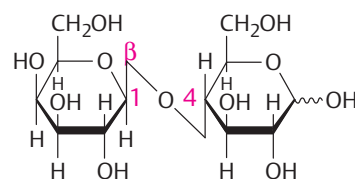
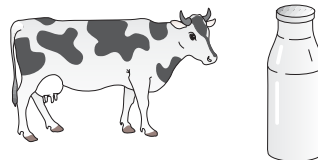
D-Mannitol



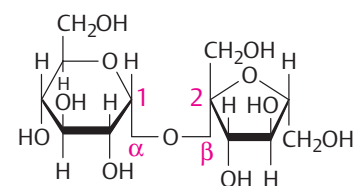
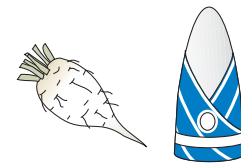
B. Disaccharides



1. Maltose

 α -D-Glucopyranosyl-(1 \rightarrow 4)-D-glucopyranose

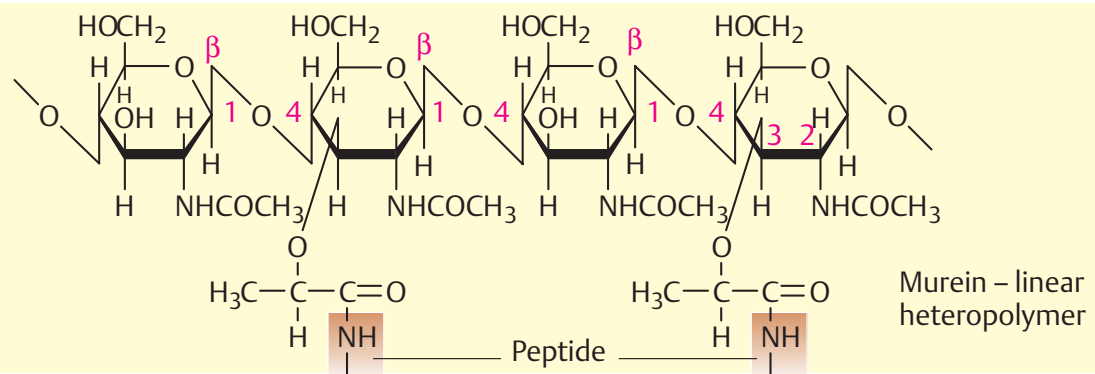
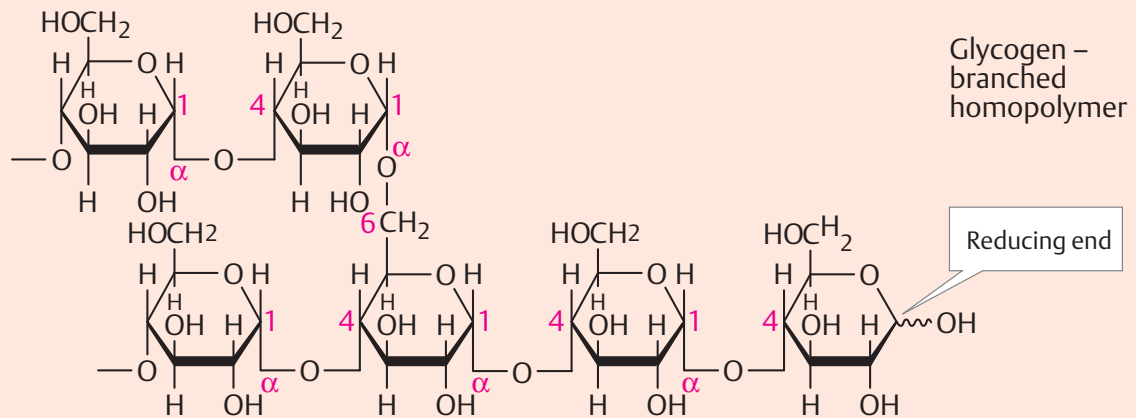
2. Lactose

 β -D-Galactopyranosyl-(1 \rightarrow 4)-D-glucopyranose

3. Sucrose

 α -D-Glucopyranosyl-(1 \leftrightarrow 2)- β -D-fructofuranoside

A. Polysaccharides: structure



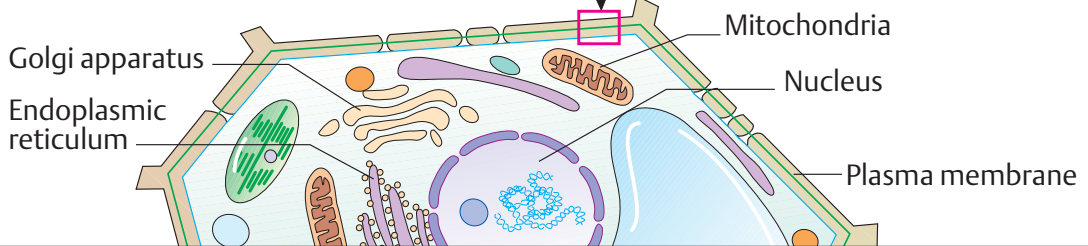
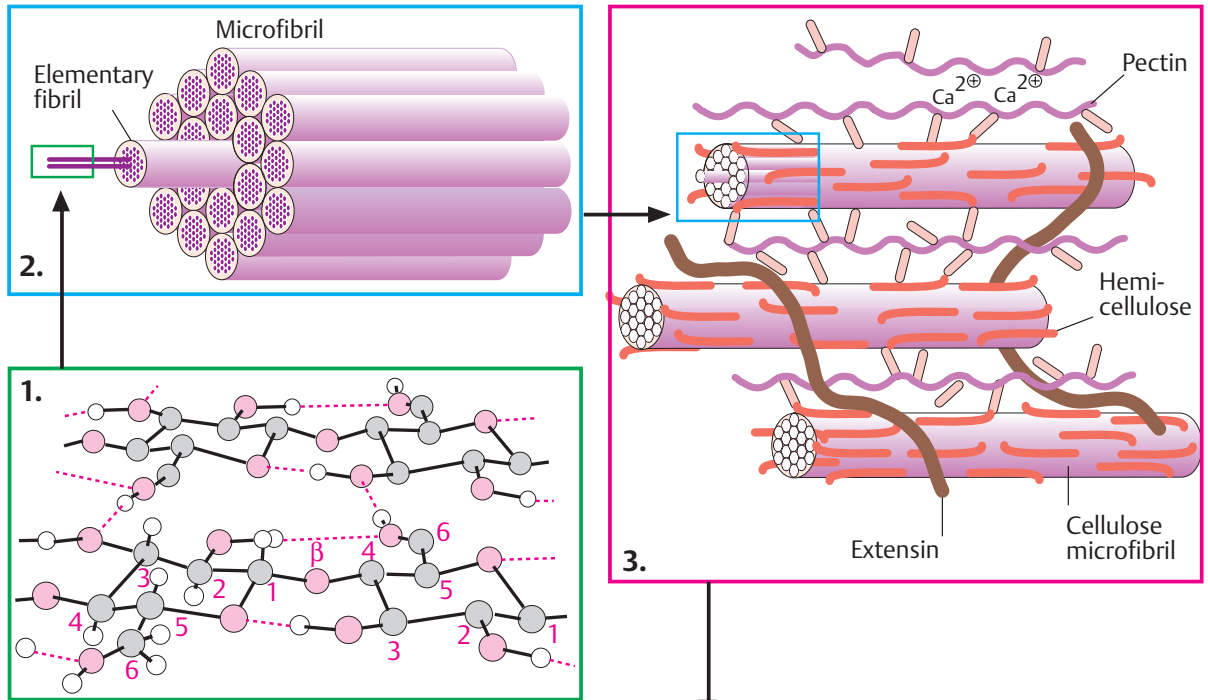
B. Important polysaccharides

Poly-saccharide	Mono-saccharide 1	Mono-saccharide 2	Linkage	Branching	Occurrence	Function
Bacteria						
Murein	D-GlcNAc	D-MurNAc ¹⁾	$\beta 1 \rightarrow 4$	—	Cell wall	SC
Dextran	D-Glc	—	$\alpha 1 \rightarrow 6$	$\alpha 1 \rightarrow 3$	Slime	WB
Plants						
Agarose	D-Gal	L-aGal ²⁾	$\beta 1 \rightarrow 4$	$\beta 1 \rightarrow 3$	Red algae (agar)	WB
Carrageenan	D-Gal	—	$\beta 1 \rightarrow 3$	$\alpha 1 \rightarrow 4$	Red algae	WB
Cellulose	D-Glc	—	$\beta 1 \rightarrow 4$	—	Cell wall	SC
Xyloglucan	D-Glc	D-Xyl (D-Gal, L-Fuc)	$\beta 1 \rightarrow 4$	$\beta 1 \rightarrow 6$ ($\beta 1 \rightarrow 2$)	Cell wall (Hemicellulose)	SC
Arabinan	L-Ara	—	$\alpha 1 \rightarrow 5$	$\alpha 1 \rightarrow 3$	Cell wall (pectin)	SC
Amylose	D-Glc	—	$\alpha 1 \rightarrow 4$	—	Amyloplasts	RC
Amylopectin	D-Glc	—	$\alpha 1 \rightarrow 4$	$\alpha 1 \rightarrow 6$	Amyloplasts	RC
Inulin	D-Fru	—	$\beta 2 \rightarrow 1$	—	Storage cells	RC
Animals						
Chitin	D-GlcNAc	—	$\beta 1 \rightarrow 4$	—	Insects, crabs	SK
Glycogen	D-Glc	—	$\alpha 1 \rightarrow 4$	$\alpha 1 \rightarrow 6$	Liver, muscle	RK
Hyaluronic acid	D-GlcUA	D-GlcNAc	$\beta 1 \rightarrow 4$	—	Connective tissue	SK, WB
			$\beta 1 \rightarrow 3$			

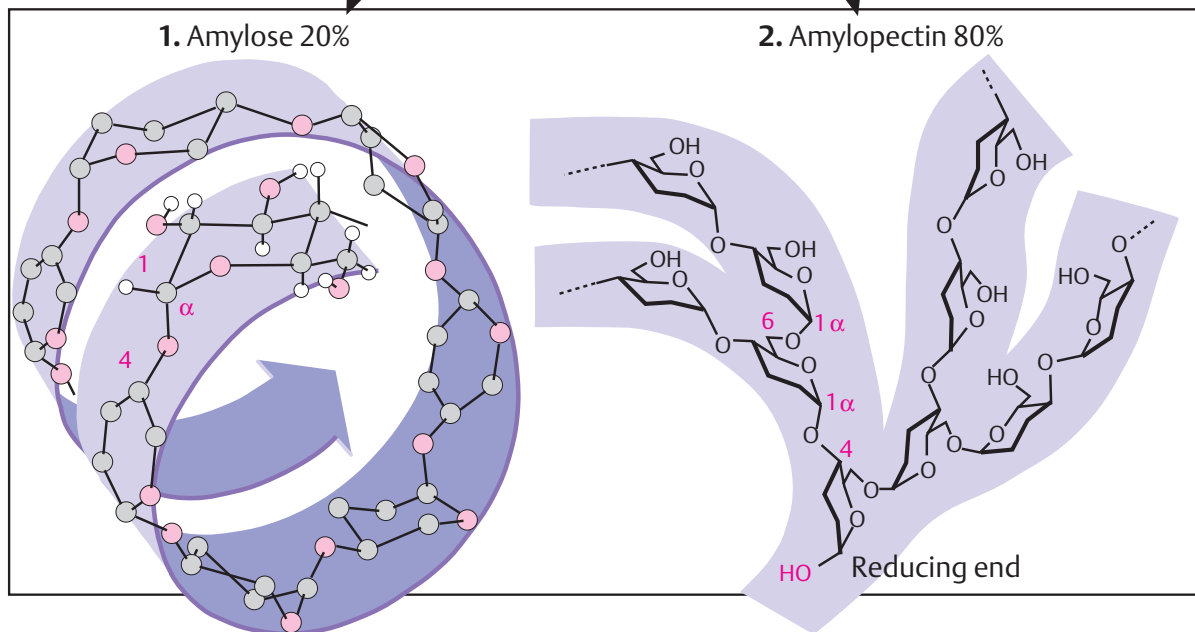
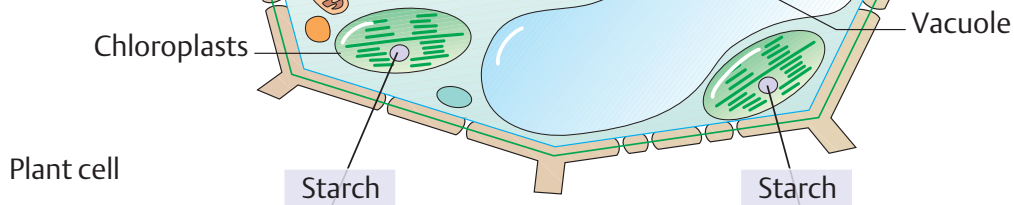
SC= structural carbohydrate, RC= reserve carbohydrate,

WB = water-binding carbohydrate; ¹⁾ N-acetylmuramic acid, ²⁾ 3,6-anhydrogalactose

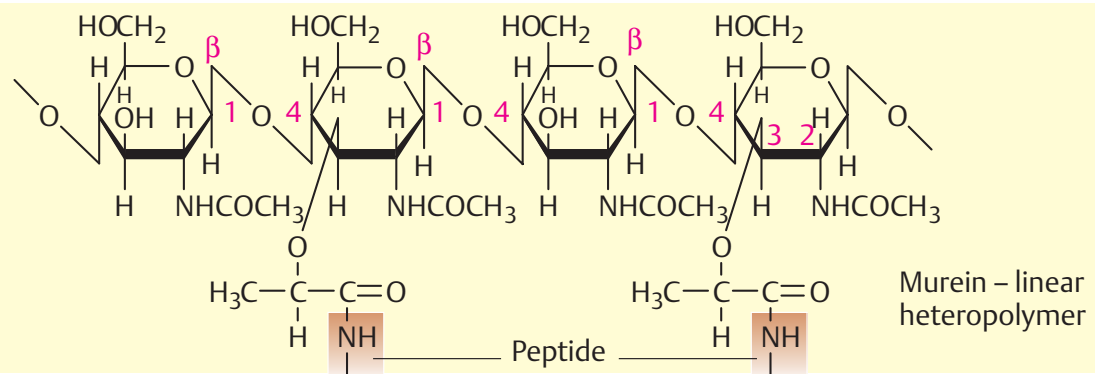
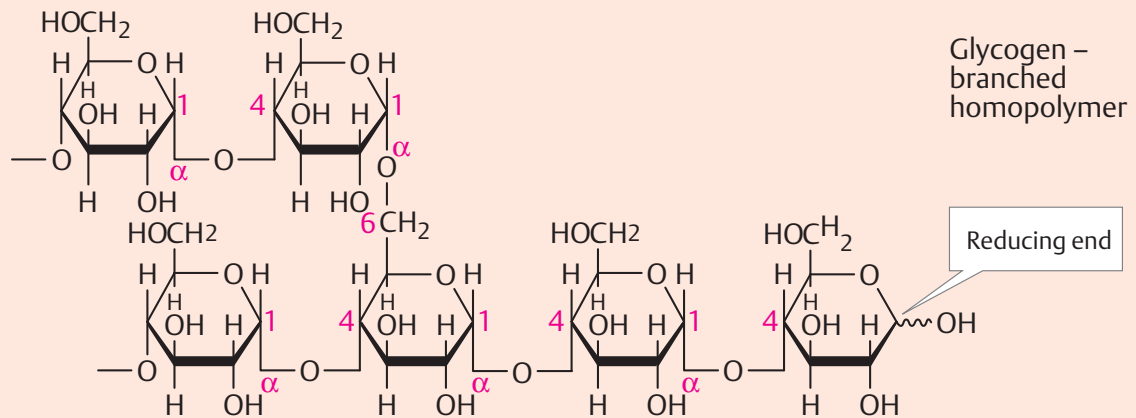
A. Cellulose



B. Starch



A. Polysaccharides: structure



B. Important polysaccharides

Poly-saccharide	Mono-saccharide 1	Mono-saccharide 2	Linkage	Branching	Occurrence	Function
Bacteria						
Murein	D-GlcNAc	D-MurNAc ¹⁾	$\beta 1 \rightarrow 4$	—	Cell wall	SC
Dextran	D-Glc	—	$\alpha 1 \rightarrow 6$	$\alpha 1 \rightarrow 3$	Slime	WB
Plants						
Agarose	D-Gal	L-aGal ²⁾	$\beta 1 \rightarrow 4$	$\beta 1 \rightarrow 3$	Red algae (agar)	WB
Carrageenan	D-Gal	—	$\beta 1 \rightarrow 3$	$\alpha 1 \rightarrow 4$	Red algae	WB
Cellulose	D-Glc	—	$\beta 1 \rightarrow 4$	—	Cell wall	SC
Xyloglucan	D-Glc	D-Xyl (D-Gal, L-Fuc)	$\beta 1 \rightarrow 4$	$\beta 1 \rightarrow 6$ ($\beta 1 \rightarrow 2$)	Cell wall (Hemicellulose)	SC
Arabinan	L-Ara	—	$\alpha 1 \rightarrow 5$	$\alpha 1 \rightarrow 3$	Cell wall (pectin)	SC
Amylose	D-Glc	—	$\alpha 1 \rightarrow 4$	—	Amyloplasts	RC
Amylopectin	D-Glc	—	$\alpha 1 \rightarrow 4$	$\alpha 1 \rightarrow 6$	Amyloplasts	RC
Inulin	D-Fru	—	$\beta 2 \rightarrow 1$	—	Storage cells	RC
Animals						
Chitin	D-GlcNAc	—	$\beta 1 \rightarrow 4$	—	Insects, crabs	SK
Glycogen	D-Glc	—	$\alpha 1 \rightarrow 4$	$\alpha 1 \rightarrow 6$	Liver, muscle	RK
Hyaluronic acid	D-GlcUA	D-GlcNAc	$\beta 1 \rightarrow 4$	—	Connective tissue	SK, WB
			$\beta 1 \rightarrow 3$			

SC= structural carbohydrate, RC= reserve carbohydrate,

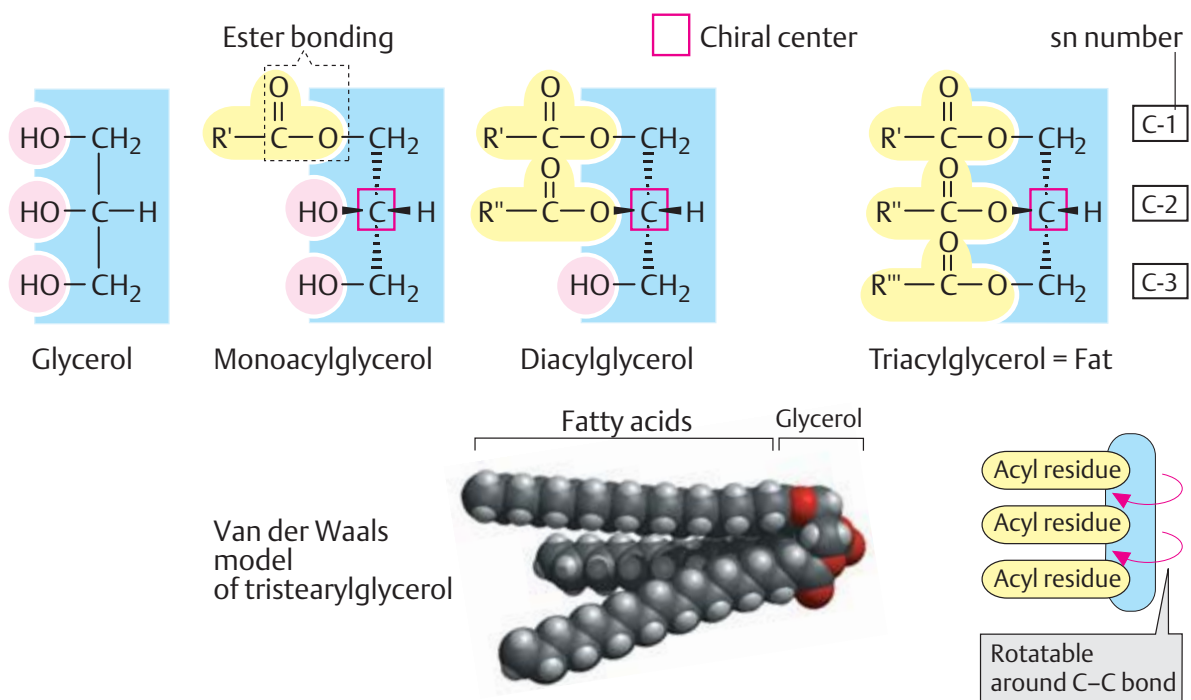
WB = water-binding carbohydrate; ¹⁾ N-acetylmuramic acid, ²⁾ 3,6-anhydrogalactose

A. Carboxylic acids

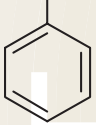

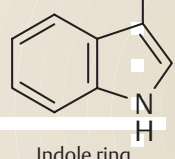
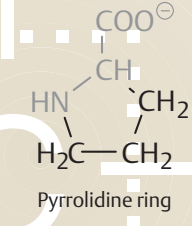
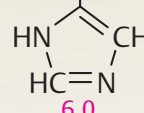

Name	Number of carbons	Number of double bonds Position of double bonds		
Formic acid	1:0			Not contained in lipids
Acetic acid	2:0			
Propionic acid	3:0			
Butyric acid	4:0			
Valerianic acid	5:0			
Caproic acid	6:0			<chem>HOOC-CH2-CH2-CH2-CH2-CH3</chem>
Caprylic acid	8:0			Caproic acid
Capric acid	10:0			
Lauric acid	12:0			
Myristic acid	14:0			
Palmitic acid	16:0			
Stearic acid	18:0			
Oleic acid	18:1; 9			
★ Linoleic acid	18:2; 9,12			
★ Linolenic acid	18:3; 9,12,15			
Arachidic acid	20:0			
★ Arachidonic acid	20:4; 5,8,11,14			
Behenic acid	22:0			
Erucic acid	22:1; 13			
Lignoceric acid	24:0			
Nervonic acid	24:1; 15			

★ Essential in human nutrition

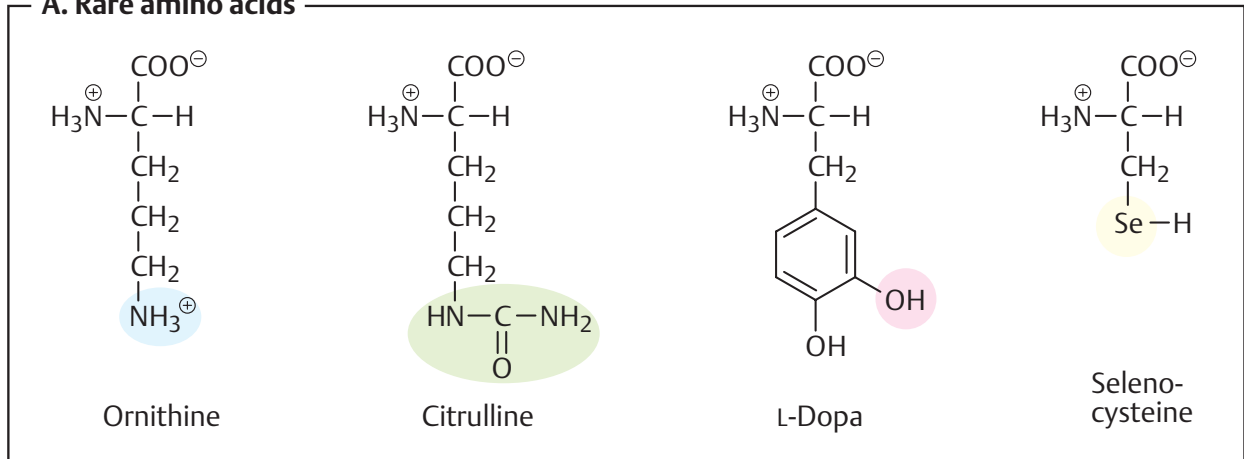
B. Structure of fats



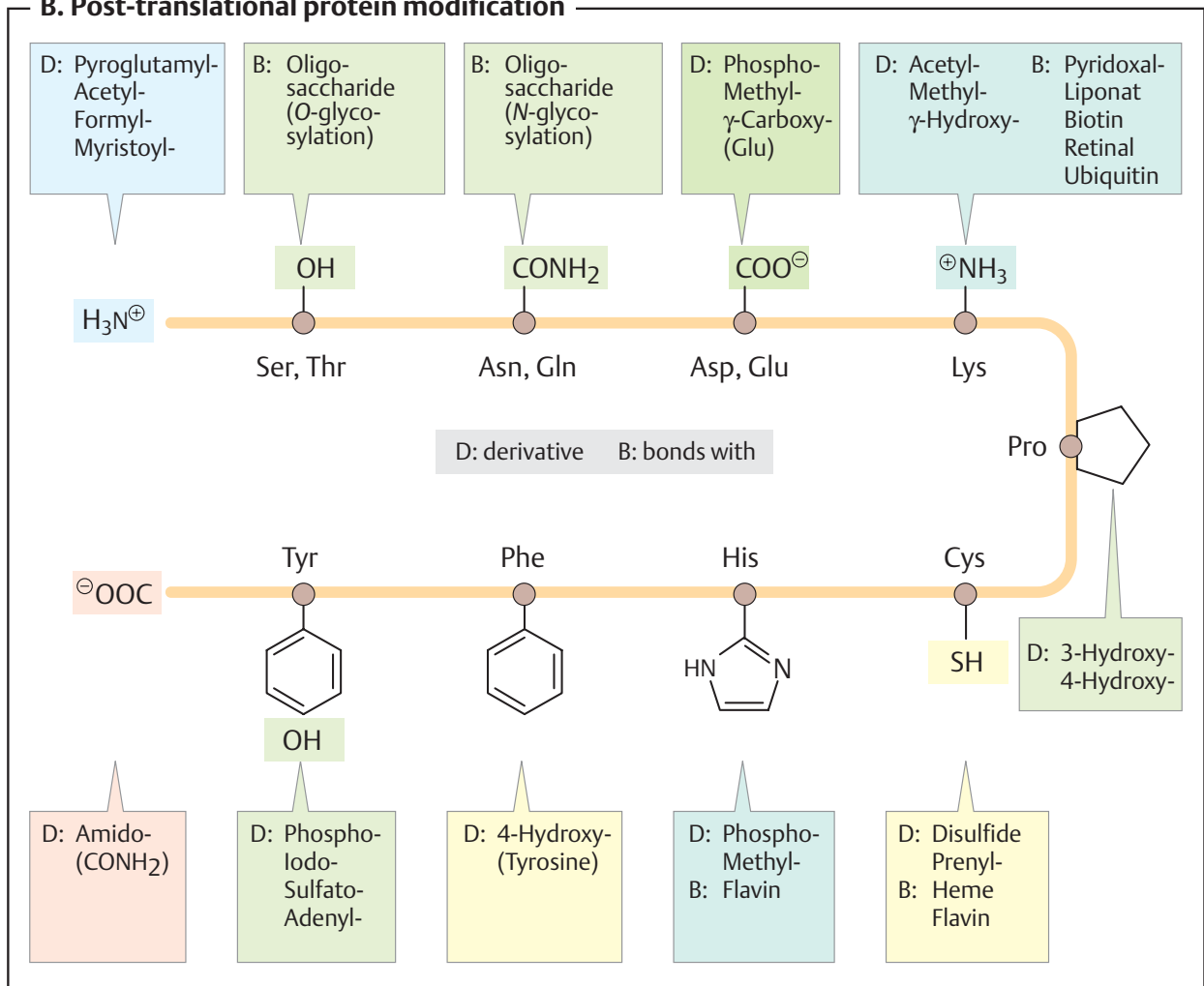
A. The proteinogenic amino acids

Aliphatic					Sulfur-containing	
Glycine (Gly, G)	Alanine (Ala, A)	Valine [☆] (Val, V)	Leucine [☆] (Leu, L)	Isoleucine [☆] (Ile, I)	Cysteine (Cys, C)	Methionine [☆] (Met, M)
H	CH ₃	H ₃ C—CH CH ₃	CH ₂ H ₃ C—CH CH ₃	H ₃ C— C —H CH ₂ CH ₃	CH ₂ SH 8.3 pK _a value	CH ₂ CH ₂ S CH ₃
-2.4	-1.9	-2.0	-2.3	-2.2	-1.2	-1.5
Aromatic			Cyclic	Neutral		
Phenylalanine [☆] (Phe, F)	Tyrosine (Tyr, Y)	Tryptophan [☆] (Trp, W)	Proline (Pro, P)	Serine (Ser, S)	Threonine [☆] (Thr, T)	
CH ₂ 	CH ₂  OH 10.1	CH ₂  Indole ring	 Pyrrolidine ring	CH ₂ OH	H ₃ C— C —H OH	
+0.8	+6.1	+5.9	+6.0	+5.1	+4.9	
☆ Essential amino acids					□ Chiral center	
Neutral		Acidic		Basic		
Asparagine (Asn, N)	Glutamine (Gln, Q)	Aspartic acid (Asp, D)	Glutamic acid (Glu, E)	Histidine (His, H)	Lysine [☆] (Lys, K)	Arginine (Arg, R)
CH ₂ CONH ₂	CH ₂ CH ₂ CONH ₂	CH ₂ COO [⊖] 4.0	CH ₂ CH ₂ COO [⊖] 4.3	CH ₂  Imidazole ring 6.0	CH ₂ CH ₂ CH ₂ CH ₂ ⊕NH ₃ 10.8	CH ₂ CH ₂ CH ₂ NH  12.5
+9.7	+9.4	+11.0	+10.2	+10.3	+15.0	+20.0

A. Rare amino acids

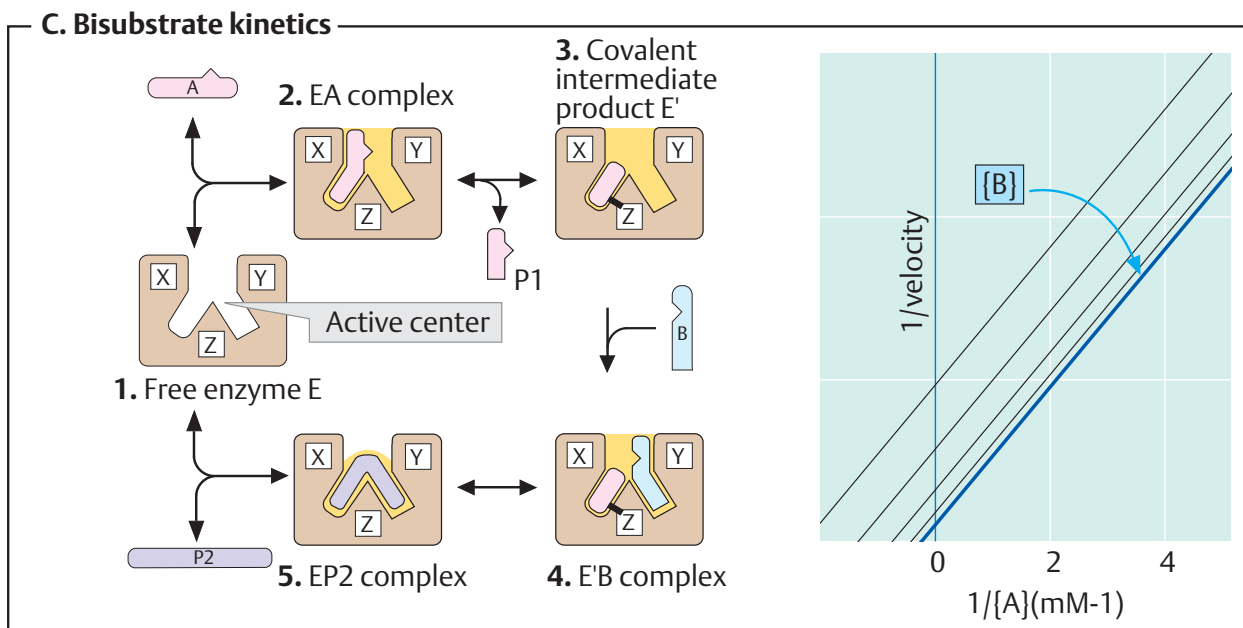
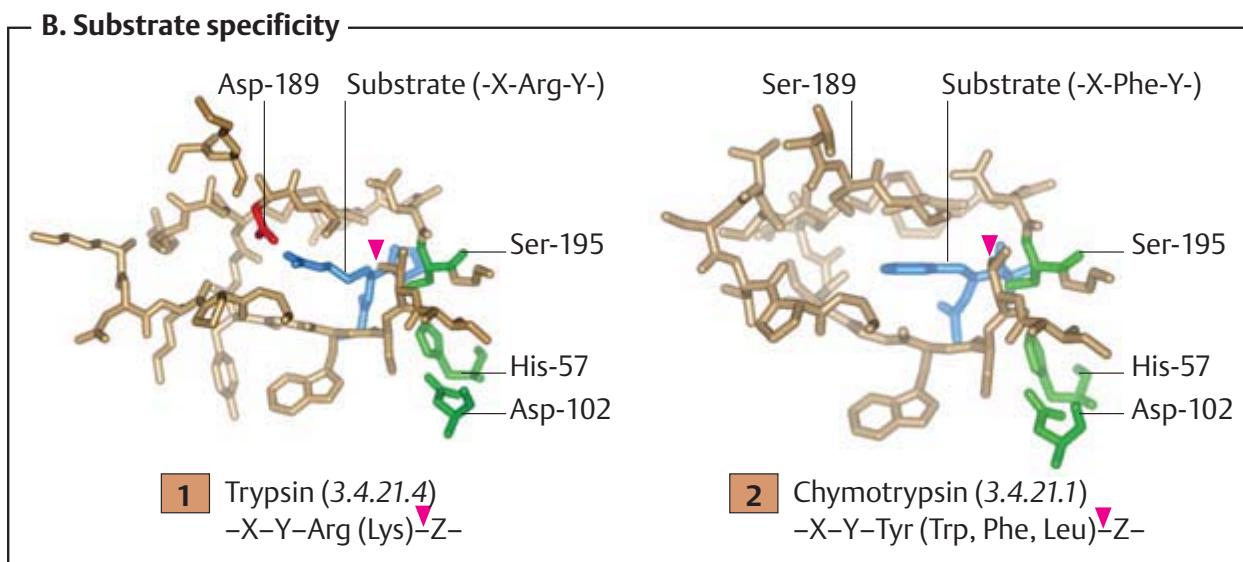
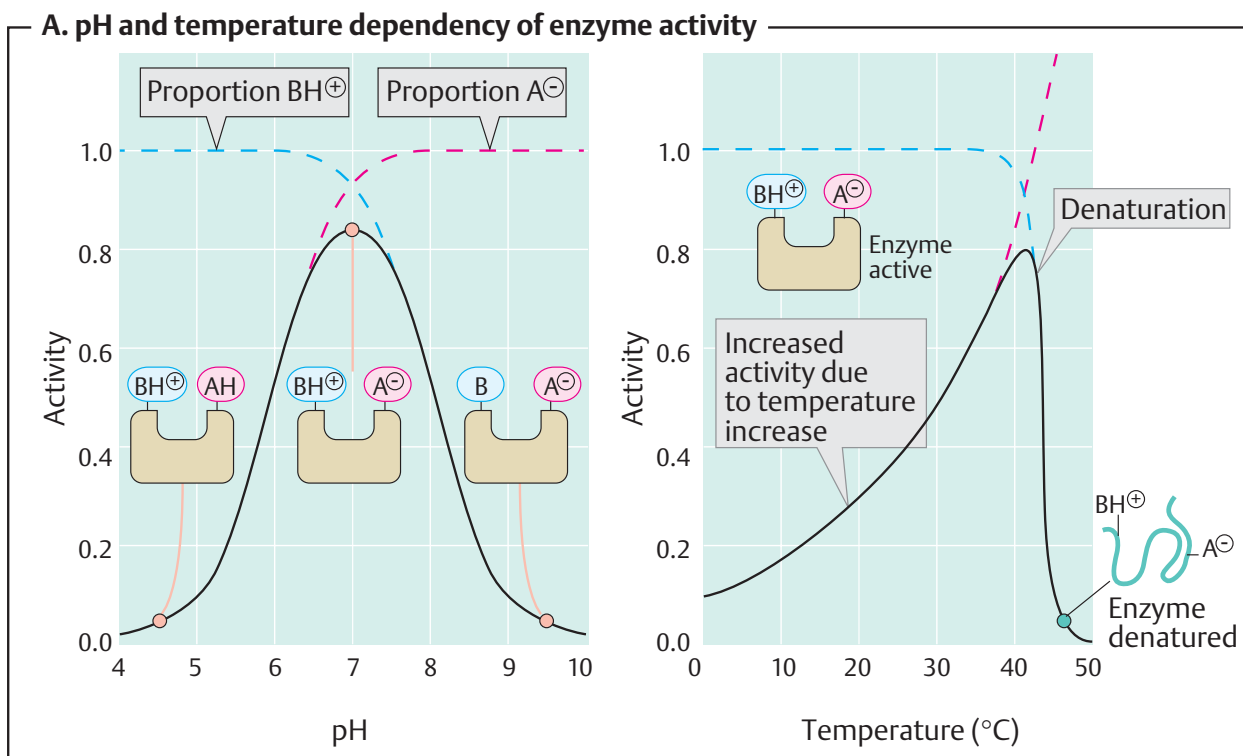


B. Post-translational protein modification

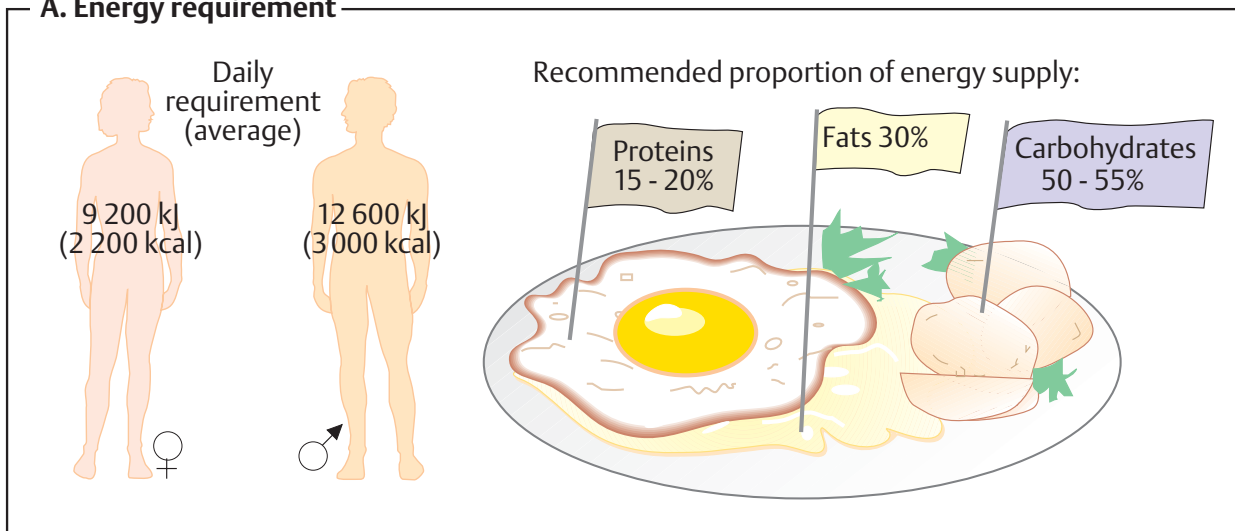


C. Biogenic amines

Amino acid	Amine	Function	Amino acid	Amine	Function
Serine	Ethanol-amine	Glutamate	Glutamate	γ-Amino-butyrates	Neurotransmitter (GABA)
Cysteine	Cysteamine	Component of coenzyme A	Histidine	Histamine	Mediator, neurotransmitter
Threonine	Amino-propanol	Component of vitamin B ₁₂	Dopa	Dopamine	Neurotransmitter
Aspartate	β-Alanine	Component of coenzyme A	5-Hydroxy-tryptophan	Serotonin	Mediator, neurotransmitter



A. Energy requirement



B. Nutrients

	Quantity in body (kg)	Energy content (kJ · g ⁻¹ (kcal · g ⁻¹))	Daily requirement (g)			General function in metabolism	Essential constituents
			a	b	c		
Proteins	10	17 (4.1)	♂ 37 ♀ 29	55 45	92 75	Supplier of amino acids Energy source	Essential amino acids: Val (14) Leu (16) Ile (12) Lys (12) Phe (16) Trp (3) Met (10) Thr (8) Cys and His stimulate growth
Carbo-hydrates	1	17 (4.1)	0	390	240-310	General source of energy (glucose) Energy reserve (glycogen) Roughage (cellulose) Supporting substances (bones, cartilage, mucus)	Non-essential nutritional constituent
Fats	10-15	39 (9.3)	10	80	130	General energy source Most important energy reserve Solvent for vitamins Supplier of essential fatty acids	Poly-unsaturated fatty acids: Linoleic acid Linolenic acid Arachidonic acid (together 10 g/day)
Water	35-40	0	2 400	-	-	Solvent Cellular building block Dielectric Reaction partner Temperature regulator	
Minerals	3	0				Building blocks Electrolytes Cofactors of enzymes	Macrominerals Microminerals (trace elements)
Vitamins	-	-				Often precursors of coenzymes	Lipid-soluble vitamins Water-soluble vitamins

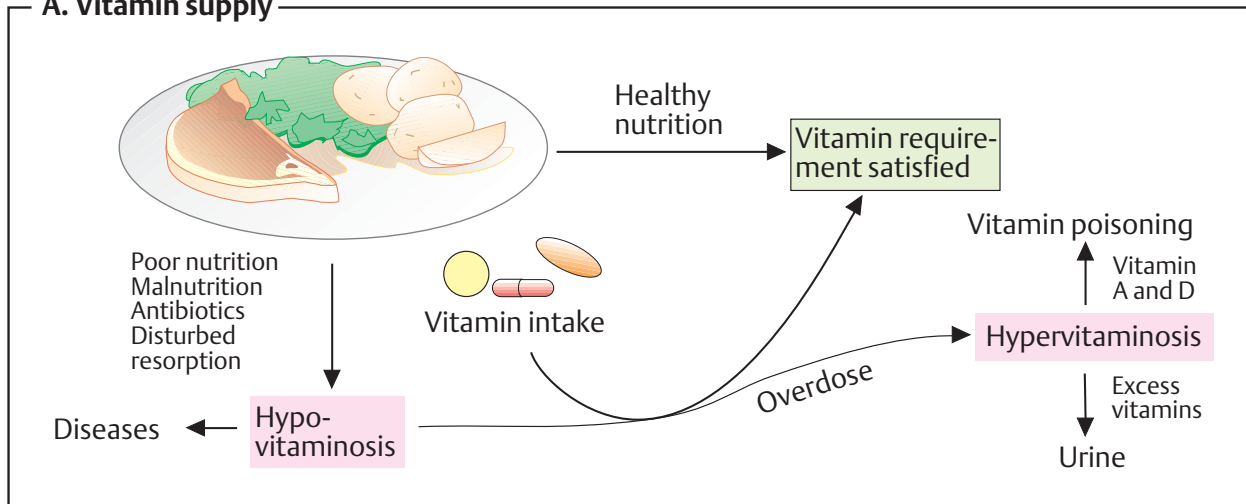
a: Minimum daily requirement b: Recommended daily intake c: Actual daily intake in industrialized nations

A. Minerals

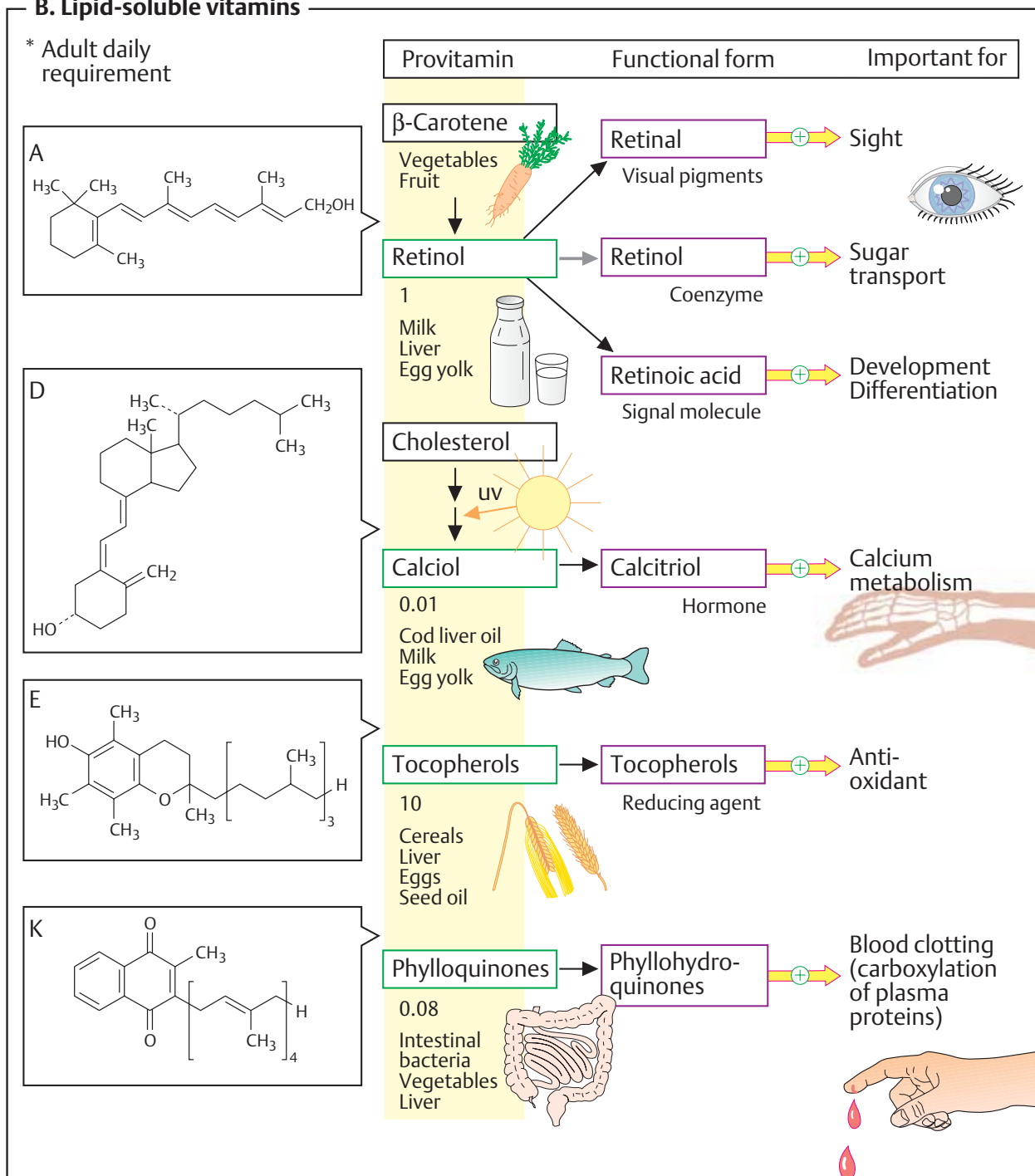
Mineral	Content* (g)	Major source	Daily requirement (g)	Functions/Occurrence
Water	35 000-40 000	Drinks Water in solid foods From metabolism 300g	1200 900	Solvent, cellular building block, dielectric, coolant, medium for transport, reaction partner
Macroelements (daily requirement >100 mg)				
Na	100	Table salt	1.1-3.3	Osmoregulation, membrane potential, mineral metabolism
K	150	Vegetables, fruit, cereals	1.9-5.6	Membrane potential, mineral metabolism
Ca	1 300	Milk, milk products	0.8	Bone formation, blood clotting, signal molecule
Mg	20	Green vegetables	0.35	Bone formation, cofactor for enzymes
Cl	100	Table salt	1.7-5.1	Mineral metabolism
P	650	Meat, milk, cereals, vegetables	0.8	Bone formation, energy metabolism, nucleic acid metabolism
S	200	S-containing amino acids (Cys and Met)	0.2	Lipid and carbohydrate metabolism, conjugate formation
Microelements (trace elements) (mg)				
Fe	4-5	Meat, liver, eggs, vegetables, potatoes, cereals	10	Hemoglobin, myoglobin, cytochromes, Fe/S clusters
Zn	2-3	Meat, liver, cereals	15	Zinc enzymes
Mn	0.02	Found in many foodstuffs	2-5	Enzymes
Cu	0.1-0.2	Meat, vegetables, fruit, fish	2-3	Oxidases
Co	<0.01	Meat	Traces	Vitamin B ₁₂
Cr	<0.01		0.05-0.2	Not clear
Mo	0.02	Cereals, nuts, legumes	0.15-0.5	Redox enzymes
Se		Vegetables, meat	0.05-0.2	Selenium enzymes
I	0.03	Seafood, iodized salt, drinking water	0.15	Thyroxin
Requirement not known				
F		Drinking water (fluoridated), tea, milk	0.0015-0.004	Bones, dental enamel

* Content in the body of a 65 kg adult

A. Vitamin supply

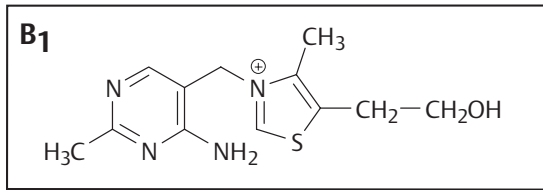


B. Lipid-soluble vitamins



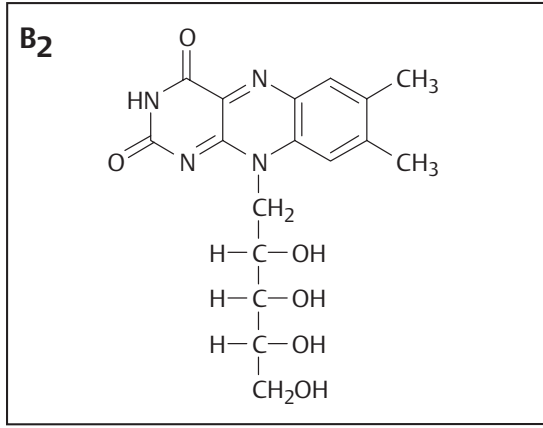
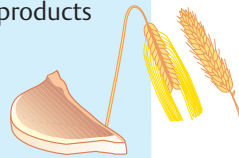
A. Water-soluble vitamins I

* Adult daily requirement



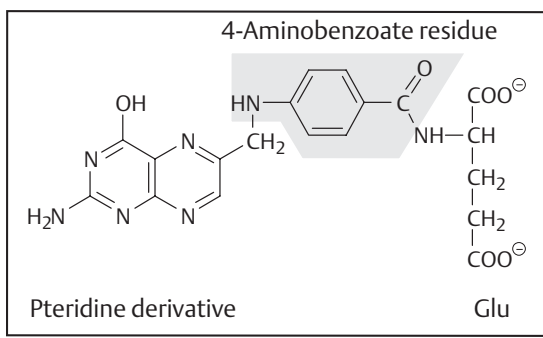
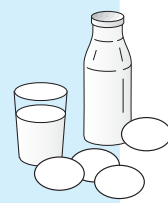
Vitamin	Active form: coenzyme	Function in metabolism
Thiamine	TPP Thiamine diphosphate	Transfer of hydroxy-alkyl residues

1.5 mg *
Grain
Yeast products
Pork



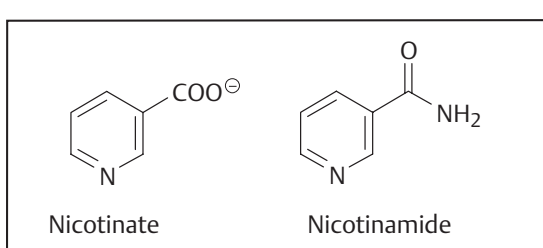
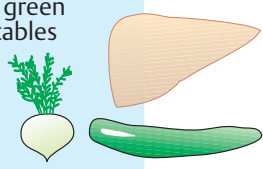
Riboflavin	FMN FAD	Hydrogen transfer
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1.8 mg *
Milk
Eggs



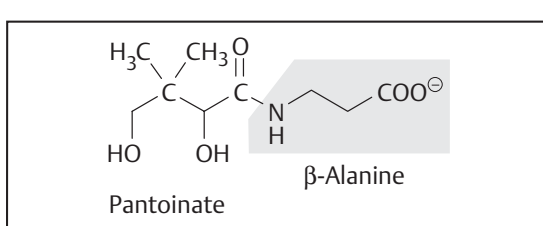
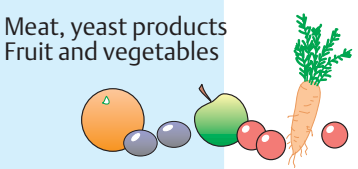
Folate	THF Tetrahydrofolate	C ₁ -metabolism
--------	-------------------------	----------------------------

0.2 mg *
Fresh green vegetables
Liver



Nicotinate Nicotinamide	NADP ⁺ NAD ⁺	Hydride transfer
----------------------------	---------------------------------------	------------------

20 mg *
(or 1.2 g tryptophan)

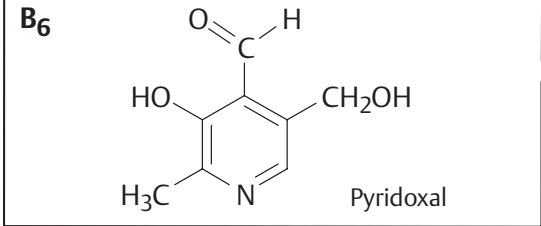


Pantothenate	CoA	Activation of carboxylic acids
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7 mg *
Widely distributed

A. Water-soluble vitamins II

* Adult daily requirement



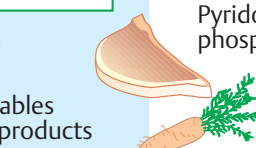
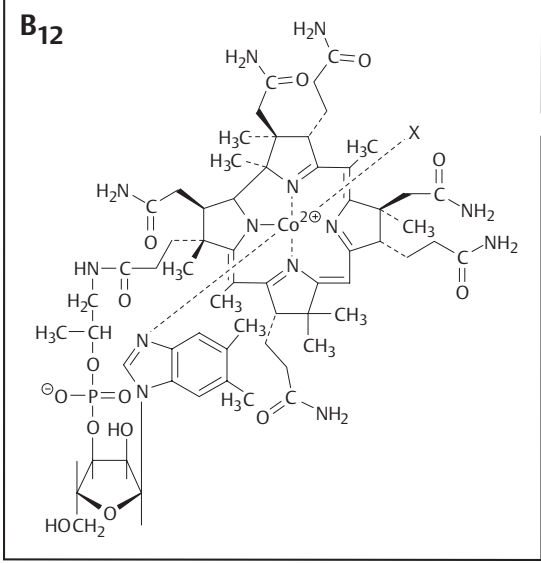
Vitamin	Active form: coenzyme	Function in metabolism
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Pyridoxal
Pyridoxol
Pyridoxamine

→ **PLP** → Activation of amino acids

Pyridoxal phosphate

2 mg*
Meat
Vegetables
Grain products

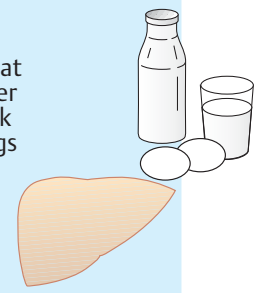



Cobalamine

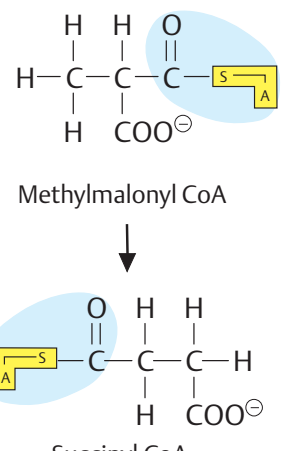
→ **5-Deoxy-adenosyl cobalamine** → Isomerization e.g.

0.002 mg*

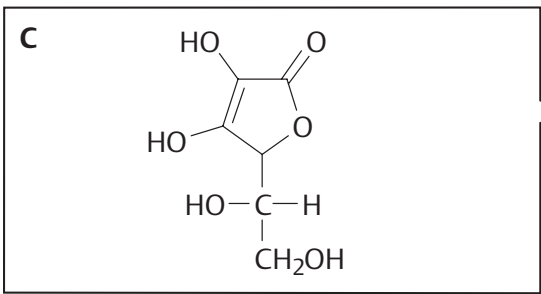
Meat
Liver
Milk
Eggs



Methylmalonyl CoA



Succinyl CoA

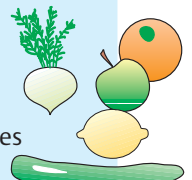
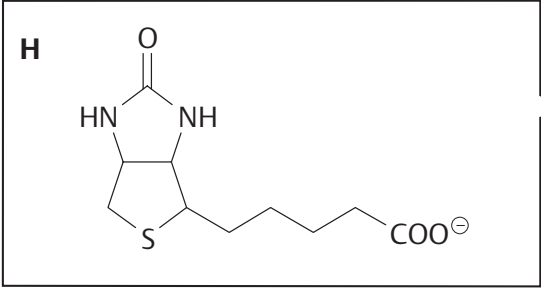


Ascorbic acid

→ **Ascorbate** → Stabilization of enzyme systems, coenzyme, antioxidant

60 mg*

Fruit
Vegetables





Biotin

→ **B** → Transfer of carboxyl groups

0.1 mg*

Yeast products
Legumes
Nuts



Color Atlas of Biochemistry

Second edition, revised and enlarged

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