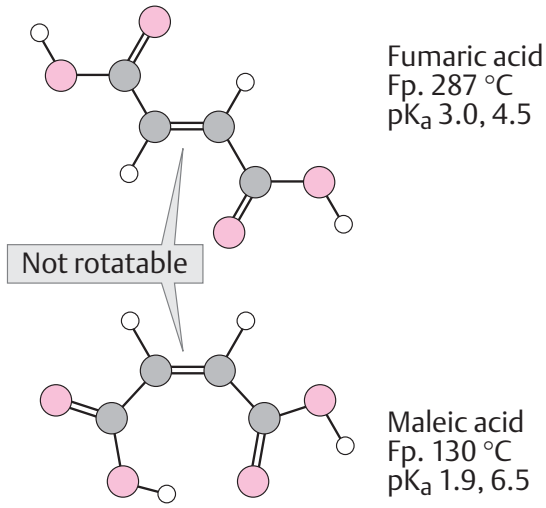
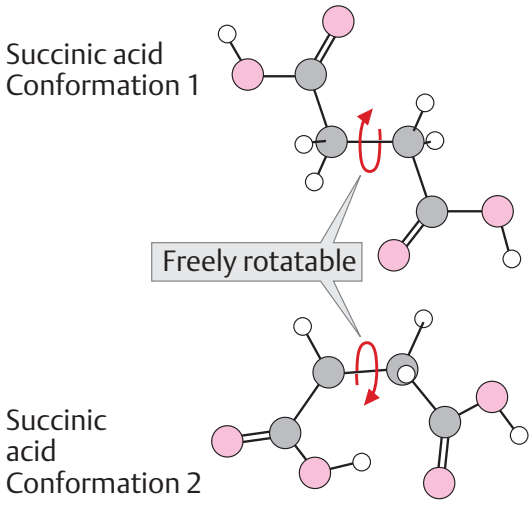
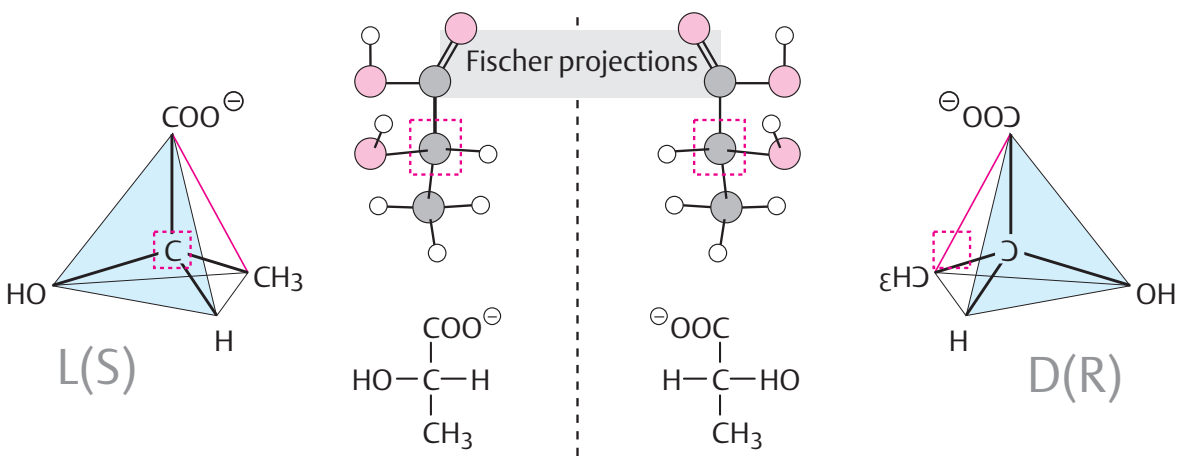
A. *cis–trans* isomers



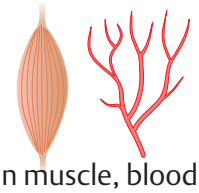
B. Conformers



C. Optical isomers



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

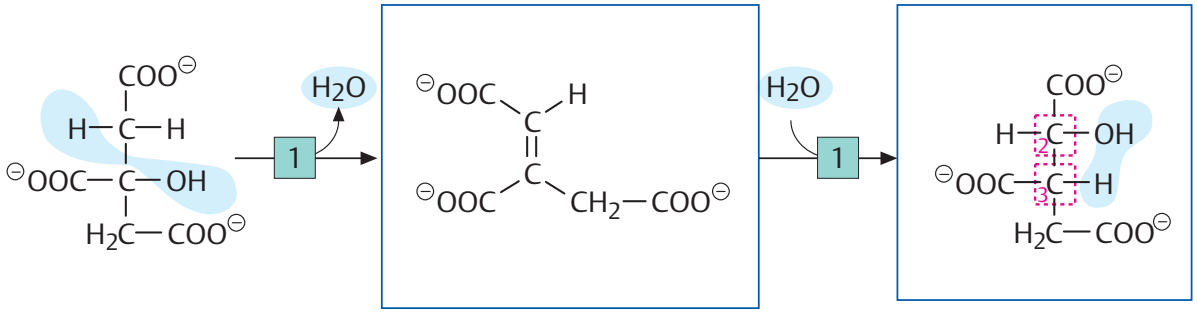


In muscle, blood

In milk products

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

D. The aconitase reaction



Citrate (prochiral)

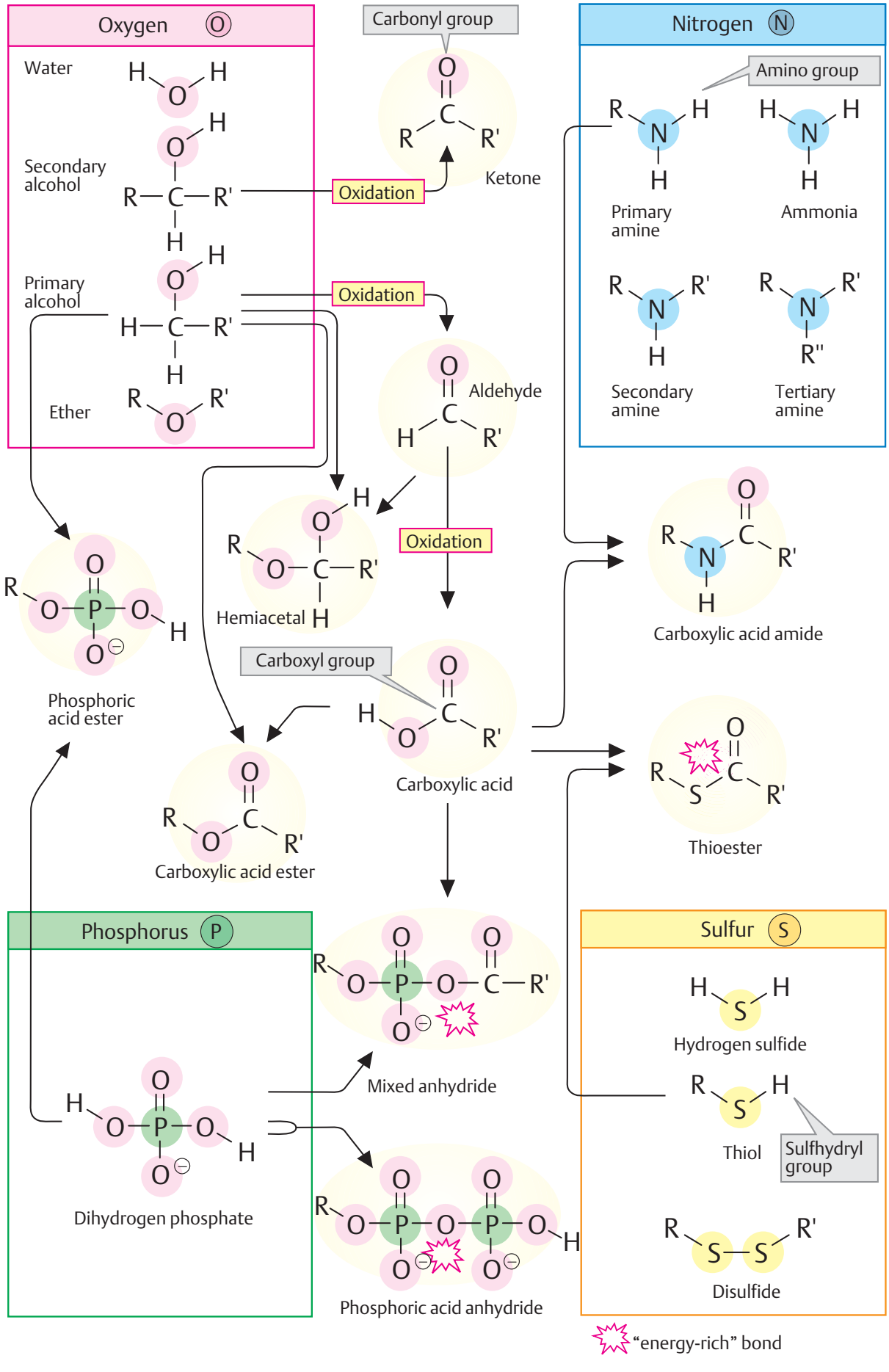
cis-Aconitate (intermediate product)

(*2R,3S*)-Isocitrate

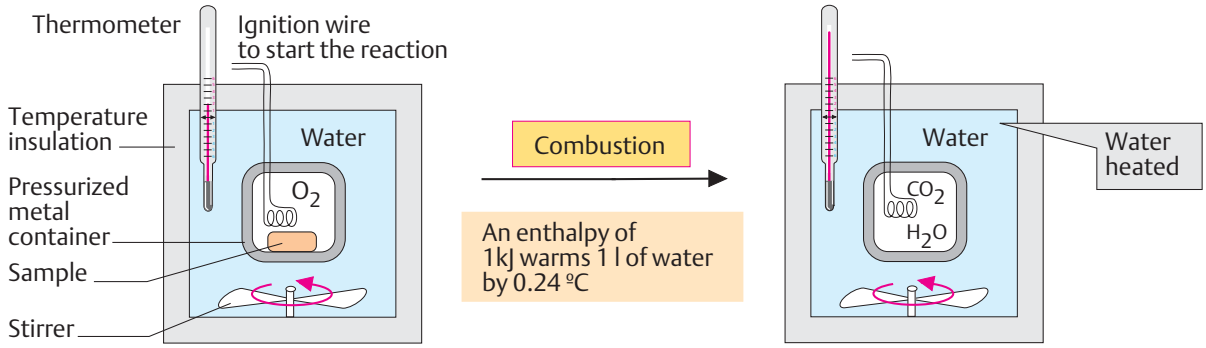
trans-Aconitate occurs in plants

1 Aconitase *4.2.1.3*

A. Important classes of compounds



A. Heat of reaction and calorimetry



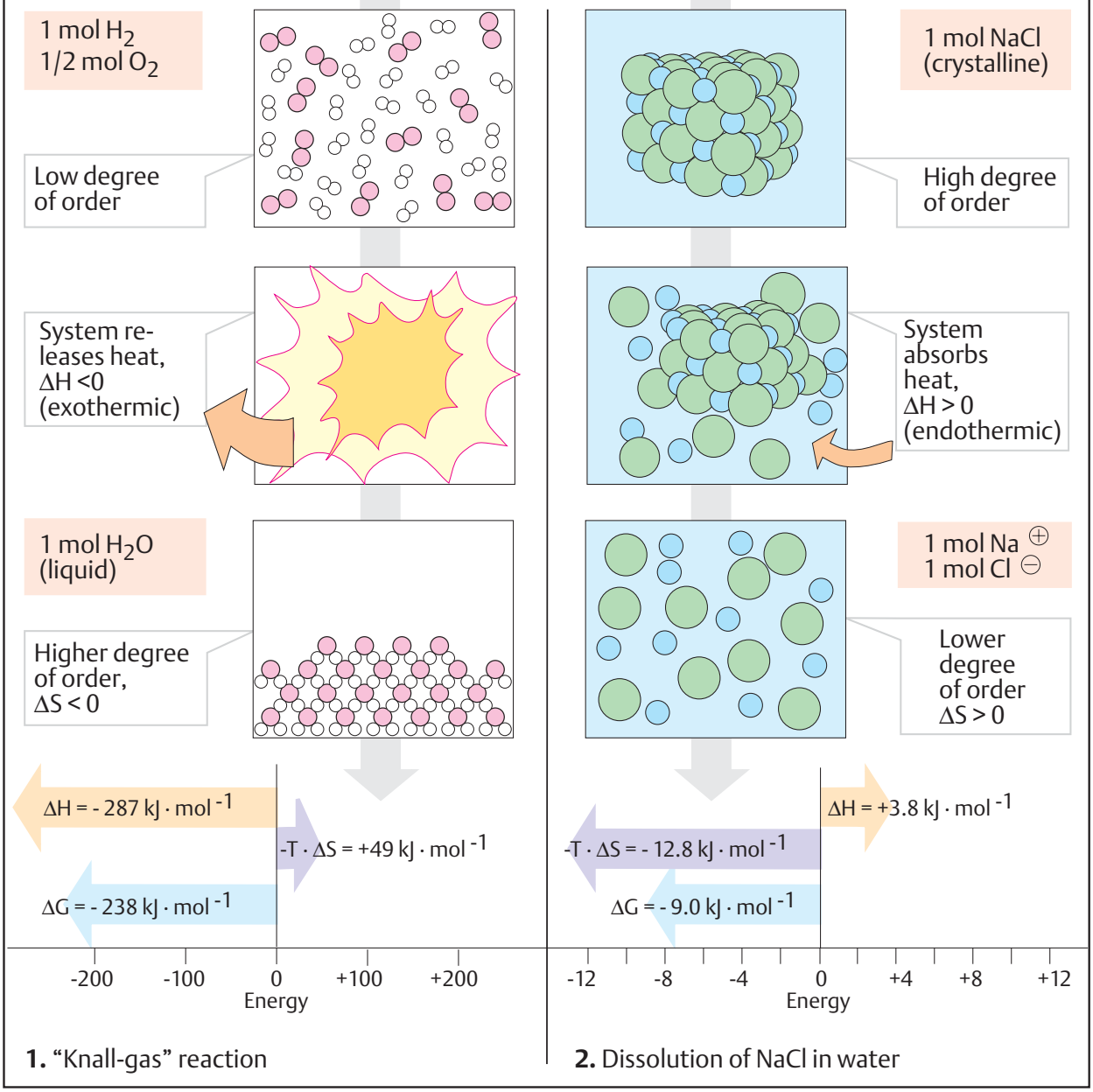
B. Enthalpy and entropy

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

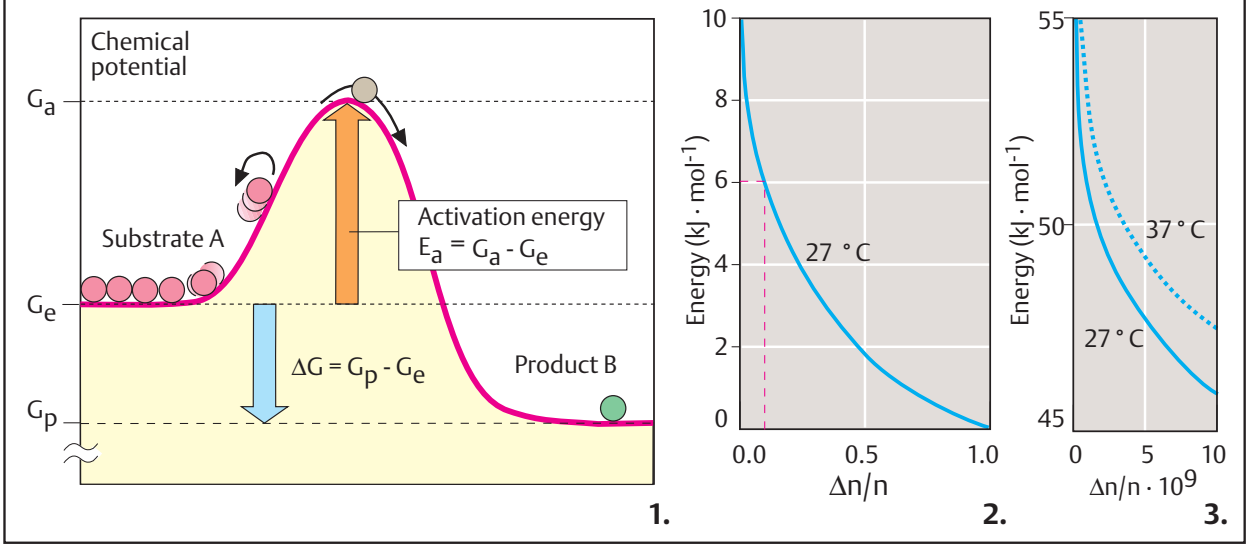
Gibbs-Helmholtz equation

ΔH: change of enthalpy, heat exchange

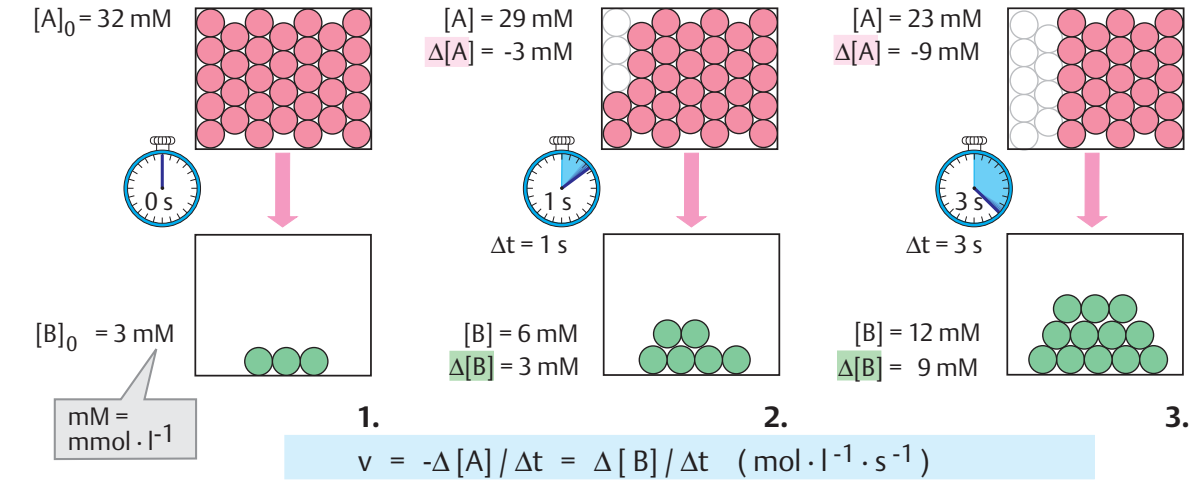
ΔS: change of entropy, i.e. degree of order



A. Activation energy

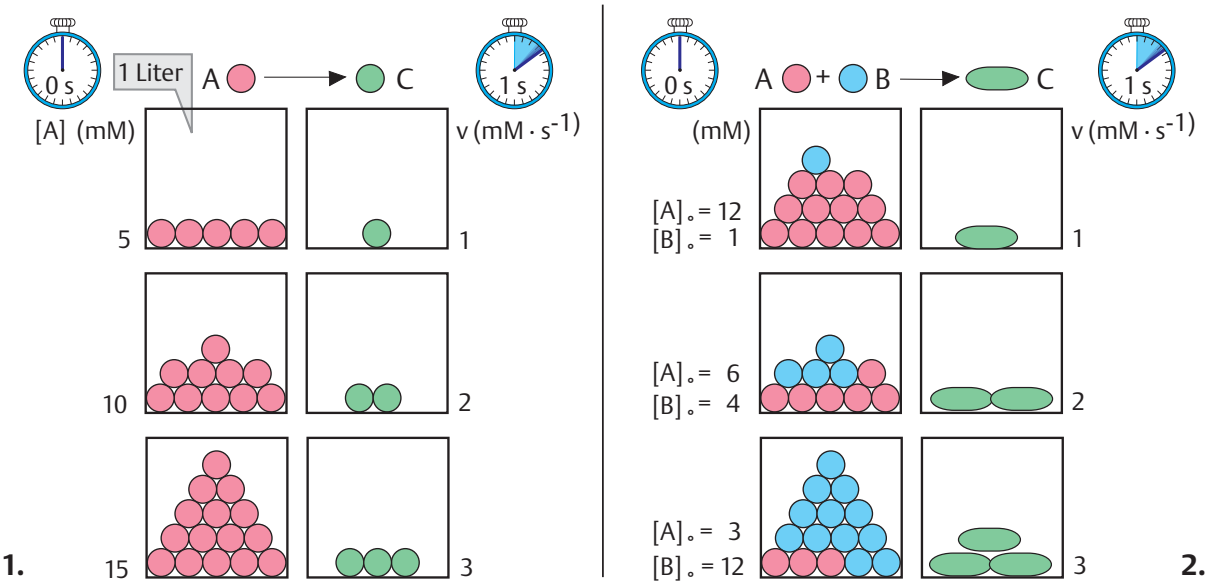


B. Reaction rate



$$v = -\Delta[A] / \Delta t = \Delta[B] / \Delta t \quad (\text{mol} \cdot \text{l}^{-1} \cdot \text{s}^{-1})$$

C. Reaction order

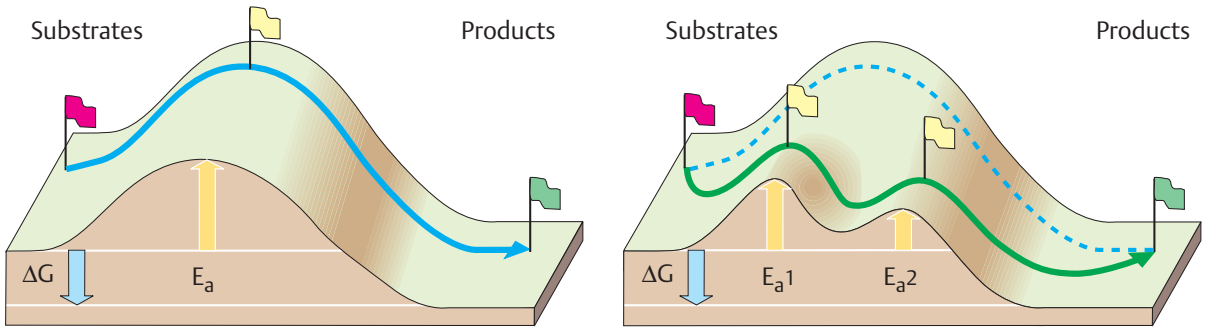


$v = k \cdot [A]$ — k, k' : Rate constants — $v = k' \cdot [A] \cdot [B]$

First-order reaction: $k = 1/5\ s^{-1}$

Second-order reaction: $k' = 1/12\ l \cdot mmol^{-1} \cdot s^{-1}$

A. Catalysis: principle

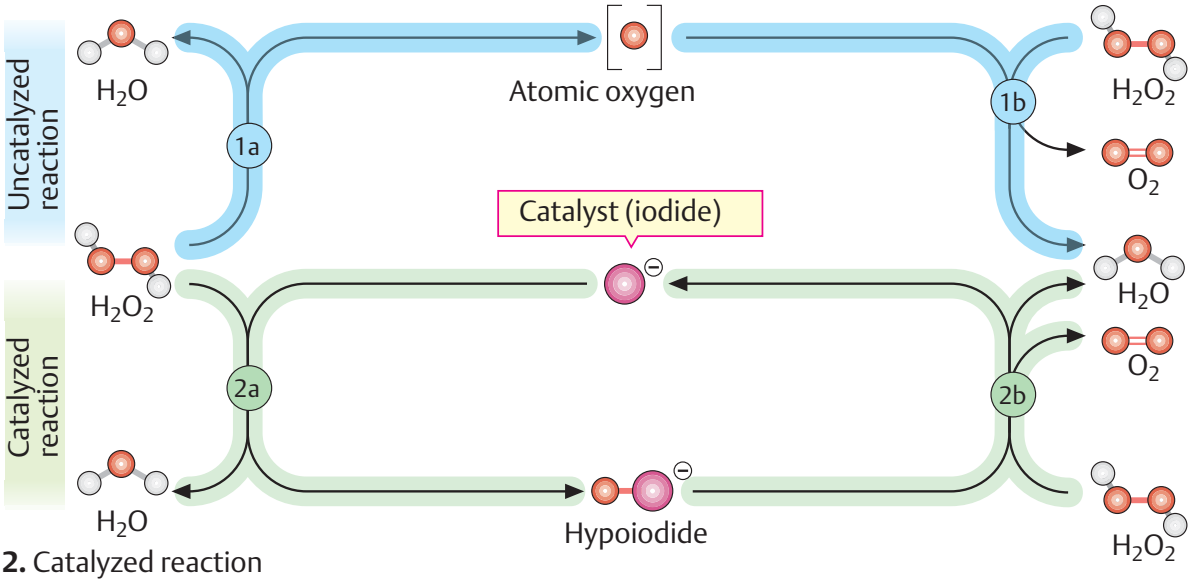


1. Energy profile without catalyst

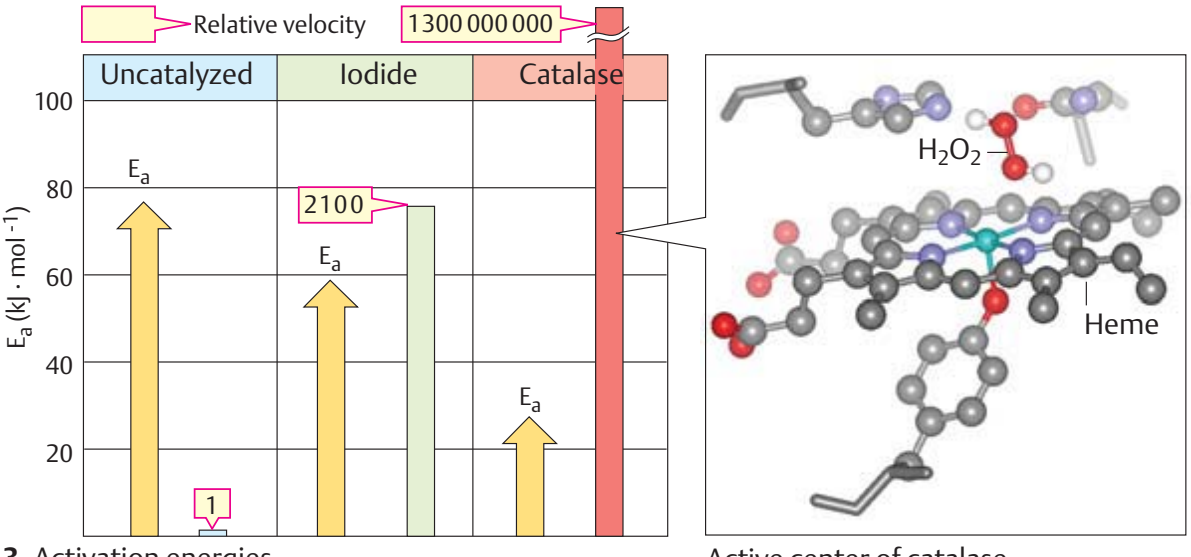
2. Energy profile with catalyst

B. Catalysis of H_2O_2 – breakdown by iodide

1. Breakdown of hydrogen peroxide



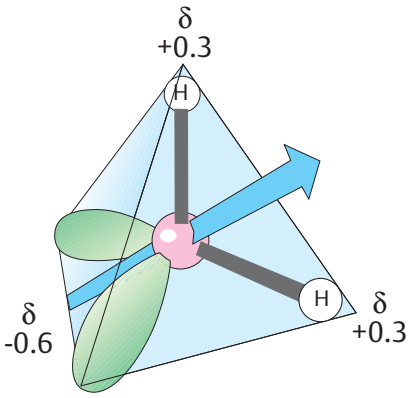
2. Catalyzed reaction



3. Activation energies

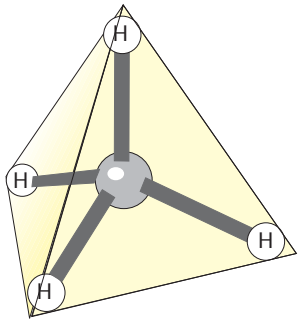
Active center of catalase

A. Water and methane



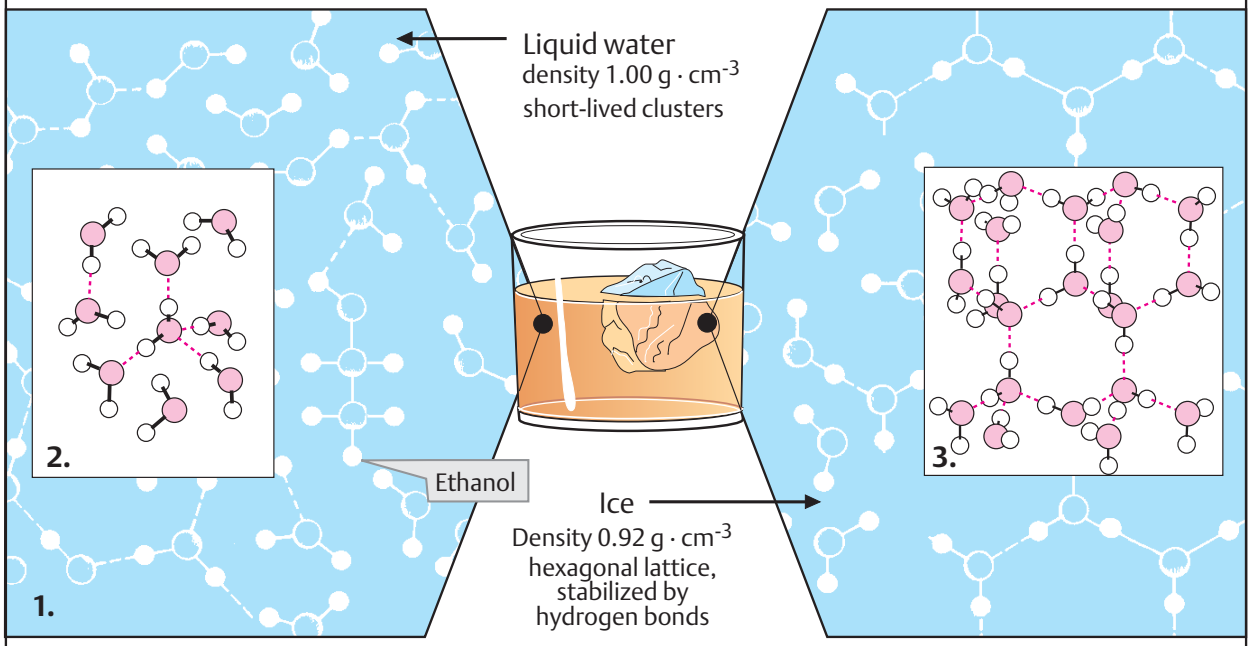
Water (H_2O)

H_2O		CH_4
18 Da	Molecular mass	16 Da
+100 °C	Boiling point	-162 °C
41	Heat of vaporization ($kJ \cdot mol^{-1}$)	8
6.2	Dipole moment (10^{-30} C · m)	0

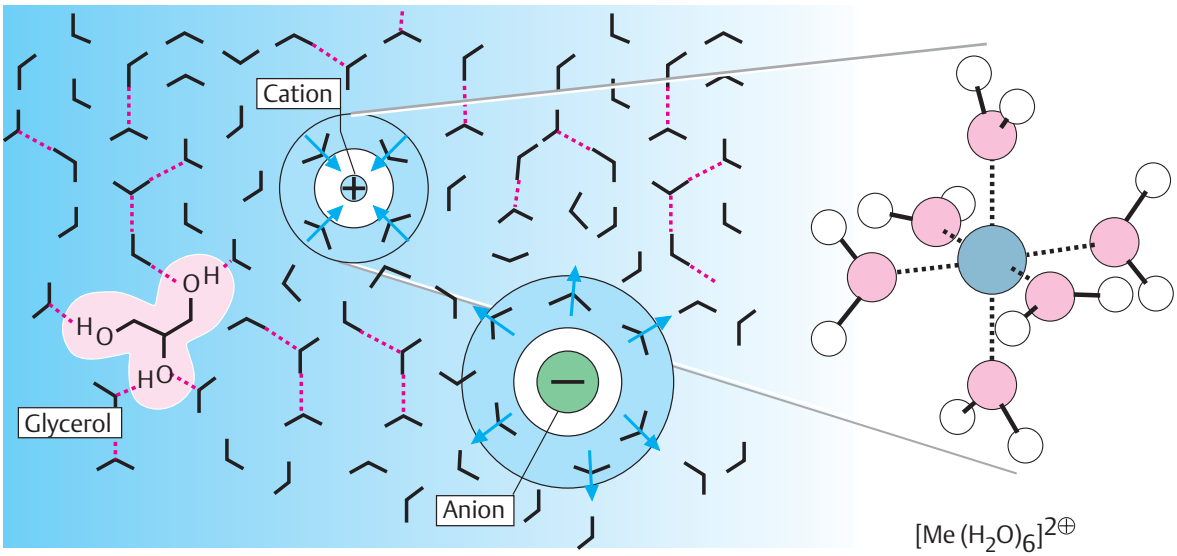


Methane (CH_4)

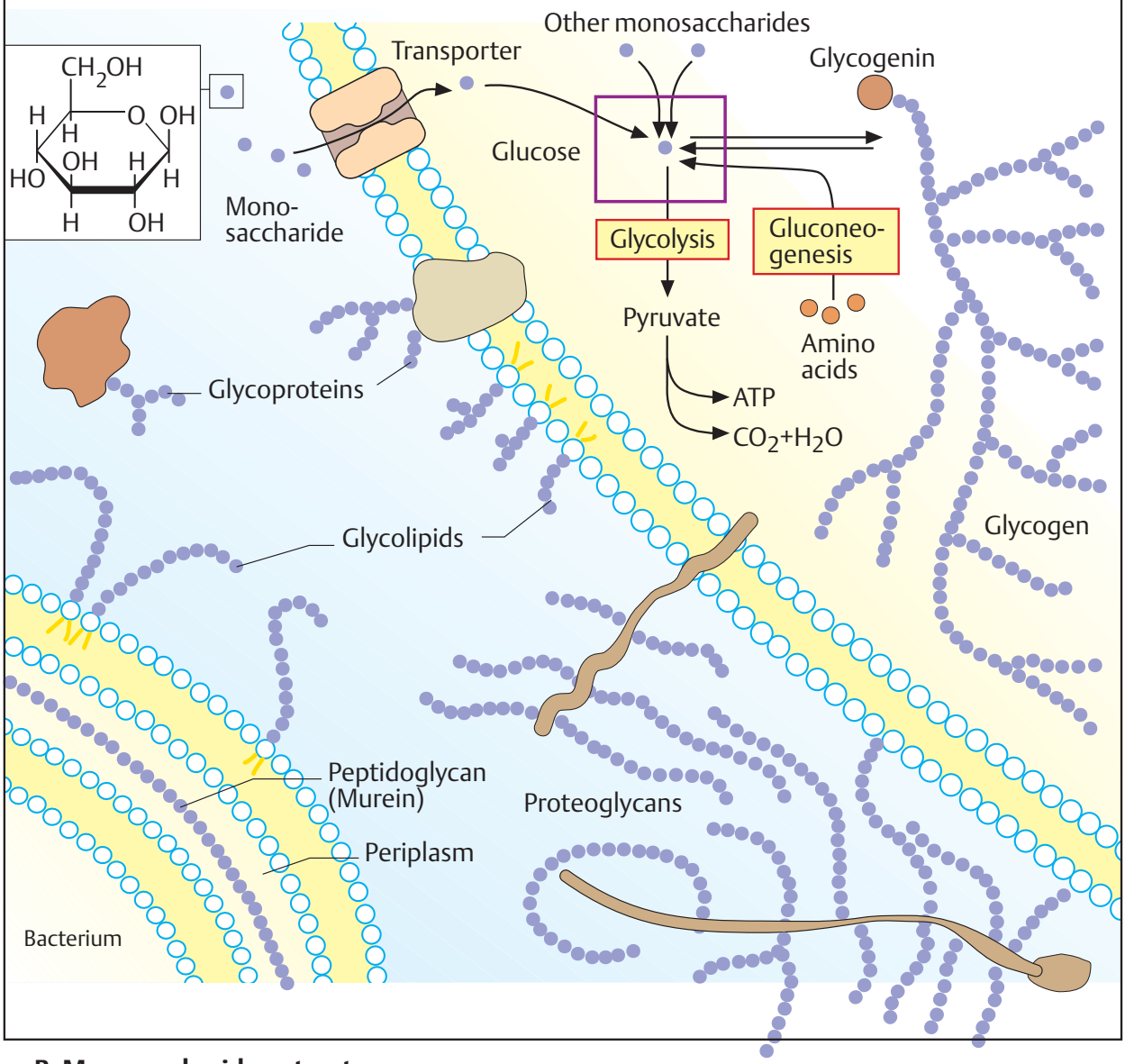
B. Structure of water and ice



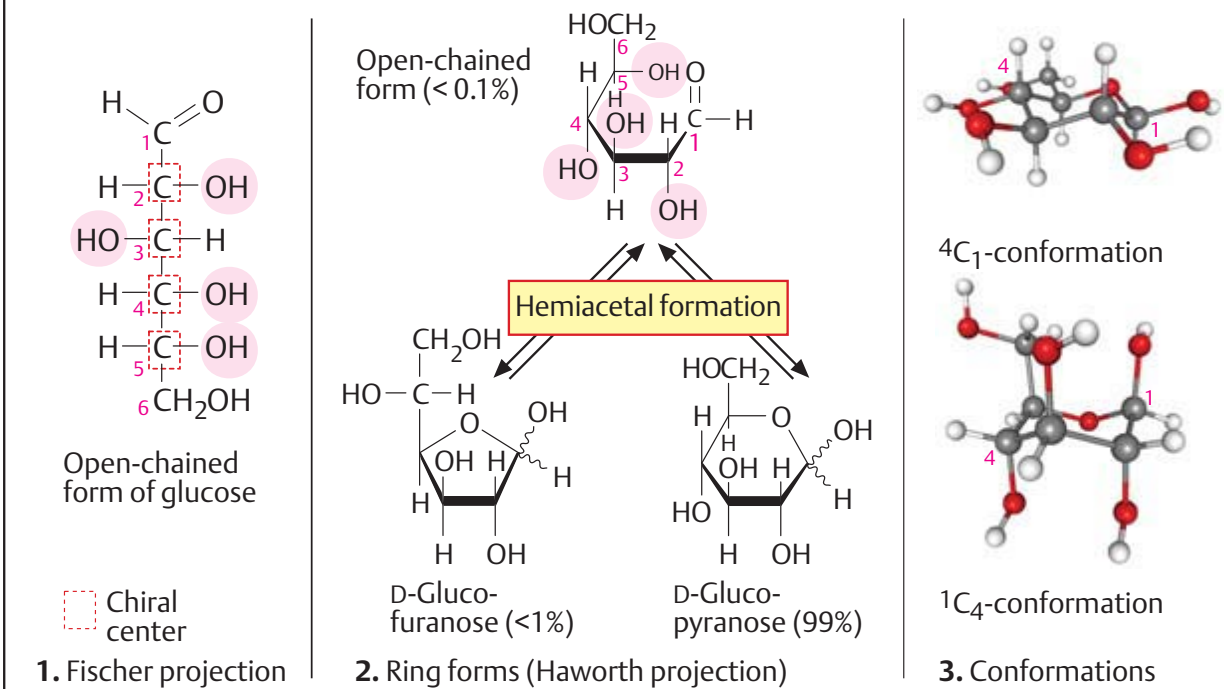
C. Hydration



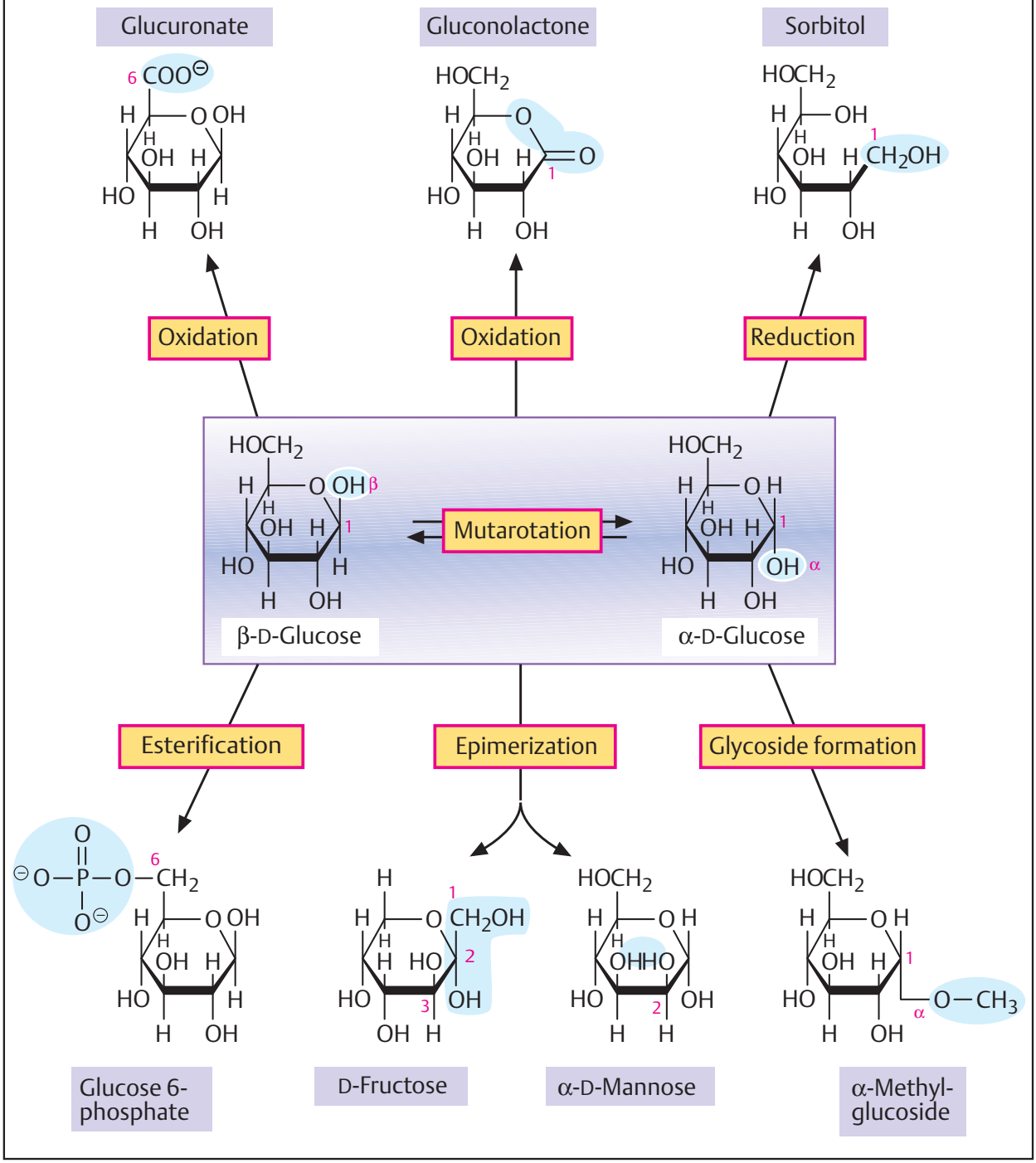
A. Carbohydrates: overview



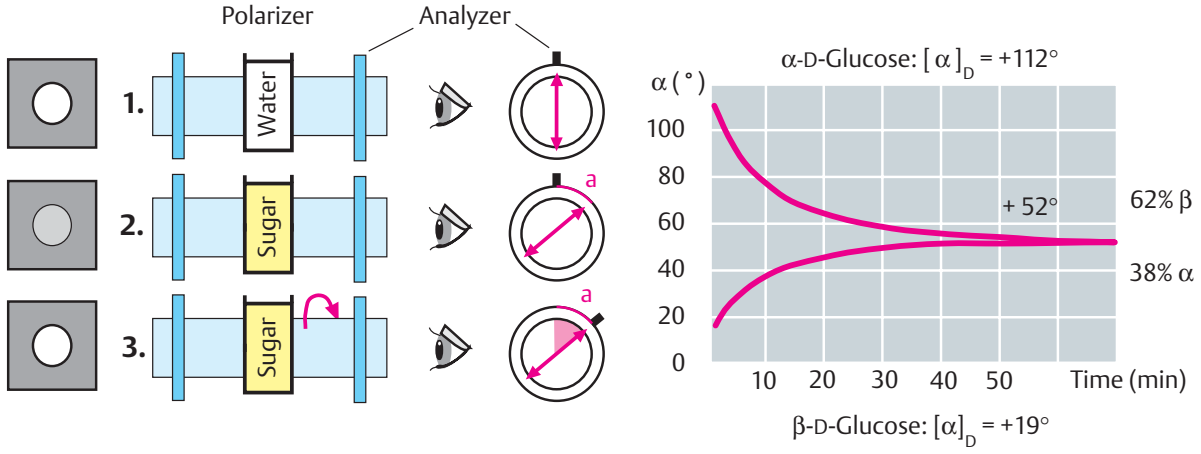
B. Monosaccharides: structure



A. Reactions of the monosaccharides



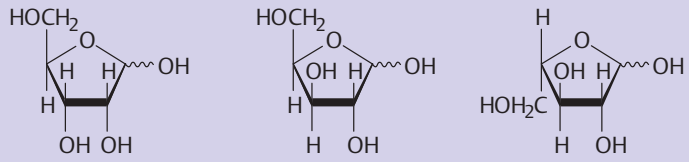
B. Polarimetry, mutarotation



A. Important monosaccharides

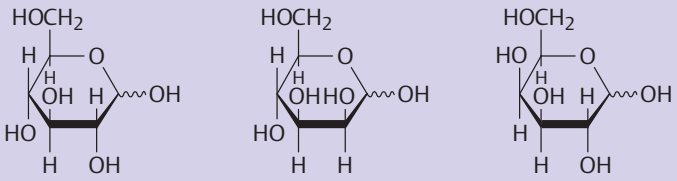
① Aldoses

D-Ribose (Rib) | D-Xylose (Xyl) | L-Arabinose (Ara)



Pentoses

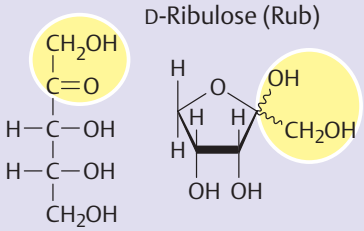
D-Glucose (Glc) | D-Mannose (Man) | D-Galactose (Gal)



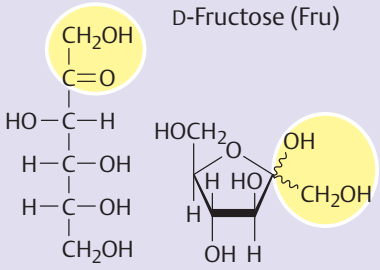
Hexoses

② Ketoses

D-Ribulose (Rub)

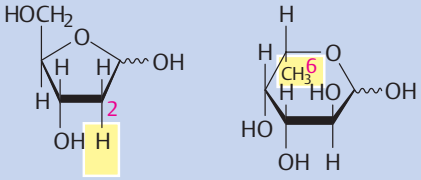


D-Fructose (Fru)



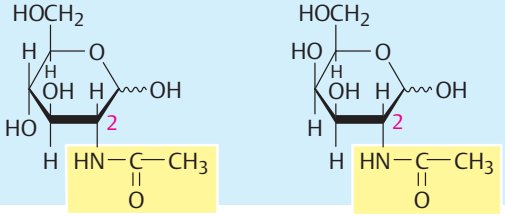
③ Deoxyaldoses

2-Deoxy-D-ribose (dRib) | L-Fucose (Fuc)



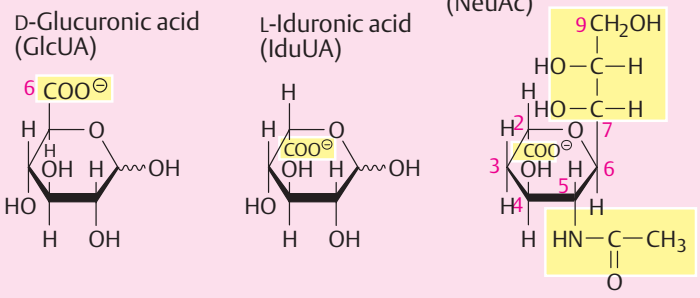
④ Acetylated amino sugars

N-Acetyl-D-glucosamine (GlcNAc) | *N*-Acetyl-D-galactosamine (GalNAc)



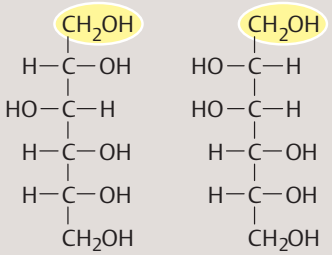
⑤ Acidic monosaccharides

D-Glucuronic acid (GlcUA) | L-Iduronic acid (IduUA) | *N*-Acetylneuraminic acid (NeuAc)

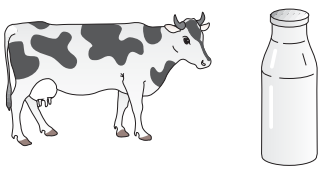


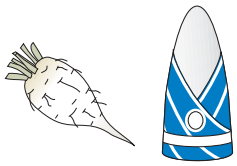
⑥ Sugar alcohols (alditoles)

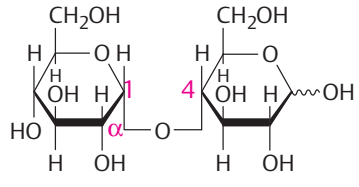
D-Sorbitol | D-Mannitol



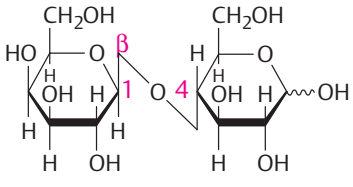
B. Disaccharides



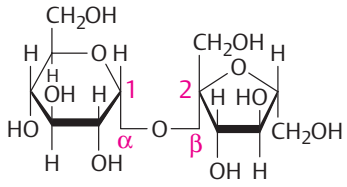




1. Maltose
α-D-Glucopyranosyl-(1→4)-D-glucopyranose

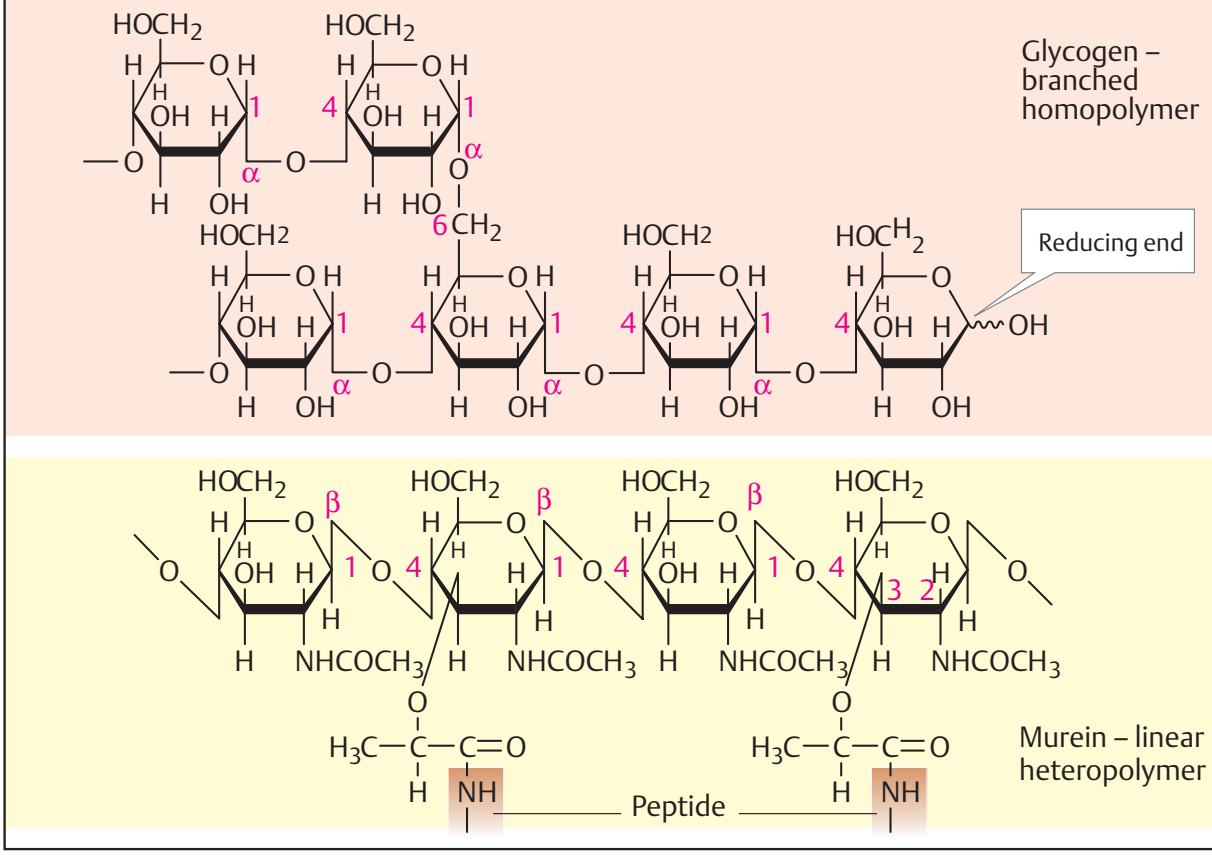


2. Lactose
β-D-Galactopyranosyl-(1→4)-D-glucopyranose



3. Sucrose
α-D-Glucopyranosyl-(1↔2)-β-D-fructofuranoside

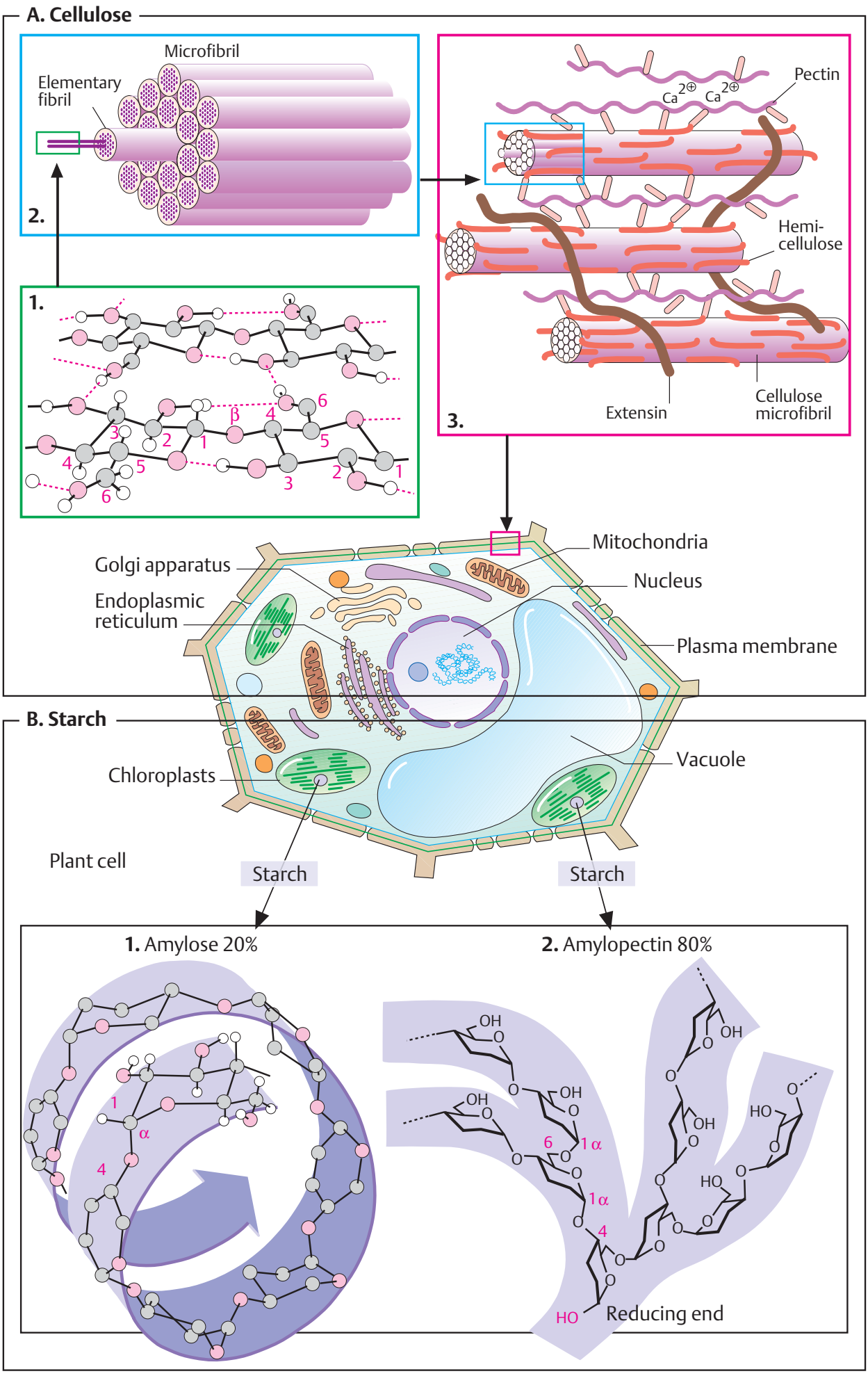
A. Polysaccharides: structure



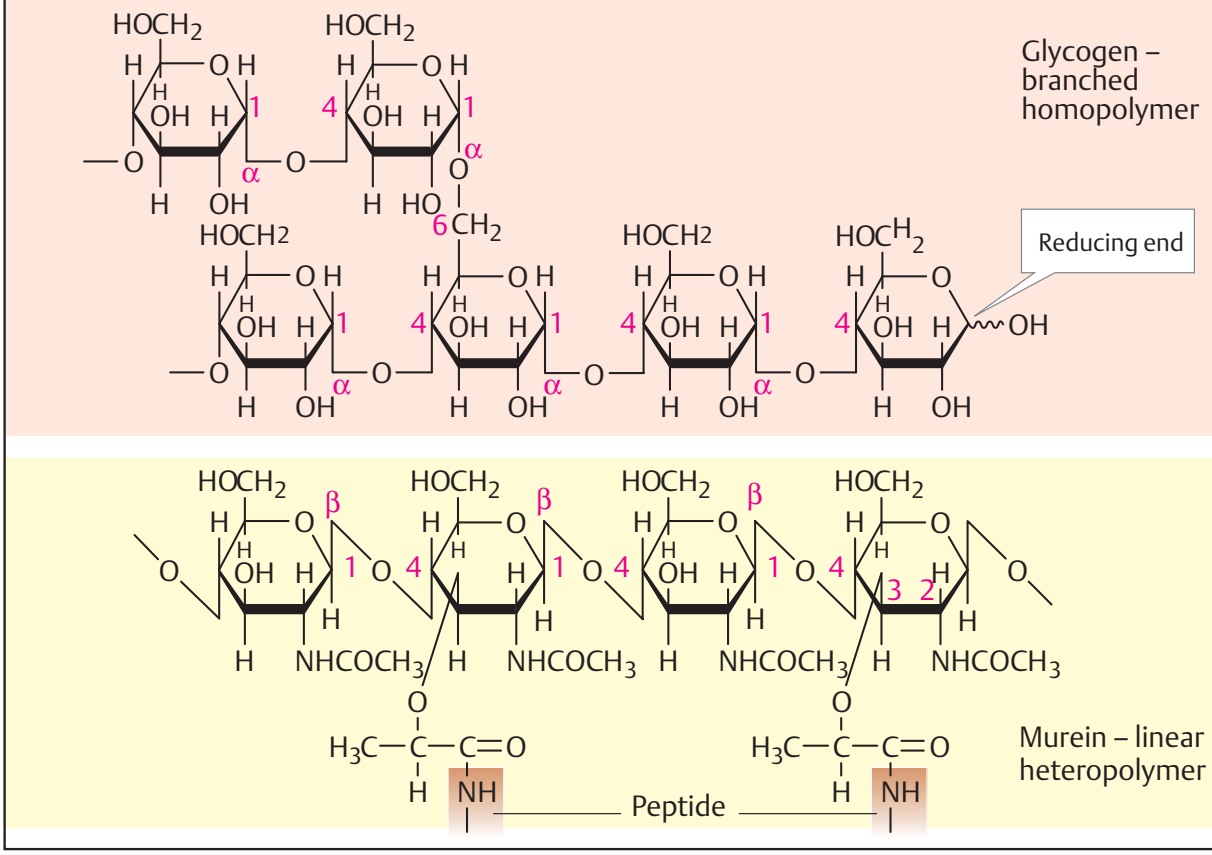
B. Important polysaccharides

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

SC= structural carbohydrate, RC= reserve carbohydrate,
WB = water-binding carbohydrate; [1)] *N*-acetylmuramic acid, [2)] 3,6-anhydrogalactose



A. Polysaccharides: structure



B. Important polysaccharides

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

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
Acetic acid	2 : 0
Propionic acid	3 : 0
Butyric acid	4 : 0
Valerianic acid	5 : 0
Caproic acid	6 : 0
Caprylic acid	8 : 0
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

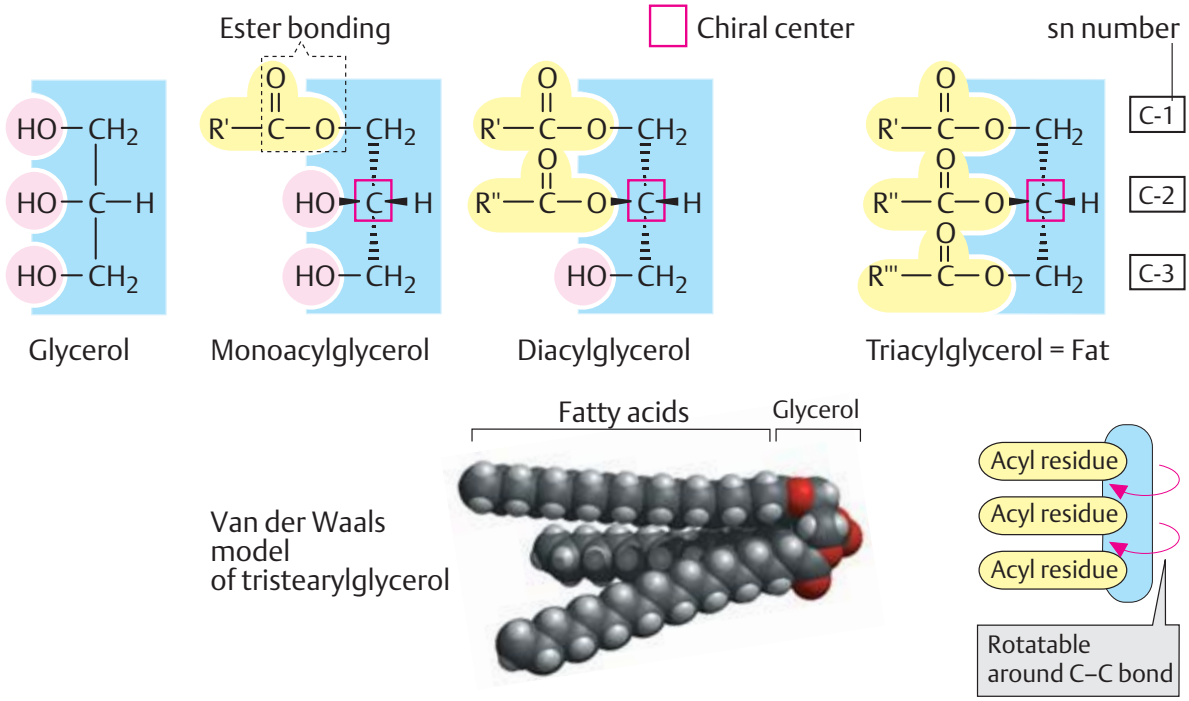
Not contained in lipids

$HOOC-CH_2-CH_2-CH_2-CH_2-CH_3$

Caproic acid

Essential in human nutrition

B. Structure of fats



A. The proteinogenic amino acids

Aliphatic

Glycine (Gly, G)	Alanine (Ala, A)	Valine (Val, V) ☆	Leucine (Leu, L) ☆	Isoleucine (Ile, I) ☆
H	CH_3	$H_3C-CH(CH_3)$	$CH_2(CH(CH_3)_2)$	$H_3C-C^*H(CH_2CH_3)$
Polarity				
−2.4	−1.9	−2.0	−2.3	−2.2

Sulfur-containing

Cysteine (Cys, C)	Methionine (Met, M) ☆
CH_2SH	$CH_2CH_2SCH_3$
8.3 (pK_a value)	
−1.2	−1.5

Aromatic

Phenylalanine (Phe, F) ☆	Tyrosine (Tyr, Y)	Tryptophan (Trp, W) ☆
CH_2-phenyl	CH_2-phenyl-OH	CH_2-indole
	OH 10.1	Indole ring
+0.8	+6.1	+5.9

Cyclic

Proline (Pro, P)
Pyrrolidine ring
+6.0

Neutral

Serine (Ser, S)	Threonine (Thr, T) ☆
CH_2OH	$H_3C-C^*H(OH)$
+5.1	+4.9

☆ Essential amino acids

□ Chiral center

Neutral

Asparagine (Asn,N)	Glutamine (Gln, Q)
CH_2CONH_2	$CH_2CH_2CONH_2$
+9.7	+9.4

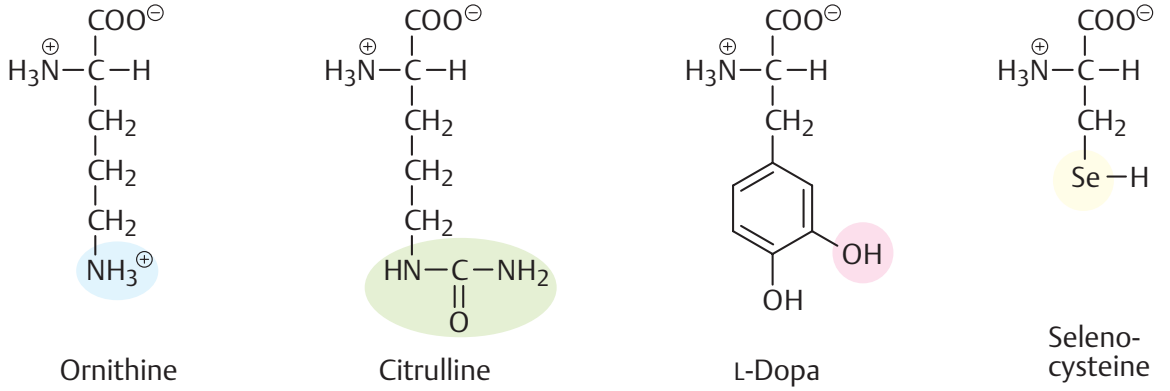
Acidic

Aspartic acid (Asp, D)	Glutamic acid (Glu, E)
CH_2COO^- 4.0	$CH_2CH_2COO^-$ 4.3
+11.0	+10.2

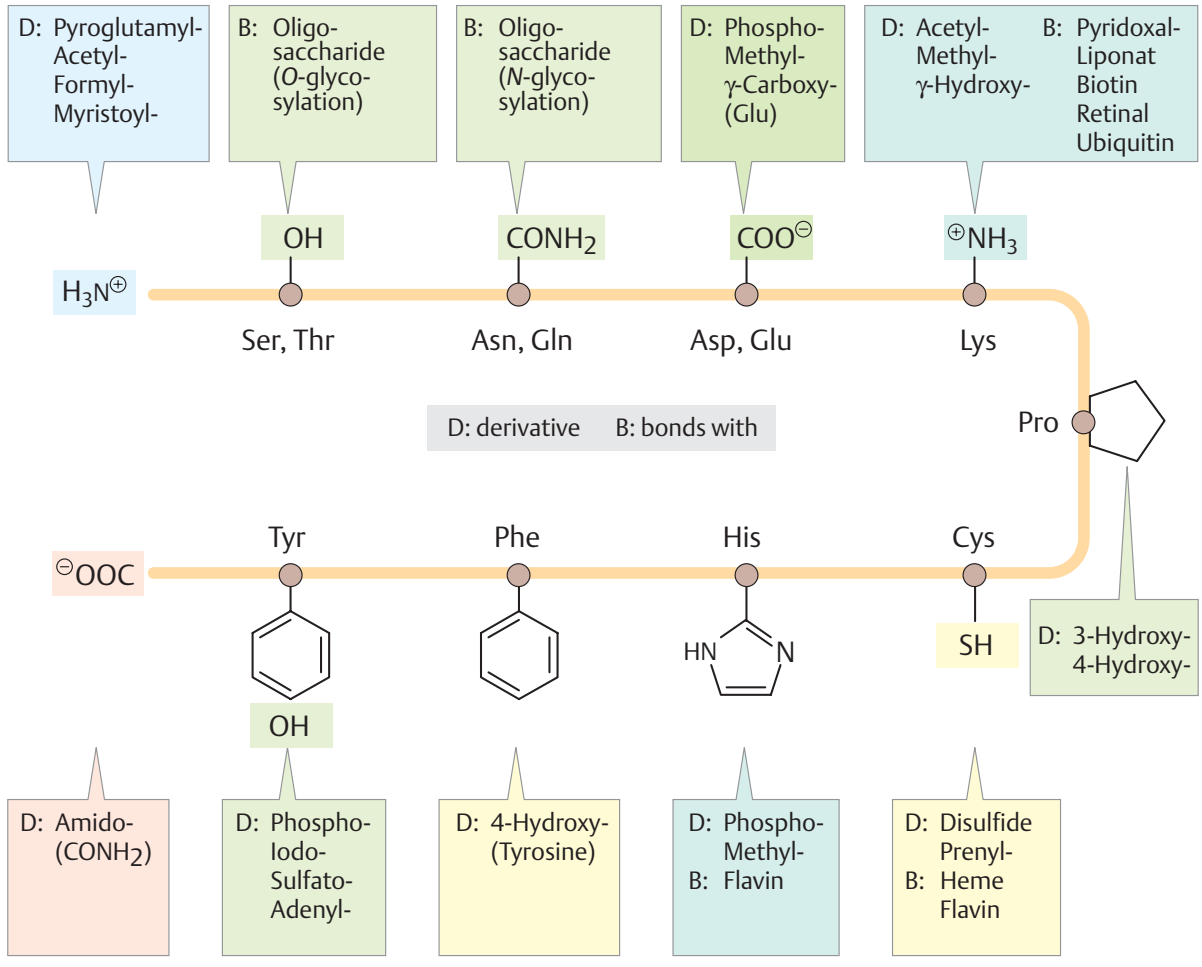
Basic

Histidine (His, H)	Lysine (Lys,K) ☆	Arginine (Arg, R)
Imidazole ring 6.0	$CH_2CH_2CH_2CH_2NH_3^+$ 10.8	$CH_2CH_2CH_2NH$-C(=NH_2^+)-NH_2 12.5
+10.3	+15.0	+20.0

A. Rare amino acids



B. Post-translational protein modification

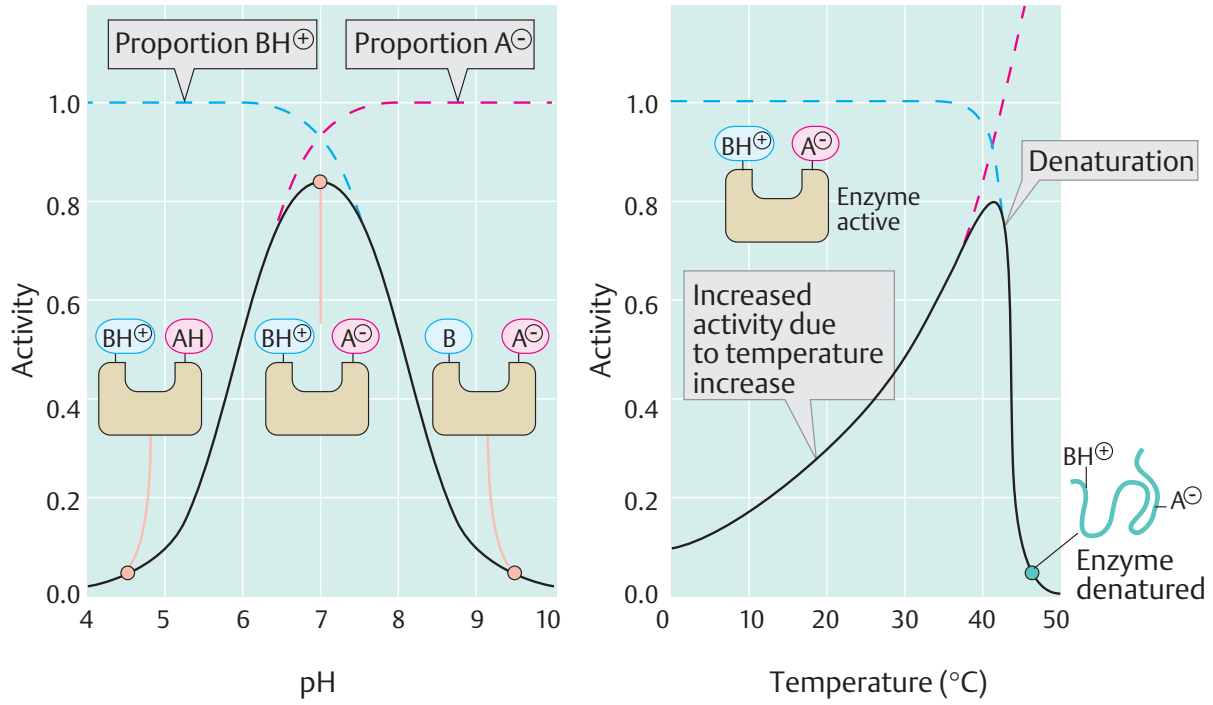


C. Biogenic amines

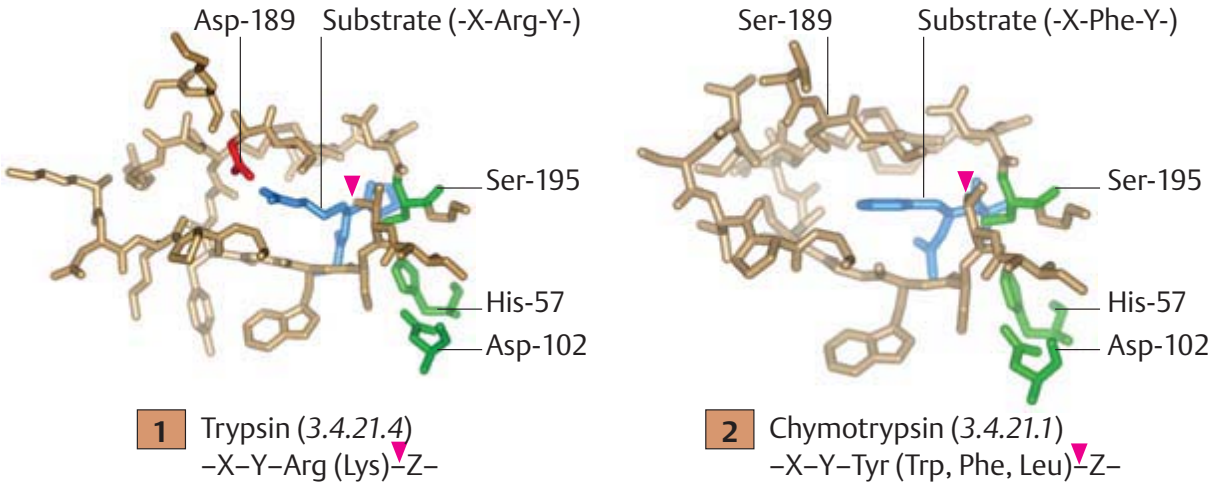
Amino acid	Amine	Function
Serine	Ethanol-amine	Glutamate
Cysteine	Cysteamine	Component of coenzyme A
Threonine	Amino-propanol	Component of vitamin B_{12}
Aspartate	β-Alanine	Component of coenzyme A

Amino acid	Amine	Function
Glutamate	γ-Amino-butyrate	Neurotrans-mitter (GABA)
Histidine	Histamine	Mediator, neuro-transmitter
Dopa	Dopamine	Neurotransmitter
5-Hydroxy-tryptophan	Serotonin	Mediator, neuro-transmitter

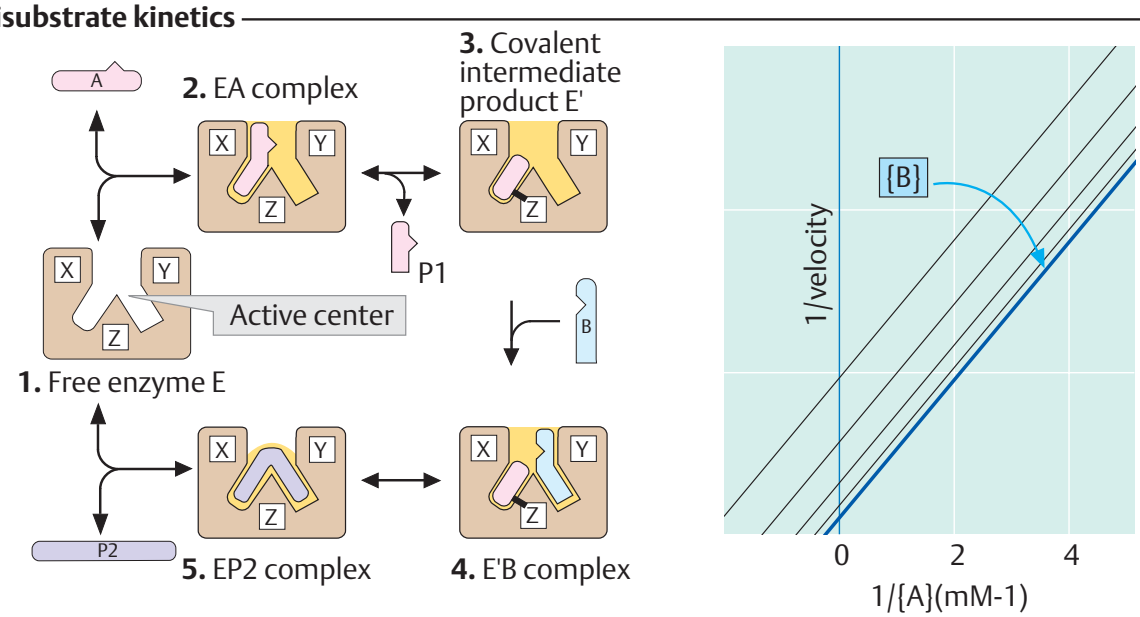
A. pH and temperature dependency of enzyme activity



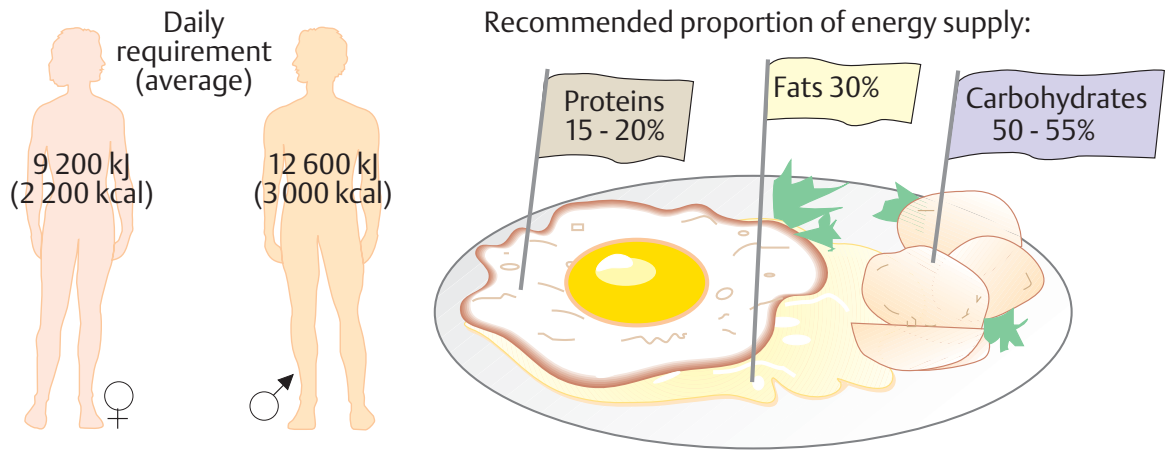
B. Substrate specificity



C. Bisubstrate kinetics



A. Energy requirement



B. Nutrients

	Quantity in body (kg)	Energy content kJ · g^{-1} (kcal · g^{-1})	Daily requirement (g) a	b	c	General function in metabolism	Essential constituents
Proteins	10	17 (4.1)	♂ 37 ♀ 29	55 45	92 75	Supplier of amino acids Energy source Daily requirement in mg per kg body weight	Essential amino acids:: Val (14) Leu (16) Ile (12) Lys (12) Phe (16) Trp (3) Met (10) Thr (8) Cys and His stimulate growth
Carbohydrates	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

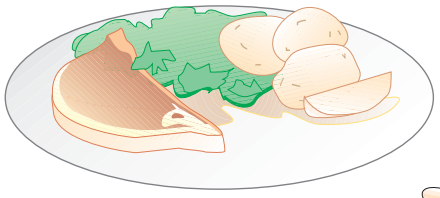
a: Minimum daily requirement b: Recommended daily intake c: Actual daily intake in industrialized nations

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				Metals Non-metals
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



Healthy nutrition

Vitamin requirement satisfied

Vitamin poisoning

Vitamin A and D

Poor nutrition
Malnutrition
Antibiotics
Disturbed resorption

Vitamin intake

Hypervitaminosis

Excess vitamins

Overdose

Diseases

Hypovitaminosis

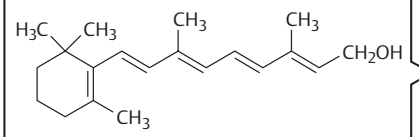
Urine

B. Lipid-soluble vitamins

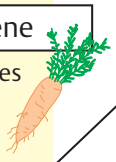
* Adult daily requirement

Provitamin	Functional form	Important for
β-Carotene	Retinal	Sight
Retinol	Retinol	Sugar transport
	Retinoic acid	Development Differentiation
Cholesterol	Calcitriol	Calcium metabolism
Tocopherols	Tocopherols	Anti-oxidant
Phylloquinones	Phyllohydroquinones	Blood clotting (carboxylation of plasma proteins)

A



Vegetables
Fruit



Visual pigments

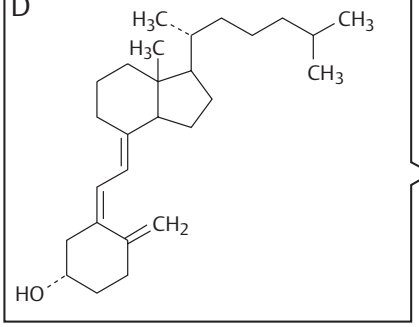
Retinol

Coenzyme

1

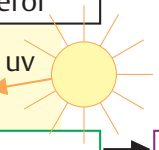
Milk
Liver
Egg yolk

D



Cholesterol

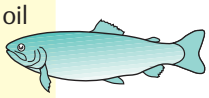
uv



Calciol

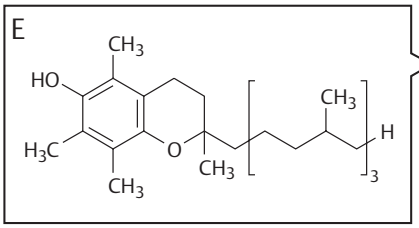
0.01

Cod liver oil
Milk
Egg yolk



Hormone

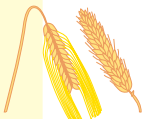
E



Tocopherols

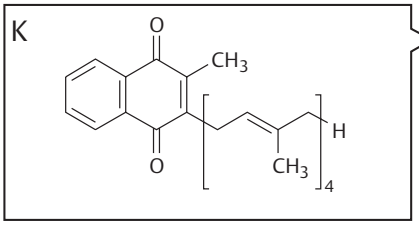
10

Cereals
Liver
Eggs
Seed oil



Reducing agent

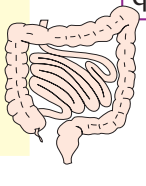
K

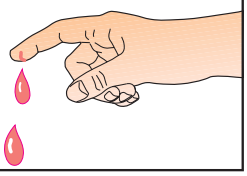


Phylloquinones

0.08

Intestinal bacteria
Vegetables
Liver





A. Water-soluble vitamins I

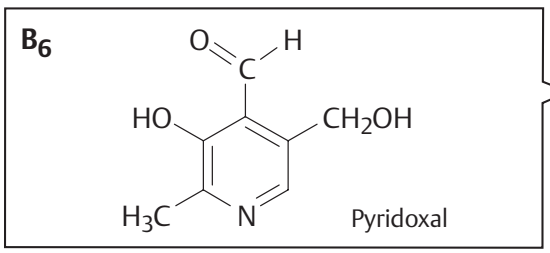
* Adult daily requirement

Vitamin	Active form: coenzyme	Function in metabolism
B_1		
Thiamine	TPP Thiamine diphosphate	Transfer of hydroxy-alkyl residues
1.5 mg *		
Grain Yeast products Pork		
B_2		
Riboflavin	FMN FAD	Hydrogen transfer
1.8 mg*		
Milk Eggs		
4-Aminobenzoate residue Pteridine derivative Glu		
Folate	THF Tetrahydro-folate	C_1-metabolism
0.2 mg*		
Fresh green vegetables Liver		
Nicotinate Nicotinamide		
Nicotinate Nicotinamide	NADP NAD	Hydride transfer
20 mg*		
(or 1.2 g tryptophan)		
Meat, yeast products Fruit and vegetables		
Pantoinate β-Alanine		
Pantothenate	CoA	Activation of carboxy-lic acids
7 mg*		
Widely distributed		

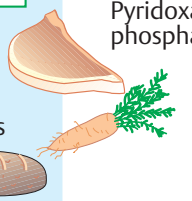
A. Water-soluble vitamins II

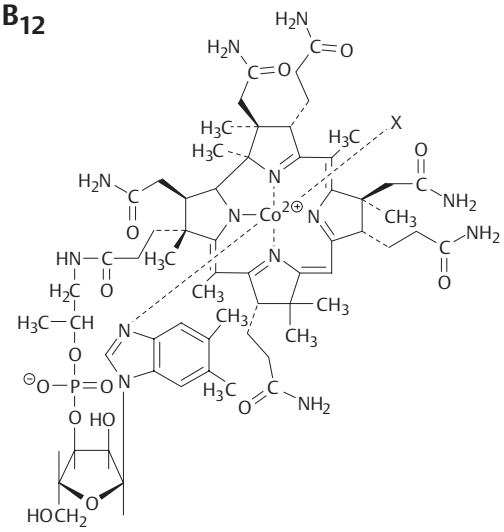
* Adult daily requirement

Vitamin	Active form: coenzyme	Function in metabolism
B_6	Pyridoxal Pyridoxol Pyridoxamine	PLP Pyridoxal phosphate	Activation of amino acids
B_{12}	Cobalamine	5-Deoxy-adenosyl cobalamine	Isomerization e.g.
C	Ascorbic acid	Ascorbate	Stabilization of enzyme systems, coenzyme, antioxidant
H	Biotin	B Biotin	Transfer of carboxyl groups

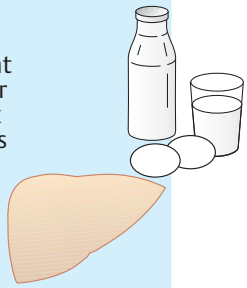


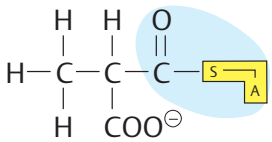
2 mg*
Meat
Vegetables
Grain products



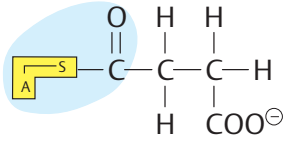


0.002 mg*
Meat
Liver
Milk
Eggs

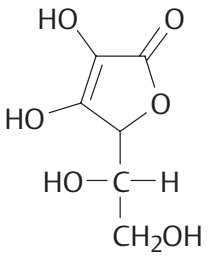




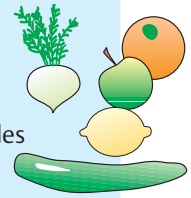
Methylmalonyl CoA

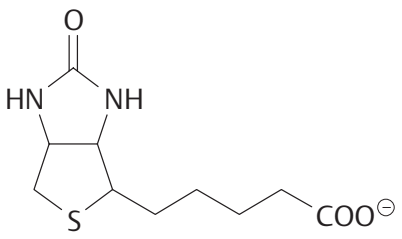


Succinyl CoA

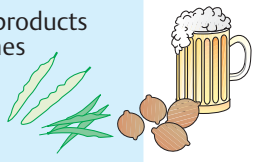


60 mg*
Fruit
Vegetables





0.1 mg*
Yeast products
Legumes
Nuts



Color Atlas of Biochemistry

Second edition, revised and enlarged

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