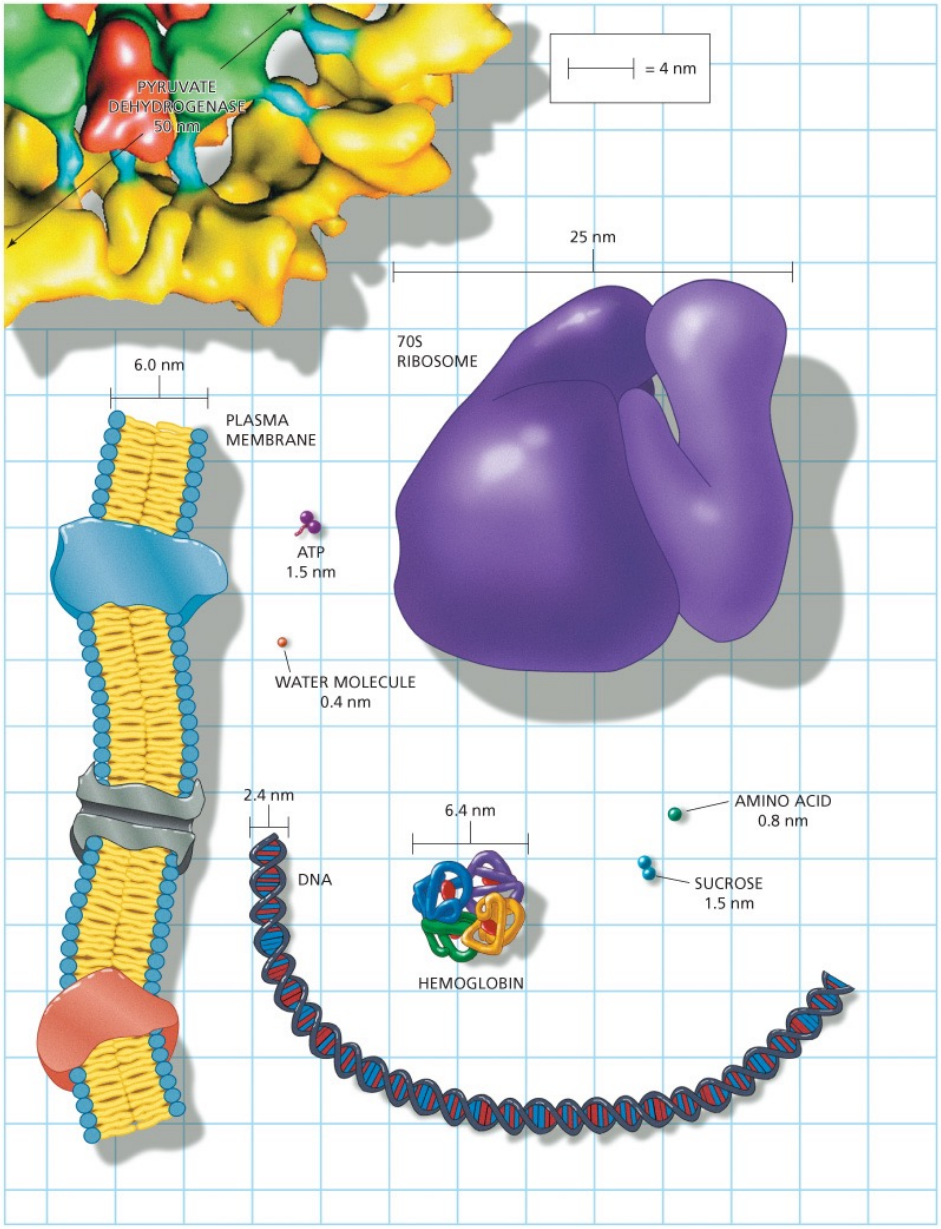
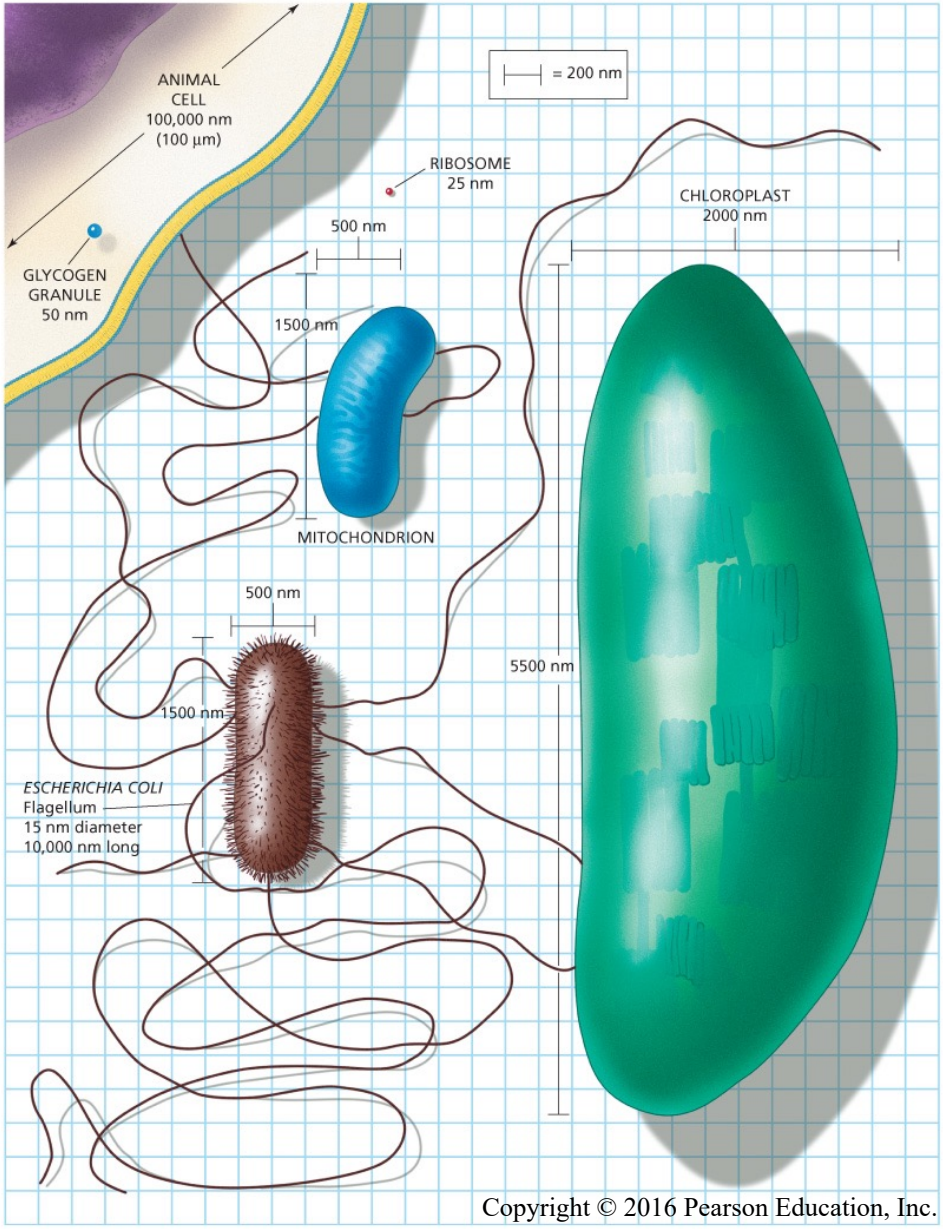




Biochemie

Prof. dr. ir. Jessika De Clippeleer

Biochemie en de Taal van Biochemie

Gebaseerd op Hoofdstuk 1 uit Biochemistry – Concepts and Connections, Appling et al., 2019, Pearson Education

Prof. dr. ir. Jessika De Clippeleer

Overzicht Hoofdstuk 1 - Inleiding

1.1 De Wetenschap van Biochemie

Wat is biochemie?

« Much of life can be understood in rational terms if expressed in the language of chemistry. It is an international language, a language for all times, and a language that explains where we came from, what we are, and where the physical world will allow us to go. »

Arthur Kornberg (1918-2007)

Wat is biochemie?

Biochemie gebruikt *“de taal van de chemie”*

⇊

Biochemische taal

Woorden = chemische namen en structuren

Zinnen = chemische reacties

Paragrafen = metabole routes

Wat is biochemie?

Biochemie =

« Studie van 'leven'
op moleculair niveau »

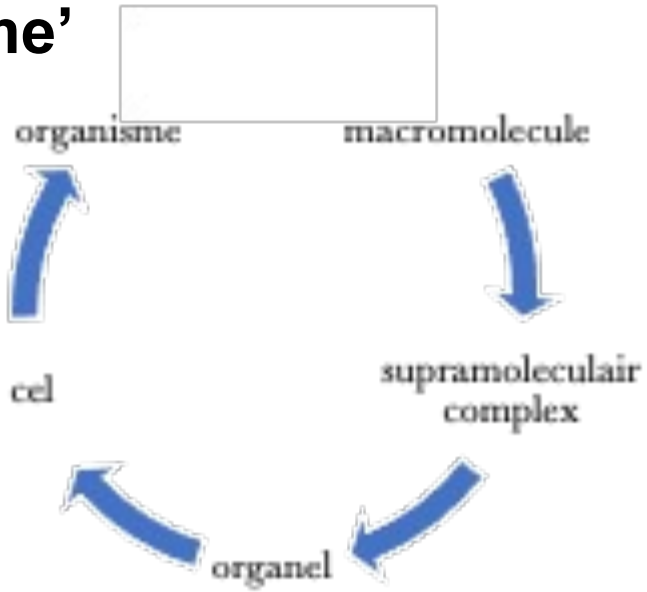
« Chemie van de levende cel »

Biologie  Chemie

Wat is biochemie?

Met die biochemische taal…

- **‘leven’** verklaren op **moleculair** vlak m.b.v. methodieken en terminologie **scheikunde**
- **praktisch gerichte wetenschap**
- gebaseerd op **‘reductionisme’**



Wat is biochemie?

- Belangrijkste vraagstellingen:
  - Wat zijn **chemische en ruimtelijke structuren** van biologische moleculen, bestanddelen van levende materie?
  - Hoe **interageren** die biomoleculen met elkaar?
  - Hoe worden biomoleculen georganiseerd tot supramoleculaire structuren, cellulaire systemen, weefsels en volledige organismen?
  - Hoe verloopt **coördinatie van cellulaire activiteiten**?
  - Hoe gebeurt **synthese/afbraak** van biomoleculen in cel?
  - Hoe wordt **energie** gewonnen, opgeslagen en verbruikt in cel?
  - Hoe wordt **genetische informatie** opgeslagen, doorgegeven en tot expressie gebracht?

Historiek van de biochemie

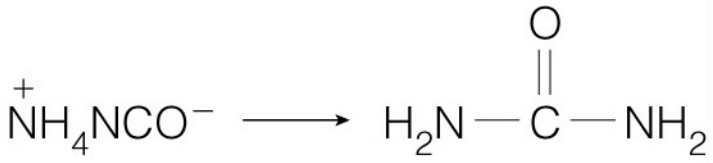
Fermentatie: een oude toepassing van biochemie

Historiek van de biochemie

Biochemie…

- is een erg **jonge wetenschap**
- 1828:

Wöhler's synthesis of urea from ammonium cynate:



Ammonium cynate → **Urea**

- Vroege biochemici moesten dus de leer van vitalisme, die beweerde dat levende materie en niet-levende materie fundamenteel verschillend waren, overwinnen

Historiek van de biochemie

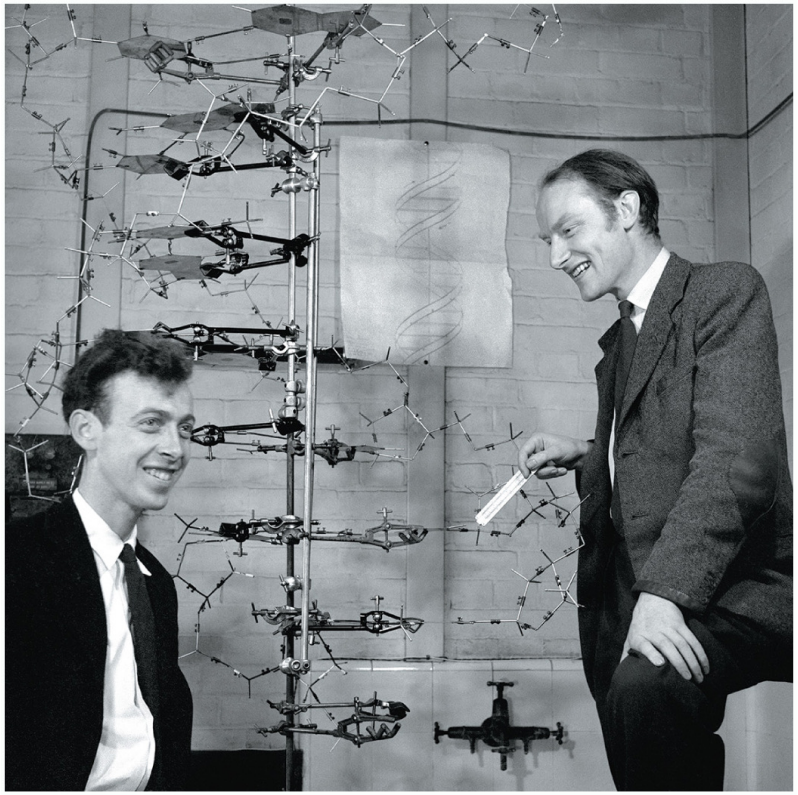
Biochemie… is een erg **jonge wetenschap**

- Eduard en Hans Buchner (Nobelprijs 1907): fermentatieprocessen (cfr. brouwen) dienen niet noodzakelijk met levende gistcellen uitgevoerd te worden, maar kunnen ook met extracten ervan plaatsgrijpen
- Eerste helft 20^{e} eeuw: ontdekking diverse metabolische wegen en dat het eiwitten (enzymen) zijn die eigenlijke biochemische reacties katalyseren
- Jaren 1950: ontdekking structuur eiwitten en kraken genetische code

Historiek van de biochemie

Biochemie… is een erg **jonge wetenschap**

- De biologie werd getransformeerd in 1953, toen Watson en Crick het dubbele helix model voor de DNA-structuur voorstelden



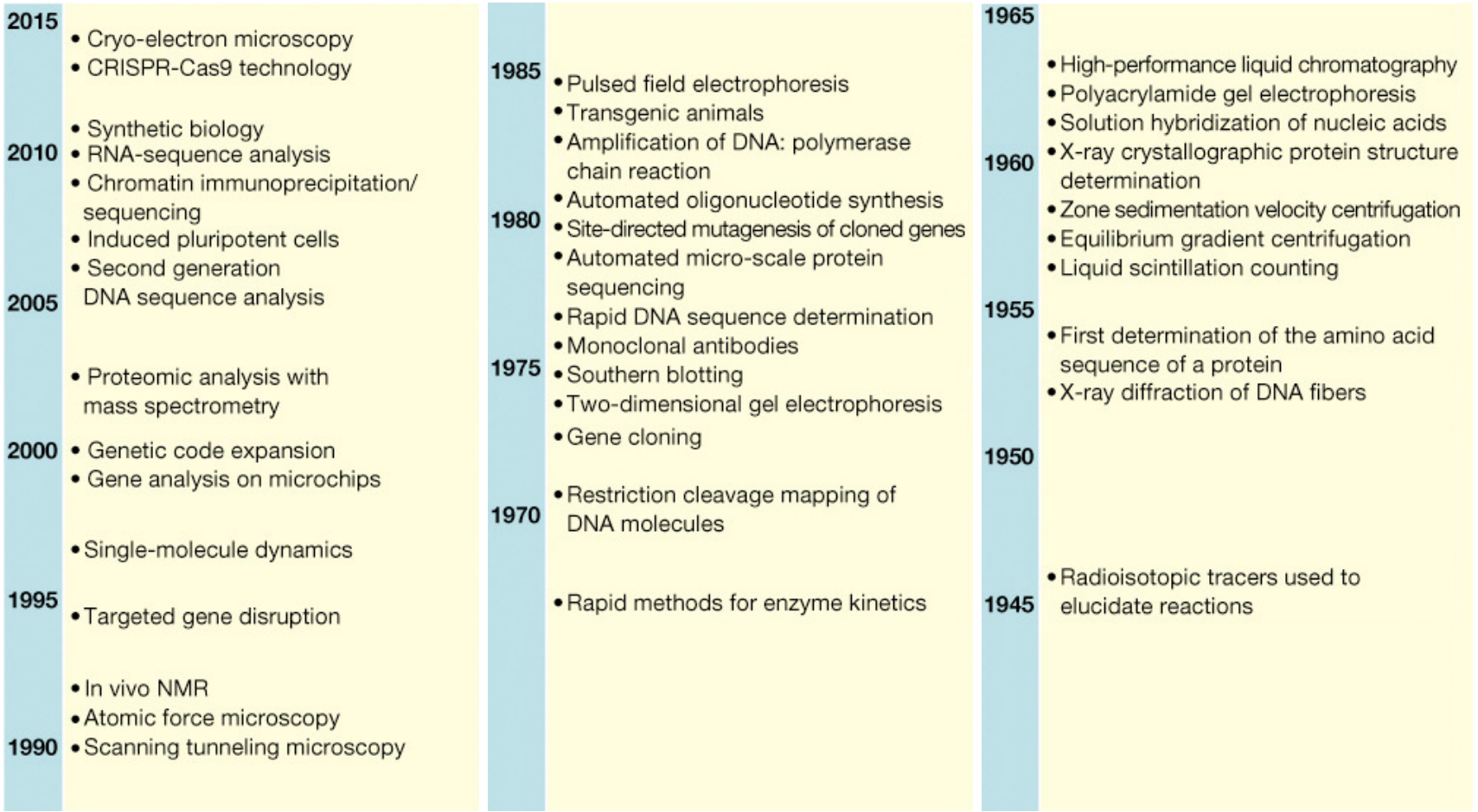
Historiek van de biochemie

Biochemie… is een erg **jonge wetenschap**

- Einde 20^{e} eeuw: ophelderen volledige **menselijke genoomsequentie**
- Vandaag: **post-genomische tijdperk**
  - Functie elk gen achterhalen en koppelen aan ziekte, groei, veroudering, etc.
  - Simultaan enorme vooruitgang in celbiologie en genetica
  - Tempo waarin biologische processen in moleculaire termen begrepen worden versneld door krachtige nieuwe chemische en fysische technieken

Historiek van de biochemie

Introductie nieuwe onderzoekstechnieken tonen recente geschiedenis



Biochemie als discipline en interdisciplinaire wetenschap

Samenbrengen van kennis uit diverse disciplines leidde tot moderne inzichten over levende materie: moleculaire biologie

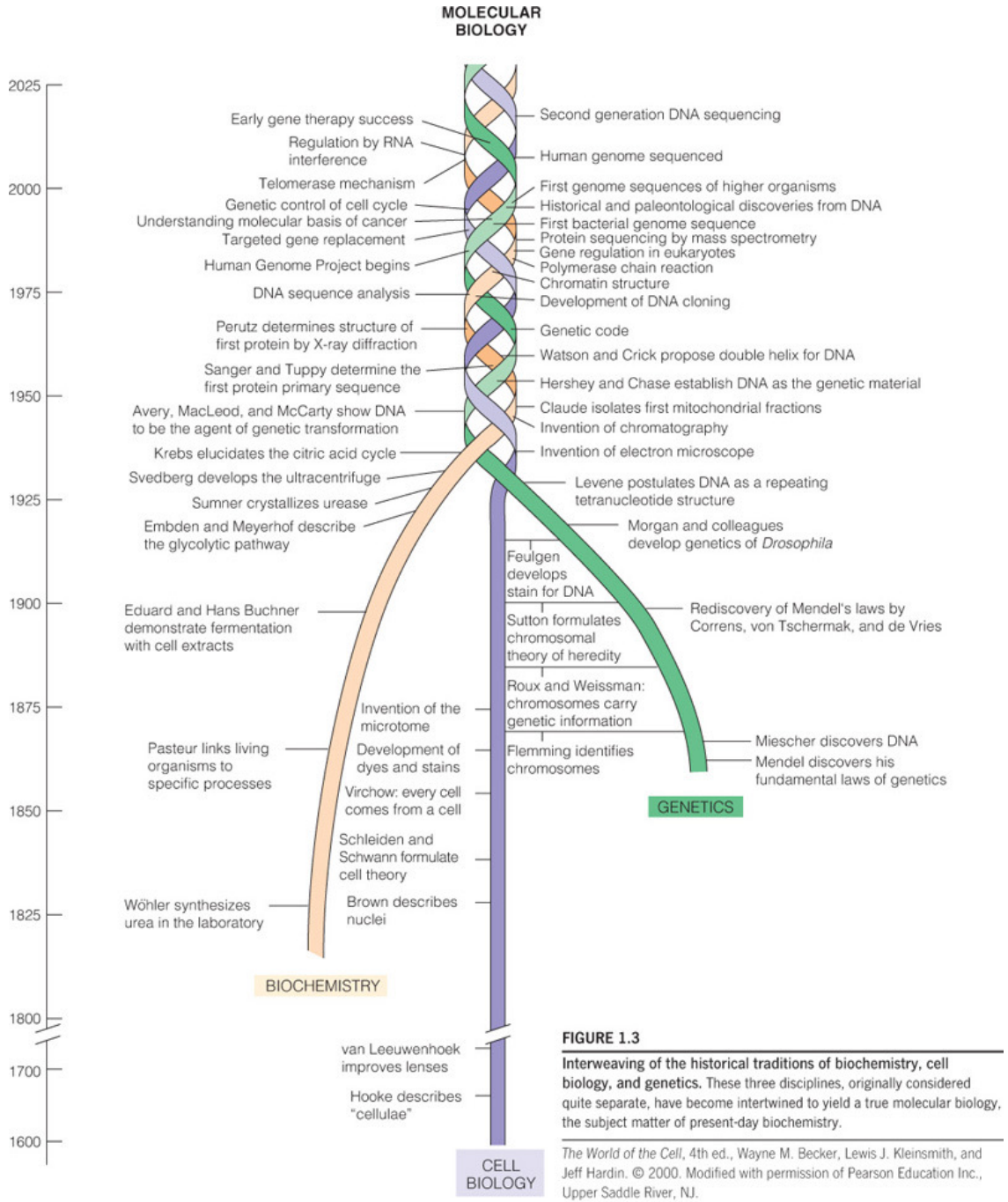
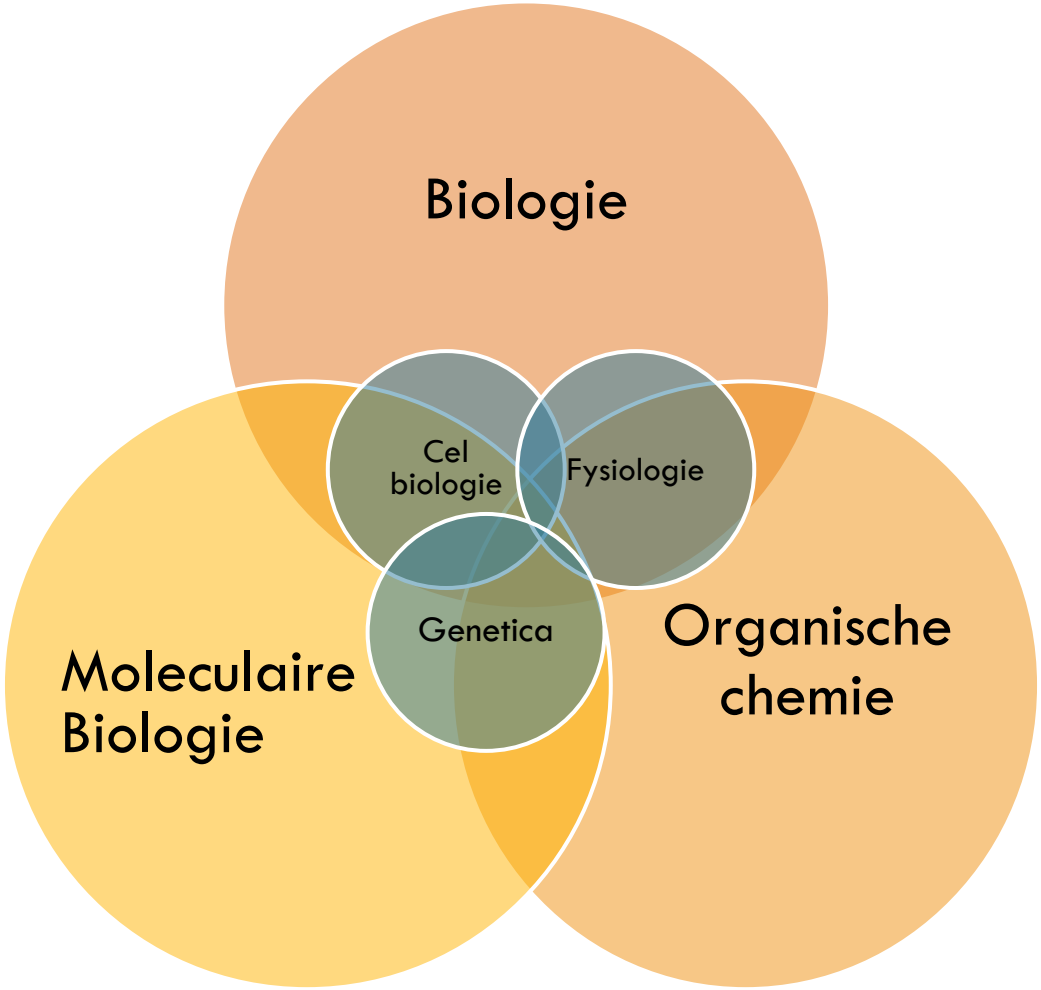


FIGURE 1.3

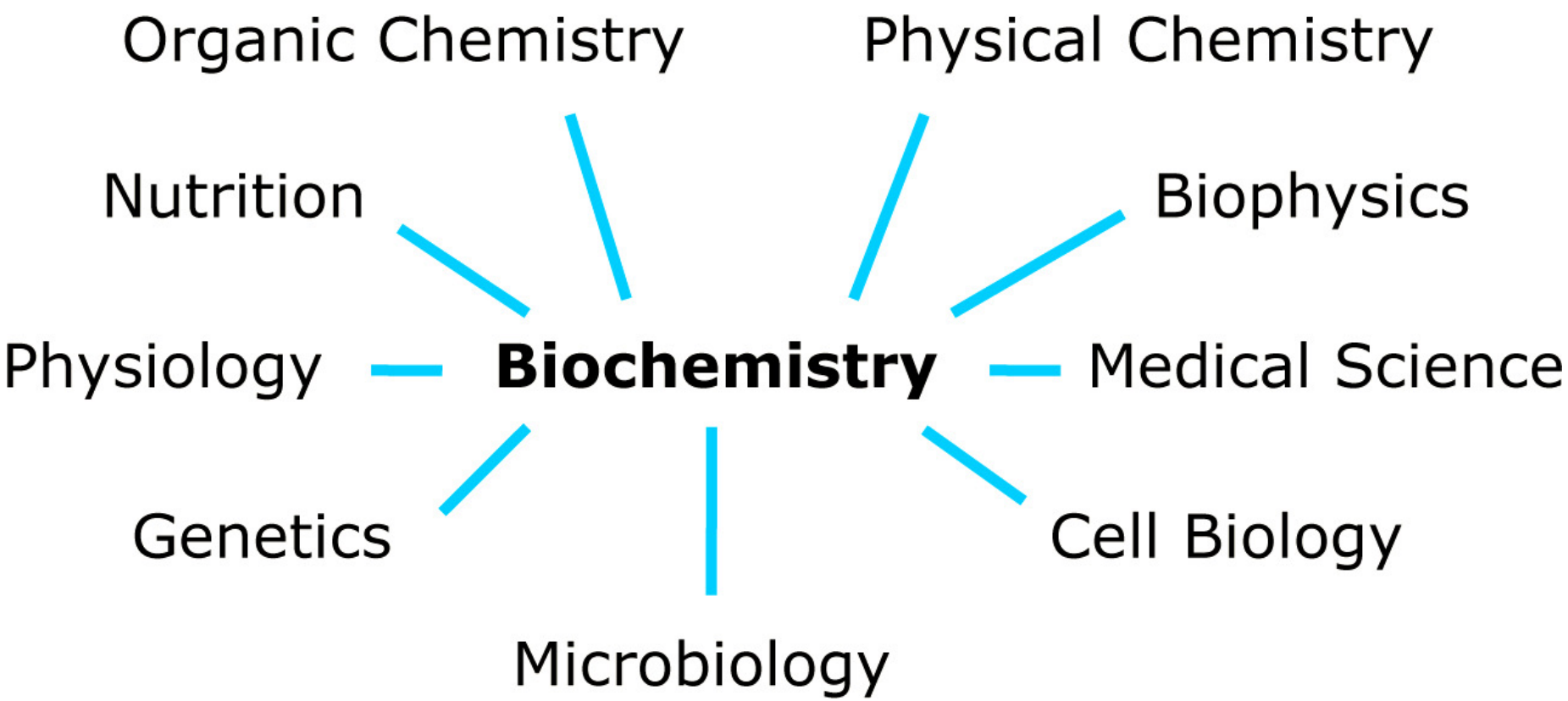
Interweaving of the historical traditions of biochemistry, cell biology, and genetics. These three disciplines, originally considered quite separate, have become intertwined to yield a true molecular biology, the subject matter of present-day biochemistry.

The World of the Cell, 4th ed., Wayne M. Becker, Lewis J. Kleinsmith, and Jeff Hardin. © 2000. Modified with permission of Pearson Education Inc., Upper Saddle River, NJ.

Biochemie als discipline en interdisciplinaire wetenschap



Biochemie als discipline en interdisciplinaire wetenschap



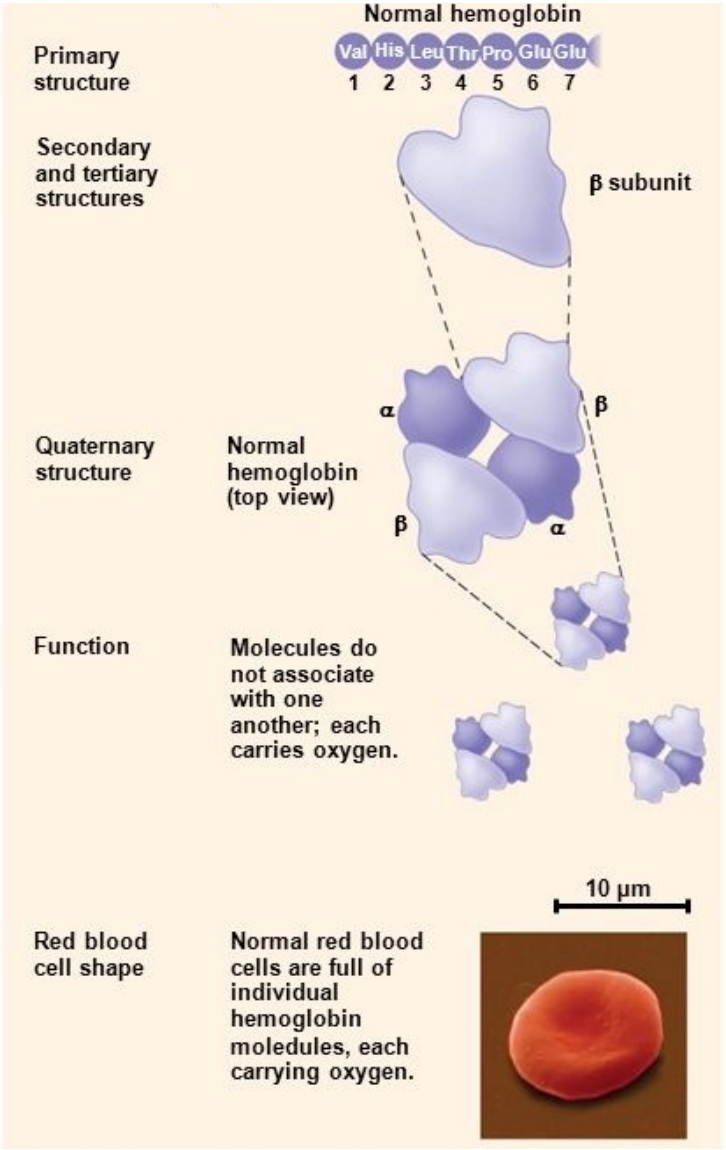
Toepassingen van biochemie

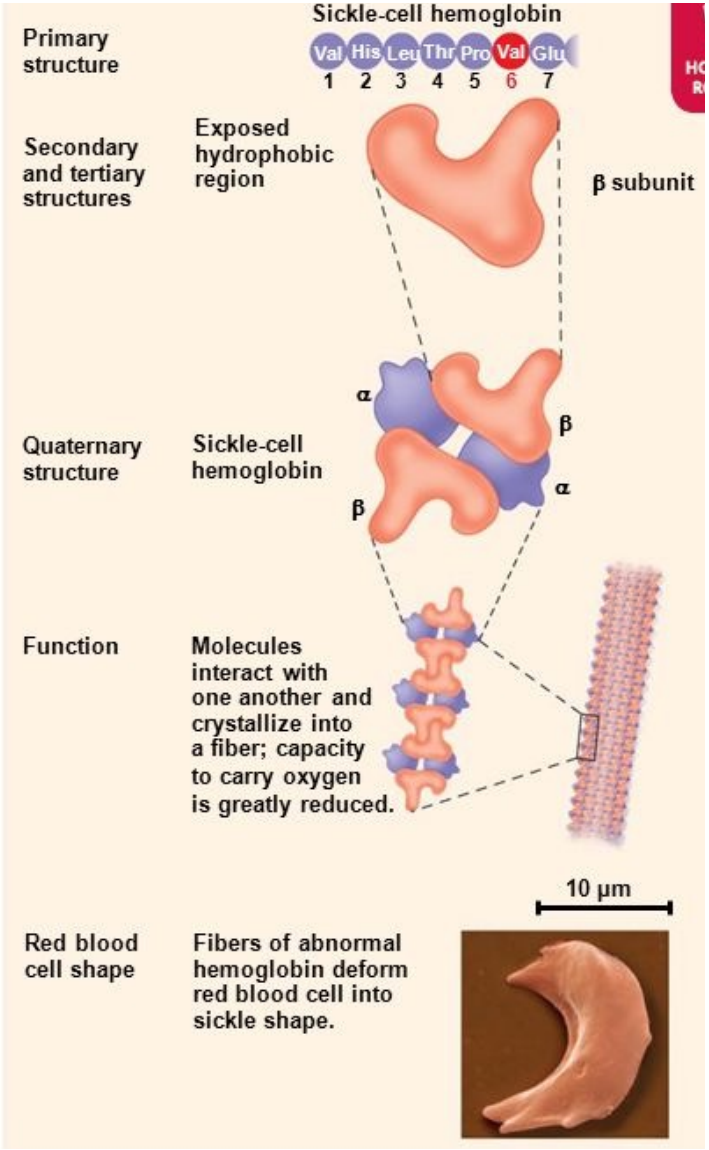
Biochemie is een **fundamentele wetenschap** met implicaties op en toepassingen in:

- GENEESKUNDE EN GEZONDHEID
- BIOTECHNOLOGIE
- LANDBOUW EN BIODIVERSITEIT
- MILIEU
- LEVENSMIDDELENTECHNOLOGIE

BIOCHEMIE: CONCRETE TOEPASSING

Sikkelcelanemie: Glu => Val





Hoofdthema's van de biochemie

Biochemie kan worden onderverdeeld in drie gebieden:

1. ***Structurele biochemie*** van de componenten van levende materie (biomoleculen) in relatie tot hun biologische **functie**

2. ***Metabolisme***, het totaal aan chemische reacties die plaatsgrijpen in levende materie (omzetting van biomoleculen, bioenergetica)

3. ***Genetische biochemie***, de chemie van processen die verband houden met opslag en doorgeven van biologische **informatie**

1.2 De Elementen en Moleculen van Levende Systemen

Biochemie als chemische wetenschap

Biochemie… is onmiskenbaar een chemisch gerichte wetenschap

- De **chemische eigenschappen** van de levende materie, de **biomoleculen**, bestuderen
- Aantal biomoleculen dat men al heeft ontdekt, is gigantisch; toch slechts een bijzonder klein gedeelte van geheel van moleculen dat theoretisch met de elementen op aarde mogelijk is

Biochemie als chemische wetenschap

Daarbij valt op dat de elementen die in het lichaam ingebouwd worden, niet diegene zijn die het meeste voorkomen in de bovenste aardlagen

⇒ chemische samenstelling van levende organismen is zeer verschillend van de omgeving

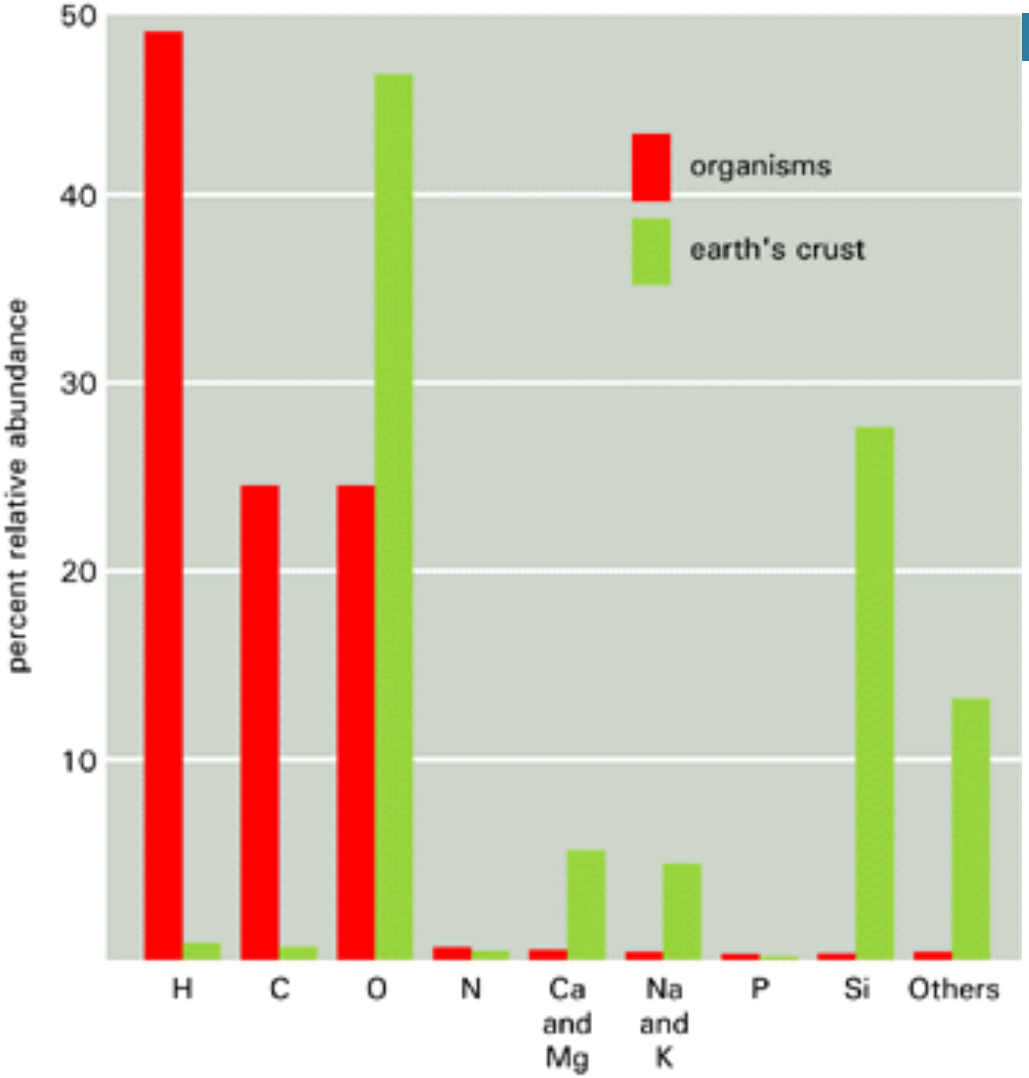


Figure 2.3 Molecular Biology of the Cell, 4th Edition

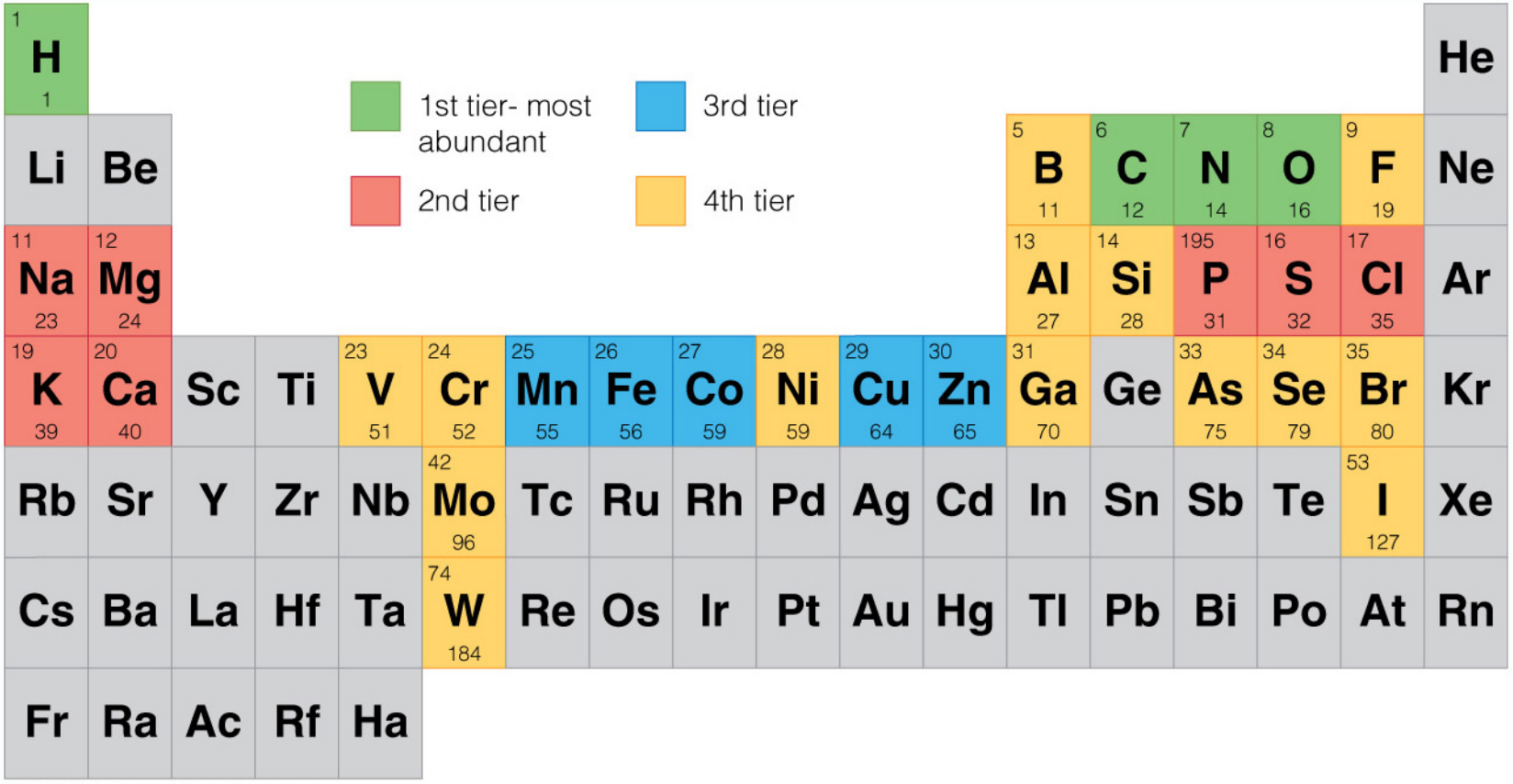
Biochemie als chemische wetenschap

TABLE 1.1 Elements found in organisms

Element	Comment
First Tier	
Carbon (C)	Most abundant in *all organisms*
Hydrogen (H)	
Nitrogen (N)	
Oxygen (O)	
Second Tier	
Calcium (Ca)	Much less abundant but found in *all organisms*
Chlorine (Cl)	
Magnesium (Mg)	
Phosphorus (P)	
Potassium (K)	
Sodium (Na)	
Sulfur (S)	
Third Tier	
Cobalt (Co)	Metals present in small amounts in *all organisms* and essential to life
Copper (Cu)	
Iron (Fe)	
Manganese (Mn)	
Zinc (Zn)	
Fourth Tier	
Aluminum (Al)	Found in or required by *some organisms* in trace amounts
Arsenic (As)	
Boron (B)	
Bromine (Br)	
Chromium (Cr)	
Fluorine (F)	
Gallium (Ga)	
Iodine (I)	
Molybdenum (Mo)	
Nickel (Ni)	
Selenium (Se)	
Silicon (Si)	
Tungsten (W)	
Vanadium (V)	

Biochemie als chemische wetenschap

Van alle elementen uit de tabel van Mendelejev wordt slechts een beperkt aantal effectief in biomoleculen ingebouwd



Biochemie als chemische wetenschap

Nagenoeg alle verbindingen die men in een organisme terugvindt, bevatten het **element koolstof**

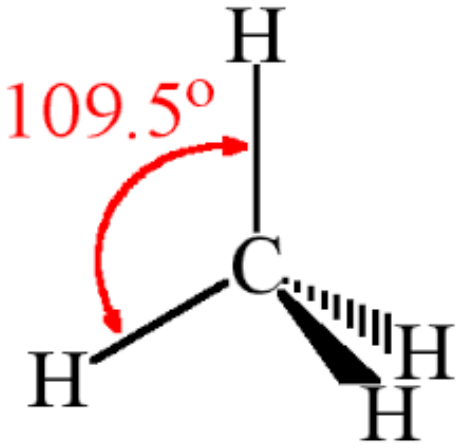
→ koolstof is centraal element: >50% van drooggewicht cel

⇒ chemische variëteit en reactiviteit in biomoleculen eerder beperkt

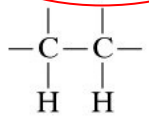
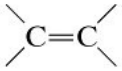
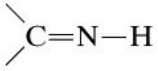
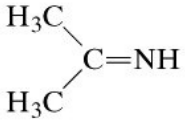
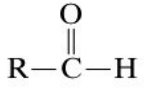
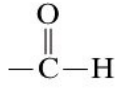
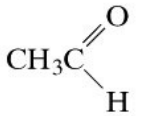
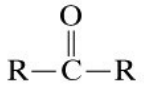
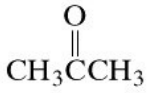
⇒ valt terug op reacties typisch in organische scheikunde

Cellen bestaan voor 70% uit **water**

⇢ meeste reacties in waterige omgeving !



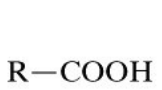
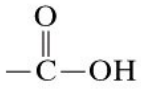
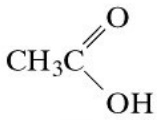
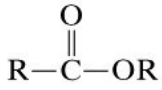
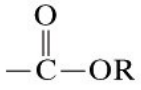
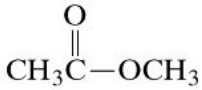
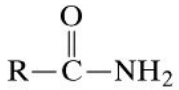
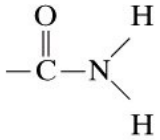
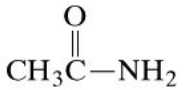
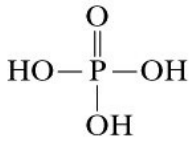
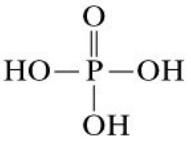
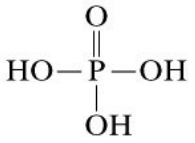
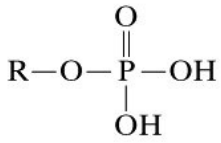
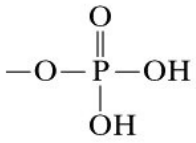
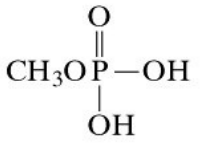
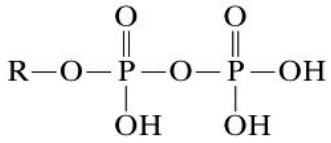
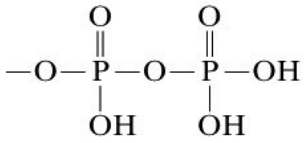
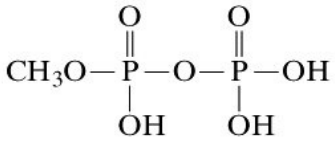
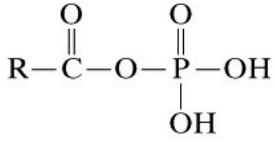
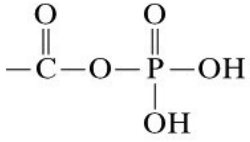
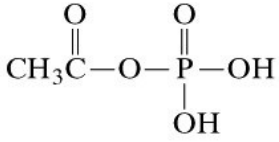
FUNCTIONELE GROEPEN

Class of Compound	General Structure[a]	Functional Group Structure	Functional Group Name	Example
Alkane	$RCH_2—CH_3$		Carbon–carbon and carbon–hydrogen single bonds	$H_3C—CH_3$
Alkene	$RCH=CH_2$		Carbon–carbon double bond	$H_2C=CH_2$
Alcohol	ROH	—OH	Hydroxyl group	CH_3OH
Thiol	RSH	—SH	Thiol or sulfhydryl group	CH_3SH
Ether	R—O—R	—O—	Ether group	$CH_3—O—CH_3$
Amine[b]	RNH_2 R_2NH R_3N		Amino group	$H_3C—NH_2$
Imine[b]	R=NH		Imino group	
Aldehyde			Carbonyl group	
Ketone			Carbonyl group	

[a] R refers to any carbon-containing group.
[b] These molecules are acids or bases and are able to donate or accept protons under physiological conditions. They may be positively or negatively charged.

Unnumbered table pg 11a Concepts in Biochemistry, 3/e

FUNCTIONELE GROEPEN

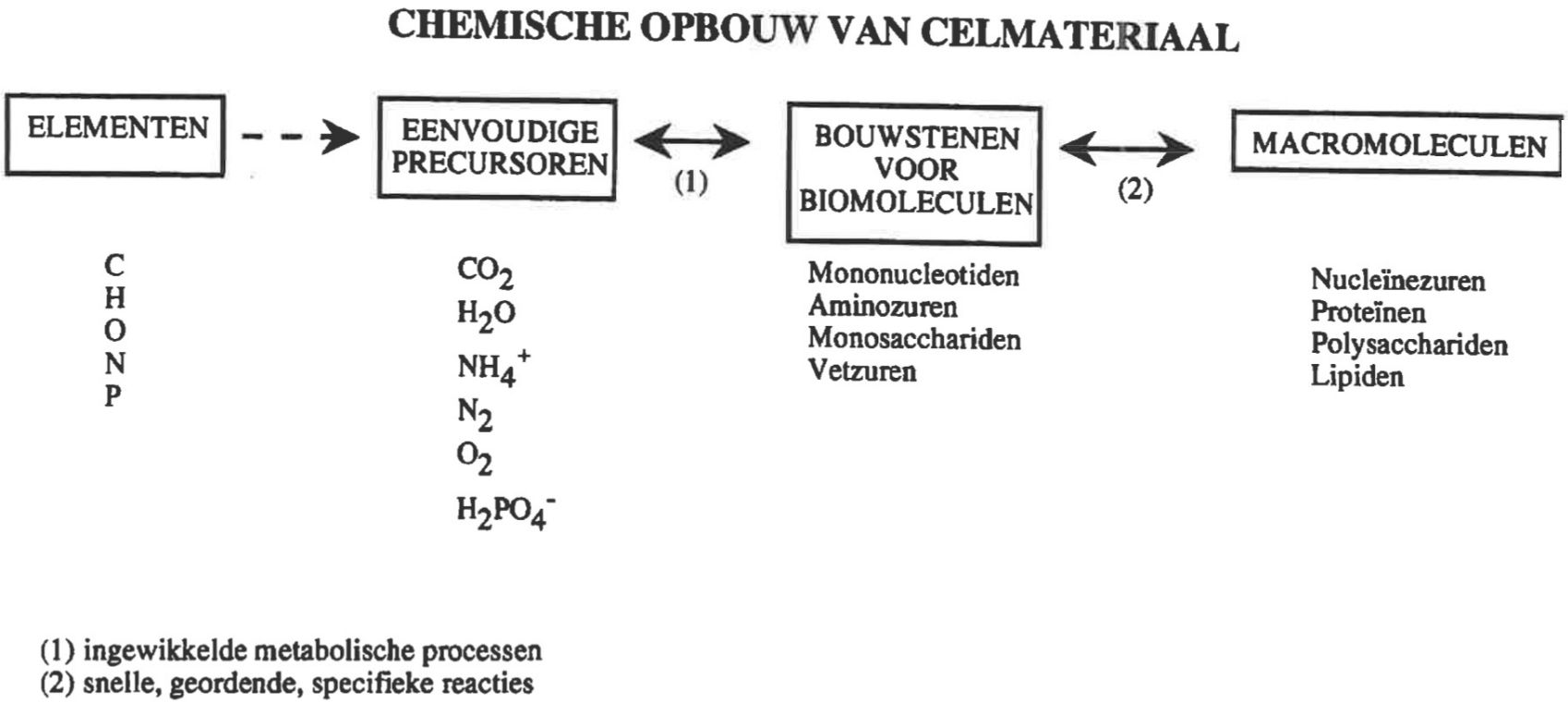
Class of Compound	General Structure[a]	Functional Group Structure	Functional Group Name	Example
Carboxylic acid[b]			Carboxyl group	
Ester			Ester group	
Amide			Amide group	
Phosphoric acid[b]			Phosphoric acid group	
Phosphoric acid ester[b]			Phosphoester group or phosphoryl group	
Phosphoric acid anhydride[b]			Phosphoric anhydride group	
Carboxylic acid–phosphoric acid mixed anhydride[b]			Acyl-phosphoryl anhydride	

[a] R refers to any carbon-containing group.

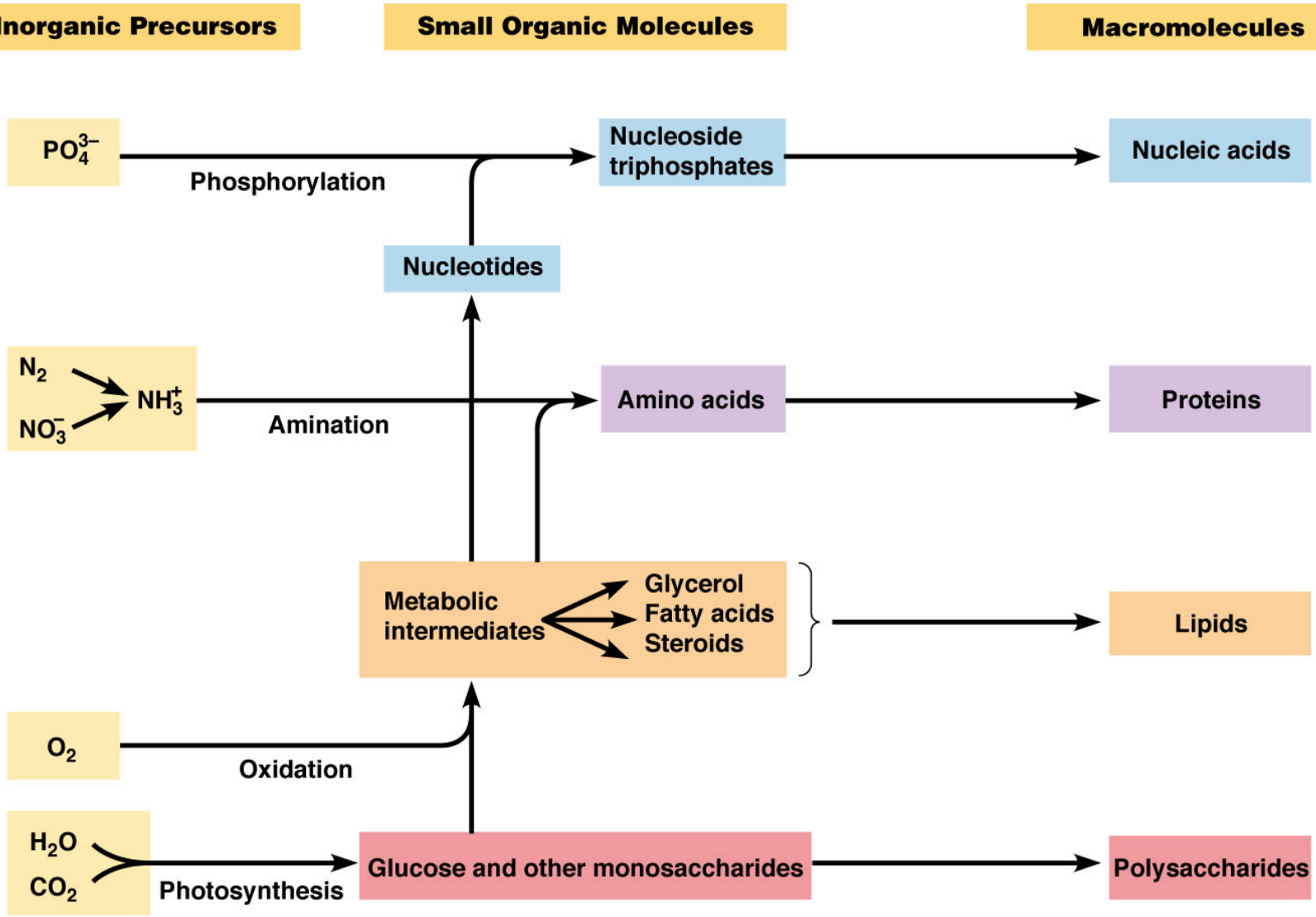
[b] These molecules are acids or bases and are able to donate or accept protons under physiological conditions. They may be positively or negatively charged.

Unnumbered table pg 11b Concepts in Biochemistry, 3/e

Biochemie als chemische wetenschap

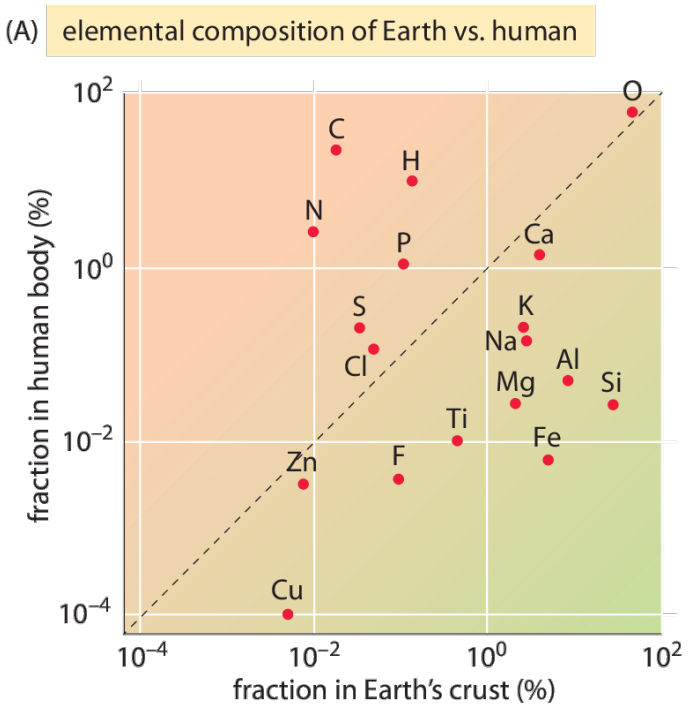


Bouwstenen van macromoleculen bestaan uit beperkt aantal elementen



ELEMENTEN, VERBINDINGEN EN BIOMOLECULEN IN LEVENDE MATERIE VERSCHILLEN VAN DEZE IN DE OMGEVING

Elementen → Verbindingen → Moleculen



Organisch C/N: levend

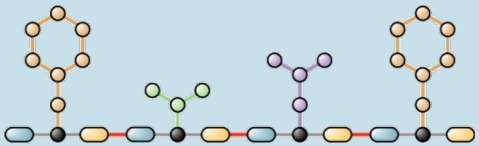
Anorganisch (N_2, CO_2)

Biomoleculen = groot Moleculaire massa's 1000 tot vele 100.000 Daltons

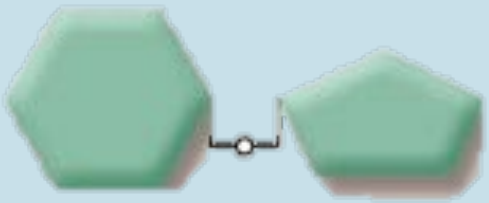
Klassieke chemische verbindingen in de natuur : ethanol 46 Da

Biologische macromoleculen

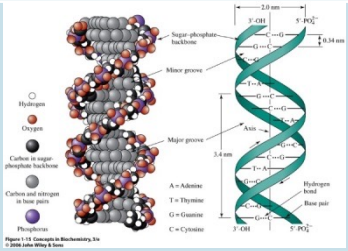
4 belangrijke groepen bio/macromoleculen



Eiwitten, proteïnen



Polysachariden, Koolhydraten, Carbohydraten, Suikers

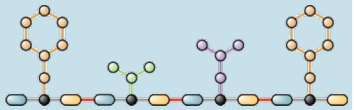
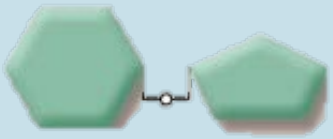
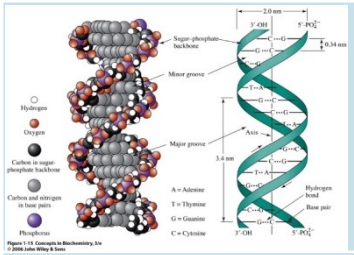


Nucleïnezuren = DNA/RNA

Lipiden

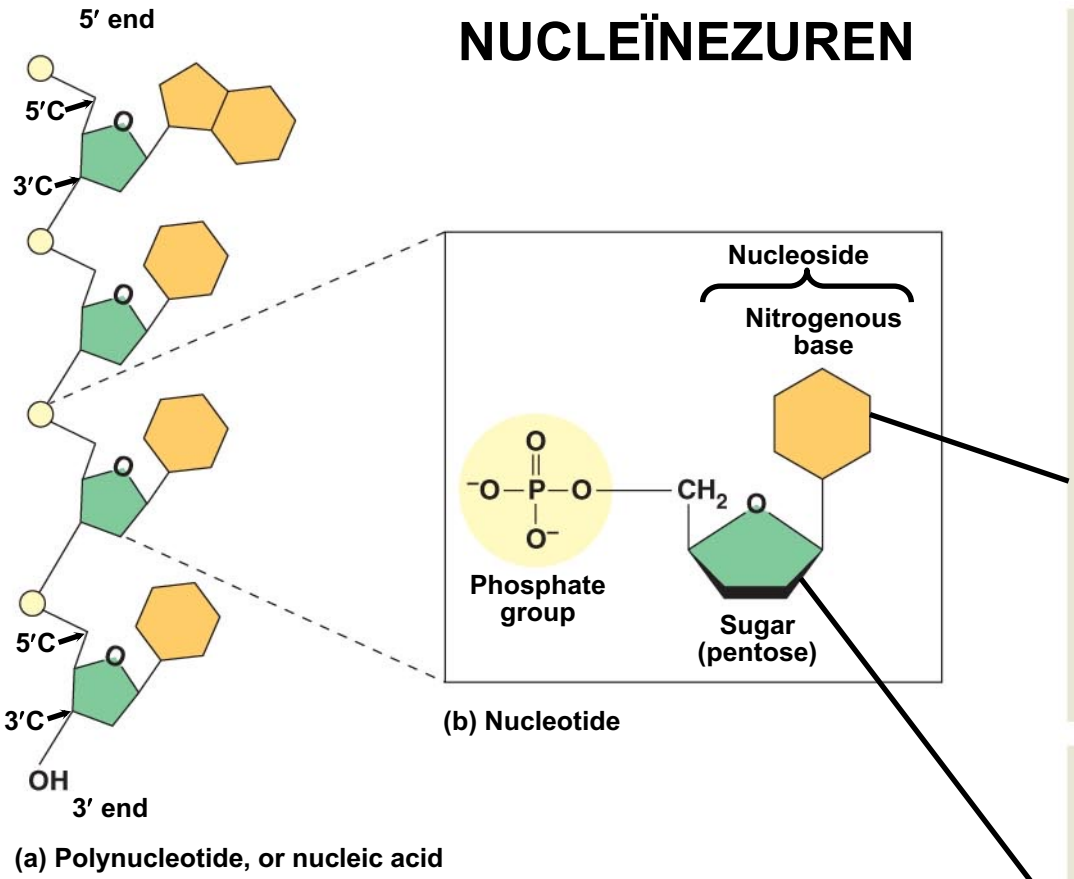
Biologische macromoleculen: essentiële functies in de cel

4 belangrijke groepen bio/macromoleculen

	Eiwitten, proteïnen	• Biologische activiteit: enzymen katalyseren chemische reacties; antilichamen; hormonen • Structurele rol: carriers, ion kanaal
	Polysachariden, Koolhydraten, Carbohydraten, Suikers	• Opslag (energiereserve): zetmeel/glycogeen • Structurele rol: cellulose, chitine
	Nucleïnezuren = DNA/RNA	• Informatiemoleculen: coderen, overdracht & expressie van genetisch materiaal
	Lipiden	• Energie reserve: triglyceriden • Structurele rol / bescherming: fosfolipiden in membraan

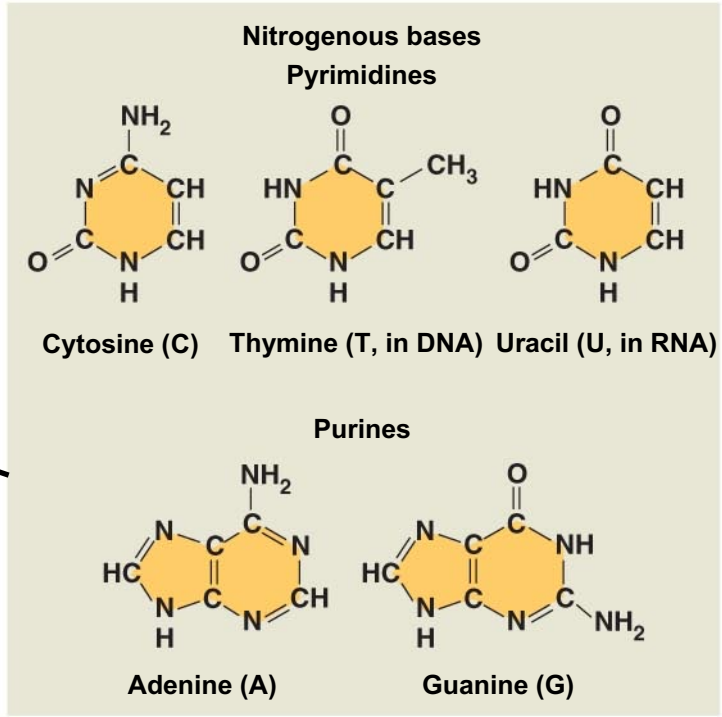
Biologische macromoleculen

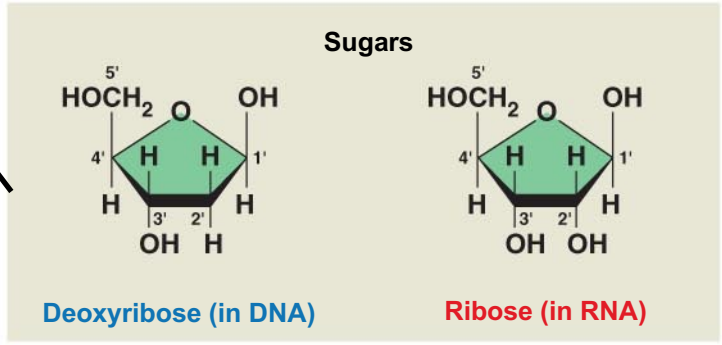
NUCLEÏNEZUREN



(a) Polynucleotide, or nucleic acid

(b) Nucleotide

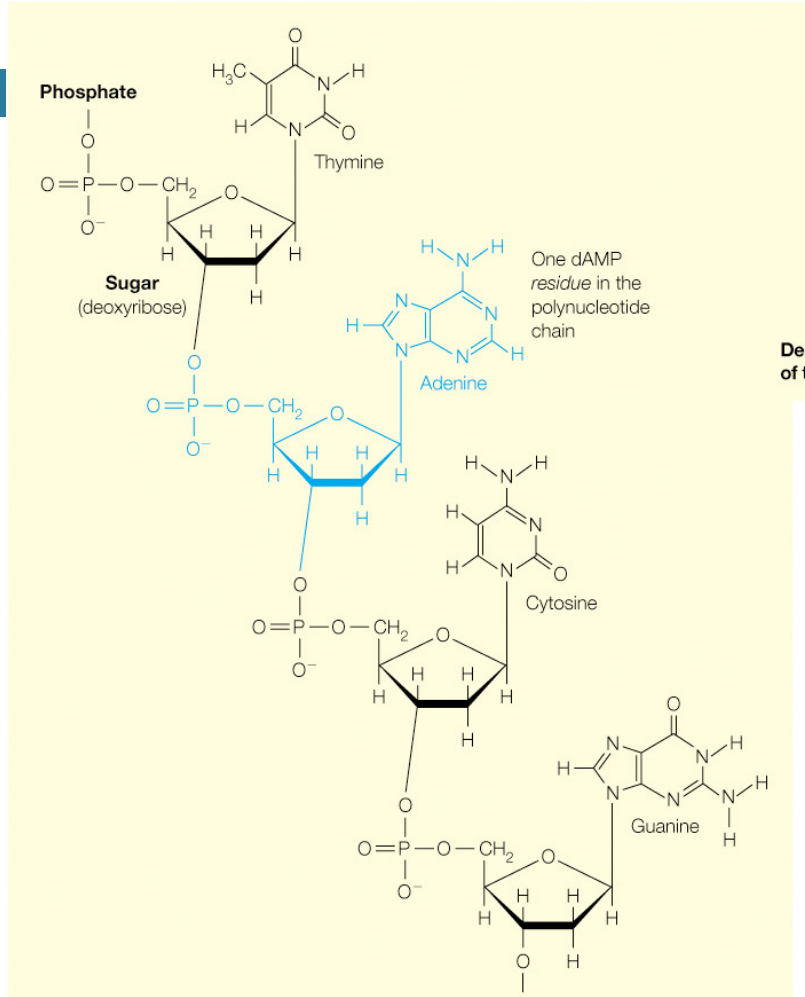




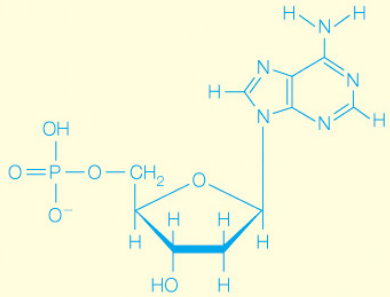
(c) Nucleoside components: sugars

Biologische macromoleculen

NUCLEÏNEZUREN



Part of deoxyribonucleic acid (DNA), a polynucleotide



Deoxyadenosine monophosphate (dAMP), one of the four kinds of monomers that make up DNA

(b) A nucleic acid. The nucleic acids, DNA and RNA, are polymers of nucleotides. Part of a DNA molecule is shown, along with one of its monomers, deoxyadenosine monophosphate.

CENTRAAL DOGMA VAN DE BIOCHEMIE

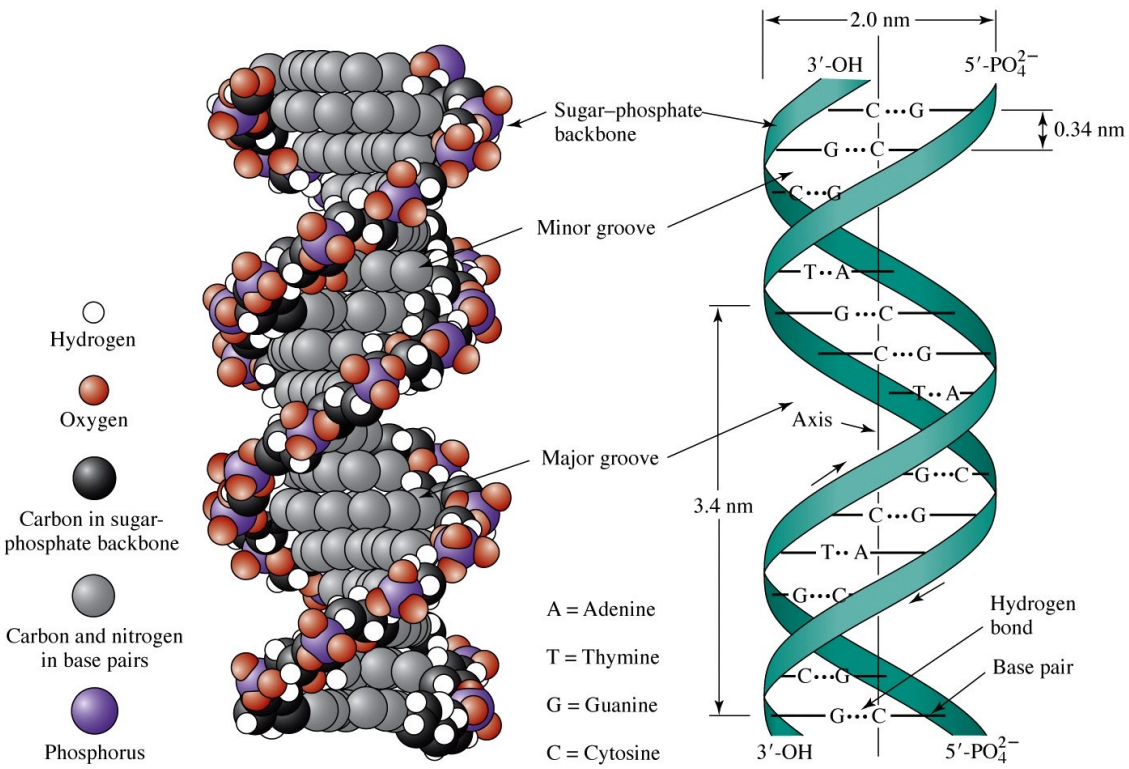
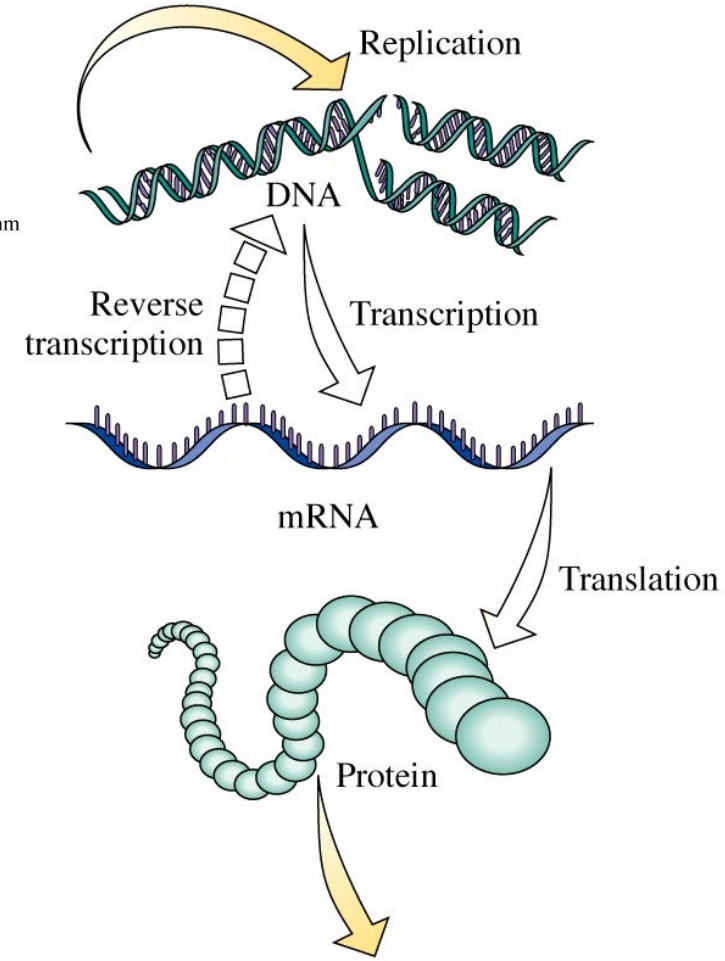


Figure 1-15 Concepts in Biochemistry, 3/e
© 2006 John Wiley & Sons

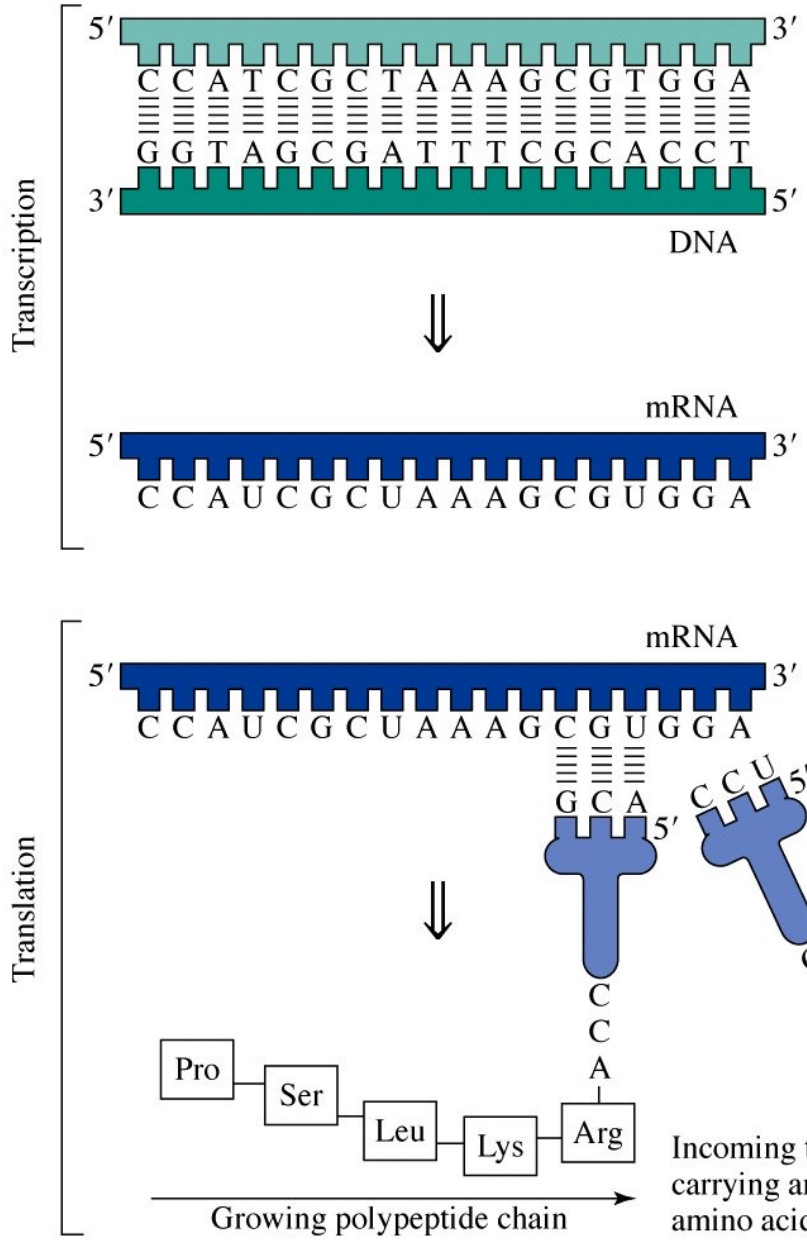
DNA: Watson & Crick



Cell structure and function
- Energy metabolism
- Synthesis and breakdown of biomolecules
- Storage and transport of biomolecules
- Muscle contraction
- Cellular communication (signal transduction)

Figure 1-14 Concepts in Biochemistry, 3/e
© 2006 John Wiley & Sons

CENTRAAL DOGMA VAN DE BIOCHEMIE

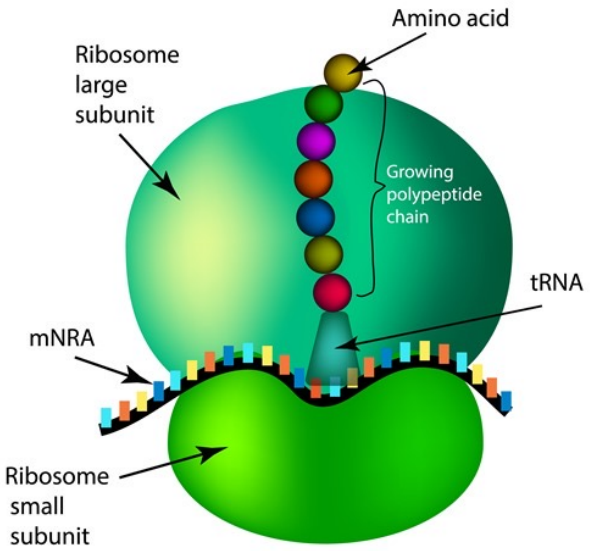


First Stage

Cytoplasma/celkern

Second Stage

Ribosomen

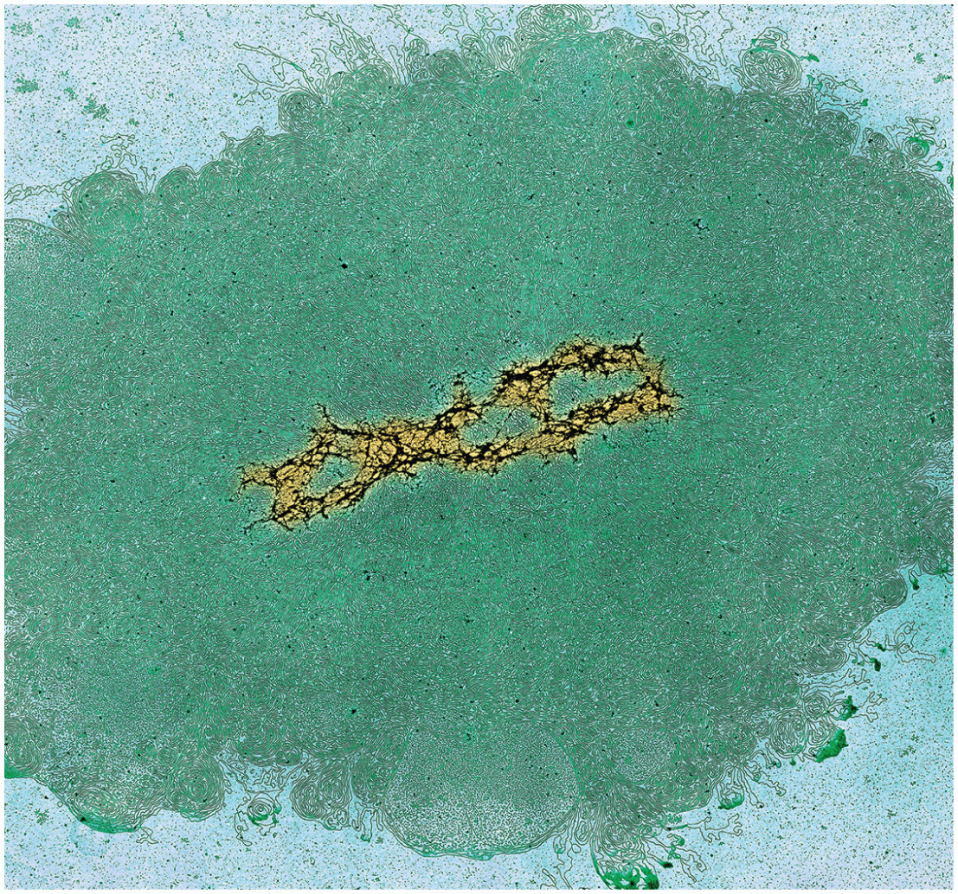


Final Stage

Figure 1-18 Concepts in Biochemistry, 3/e

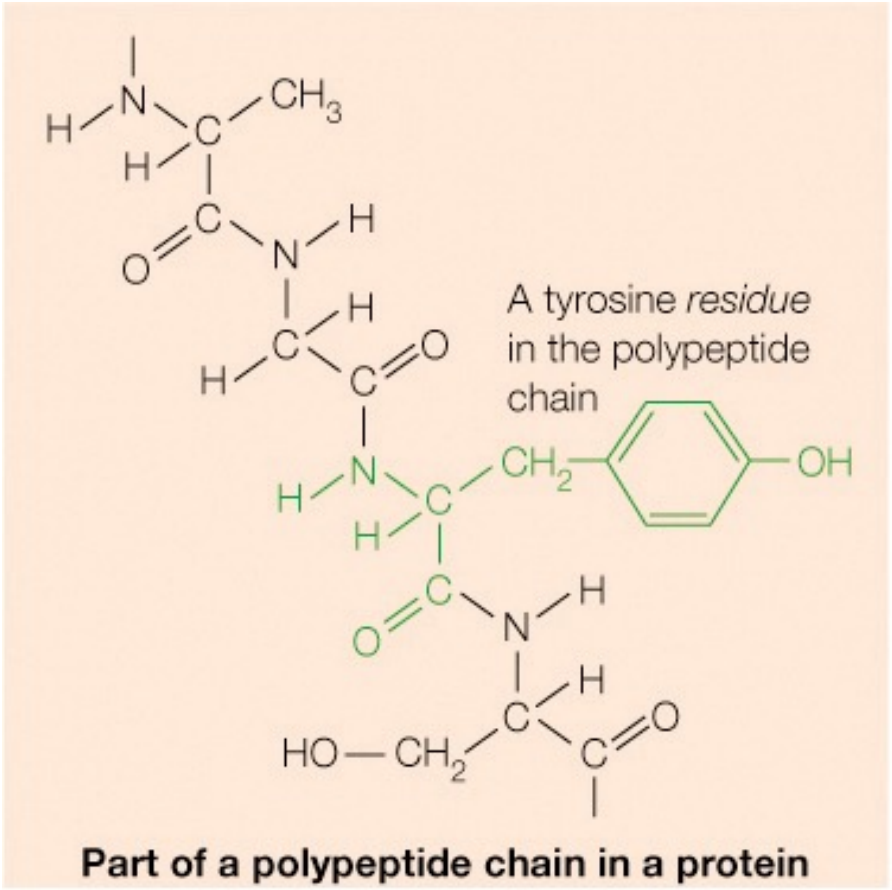
Nucleïnezuren

Een deel van het DNA van een enkel menselijk chromosoom:
moleculaire massa ongeveer 20 miljard Da

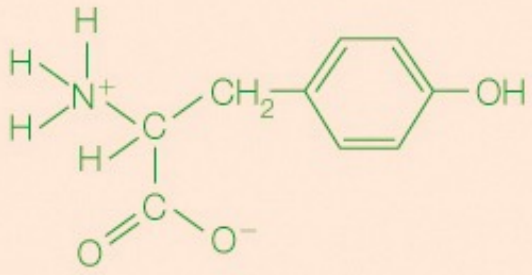


Biologische macromoleculen

PROTEÏNEN



Part of a polypeptide chain in a protein

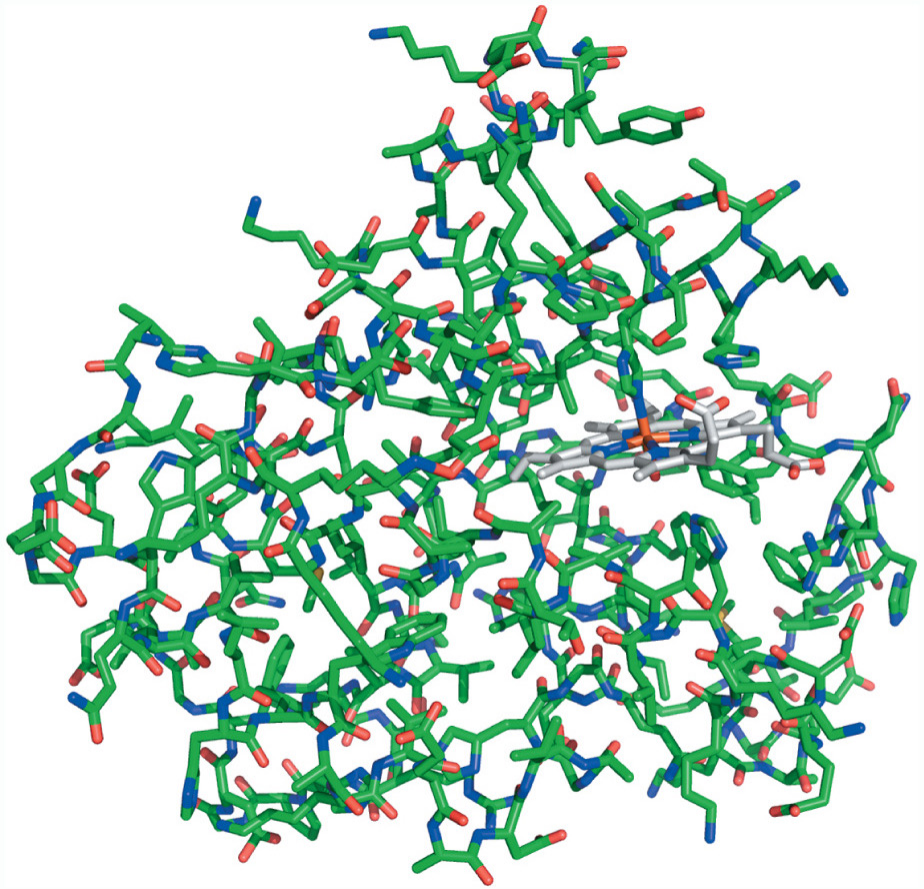


Tyrosine, one of the 20 kinds of monomers that make up polypeptides

(c) A polypeptide. Protein chains, or polypeptides, are polymers assembled from 20 different amino acids. Part of a polypeptide is shown, along with one of its monomers, tyrosine.

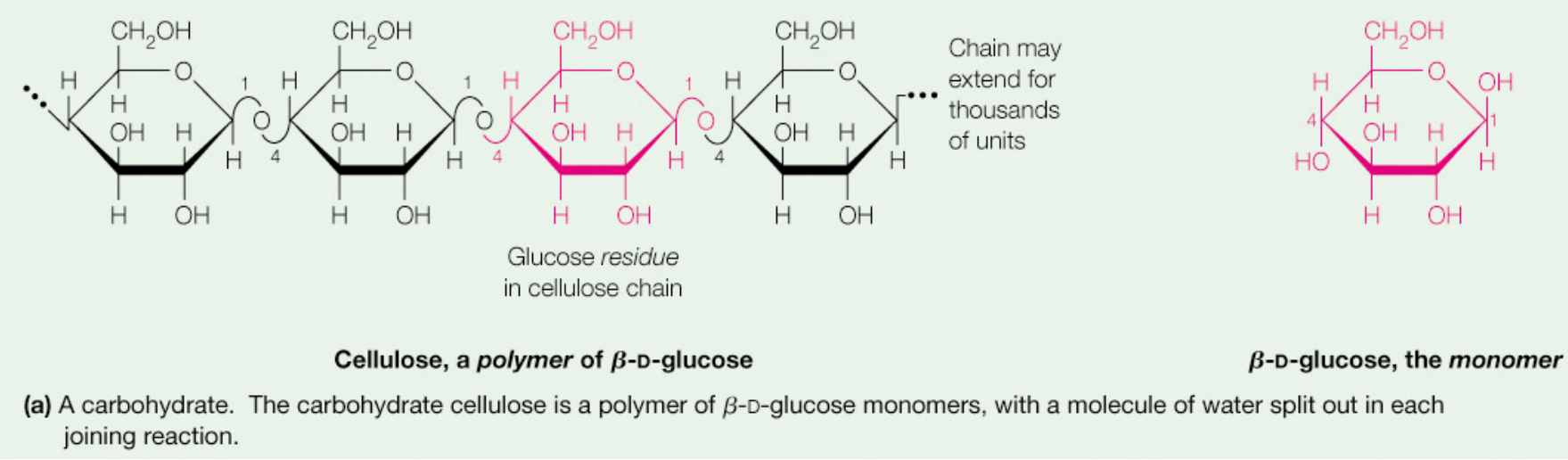
Proteïnen

Driedimensionale structuur van myoglobine, een zuurstof-dragend eiwit van spieren: moleculaire massa ongeveer 16000 Da



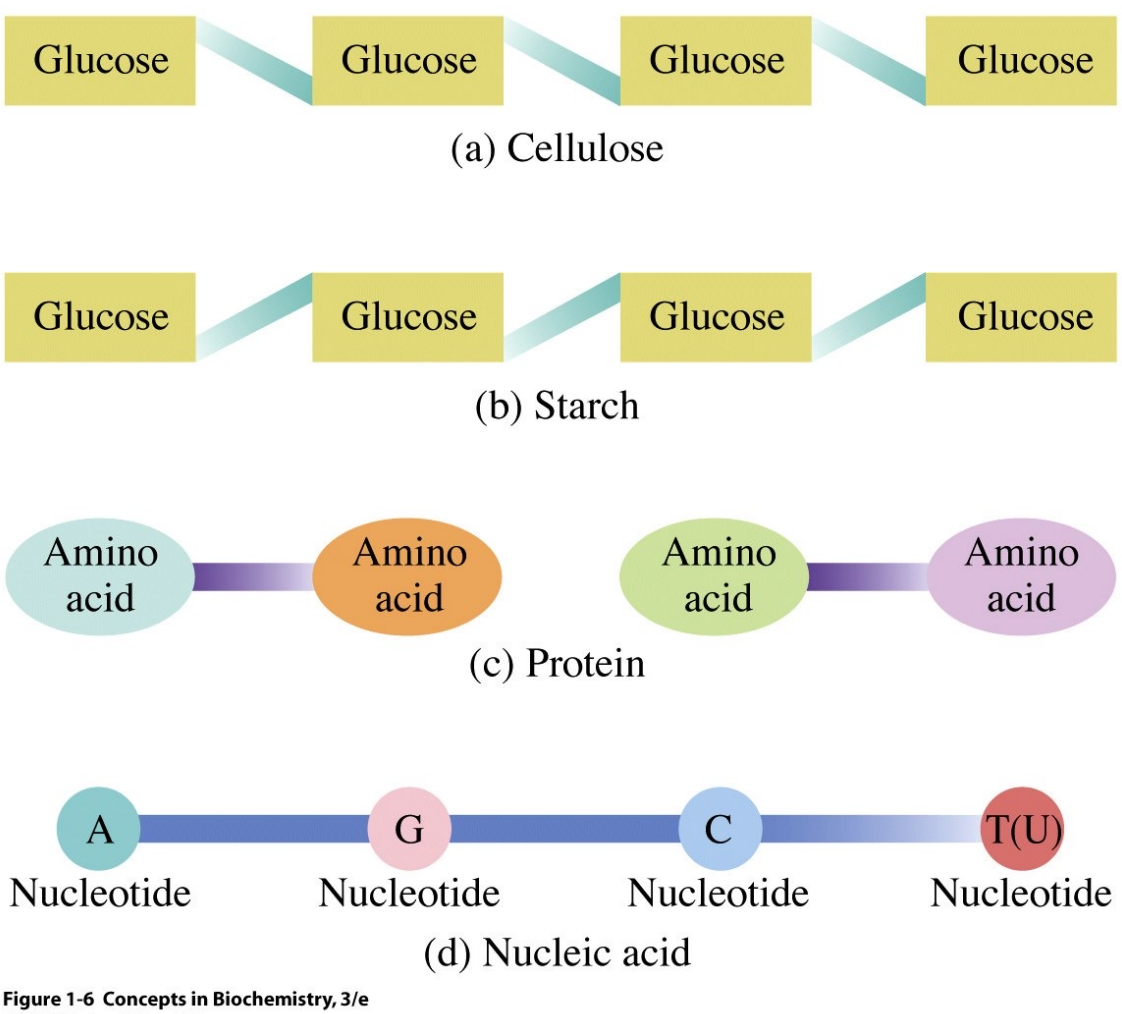
Biologische macromoleculen

POLYSACCHARIDEN



(a) A carbohydrate. The carbohydrate cellulose is a polymer of β-D-glucose monomers, with a molecule of water split out in each joining reaction.

Verschillende klassen polymeren



Homopolymeren

Heteropolymeren

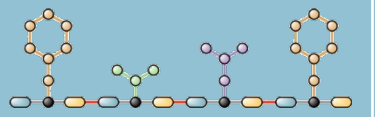
Figure 1-6 Concepts in Biochemistry, 3/e
© 2006 John Wiley & Sons

4 klassen macromoleculen: 3 polymeren

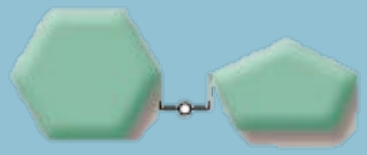
4 belangrijke groepen bio/macromoleculen

Biopolymeren (poly meros) = opgebouwd uit kleinere bouwstenen of monomeren (mono meros)

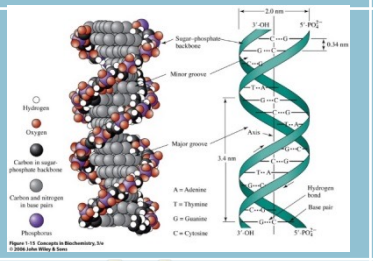
Worden niet beschouwd als polymeren



Eiwiten, proteïnen



Polysacchariden, Koolhydraten, Carbohydraten, Suikers

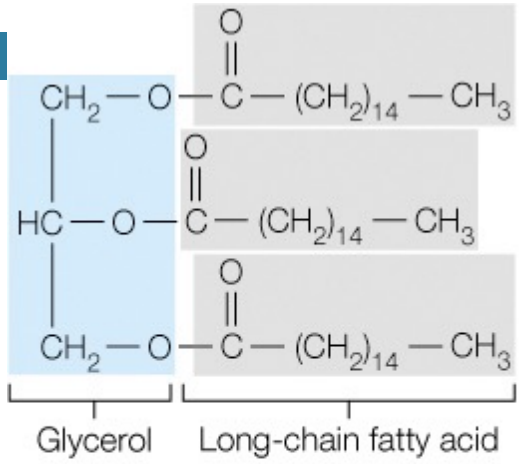


Nucleïnezuren = DNA/RNA

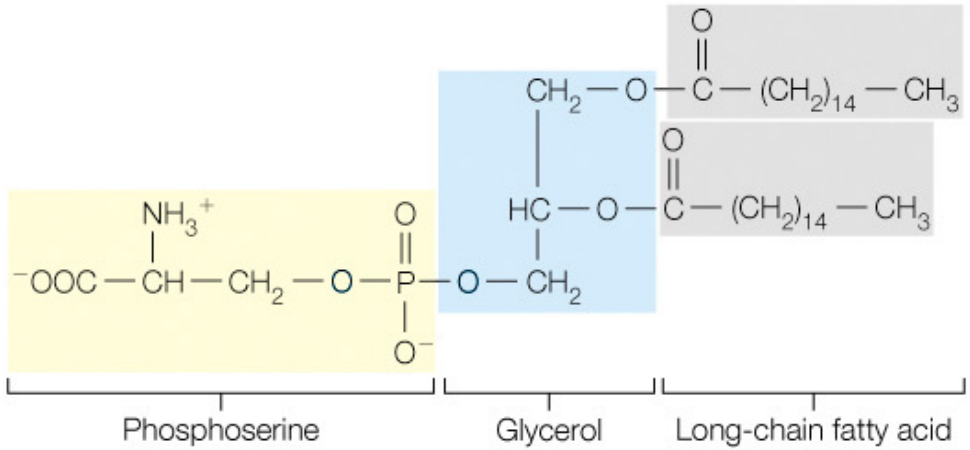
Lipiden

Biologische macromoleculen

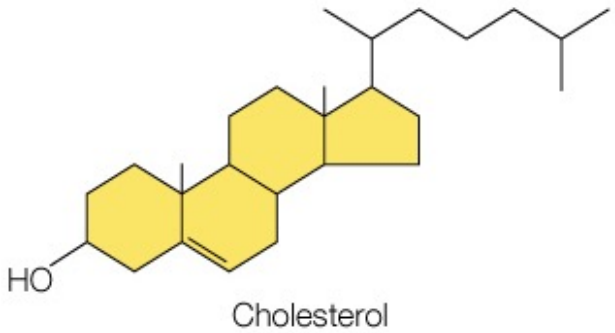
LIPIDEN



(a) A triacylglycerol. In this example, three molecules of a C_{16} saturated fatty acid, *palmitic acid*, are esterified with glycerol.



(b) A phospholipid *(phosphatidylserine)*

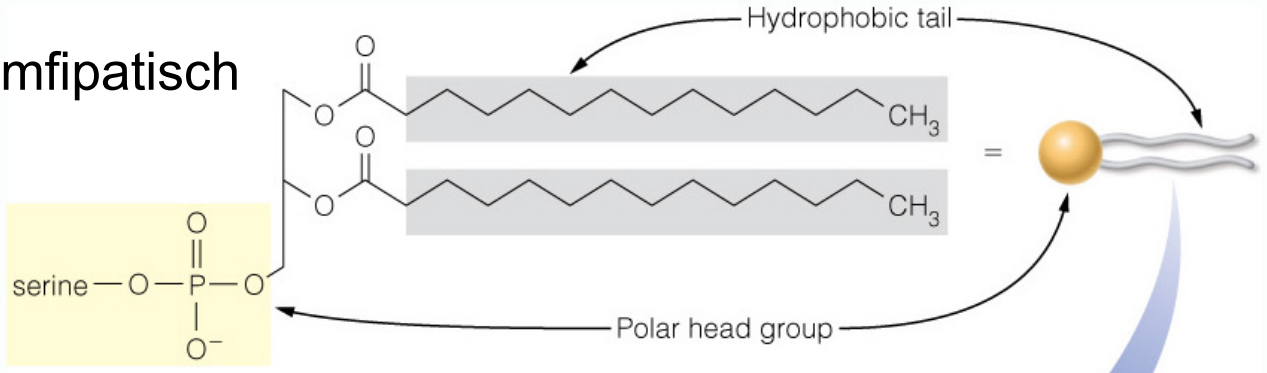


(c) *Cholesterol*, a sterol

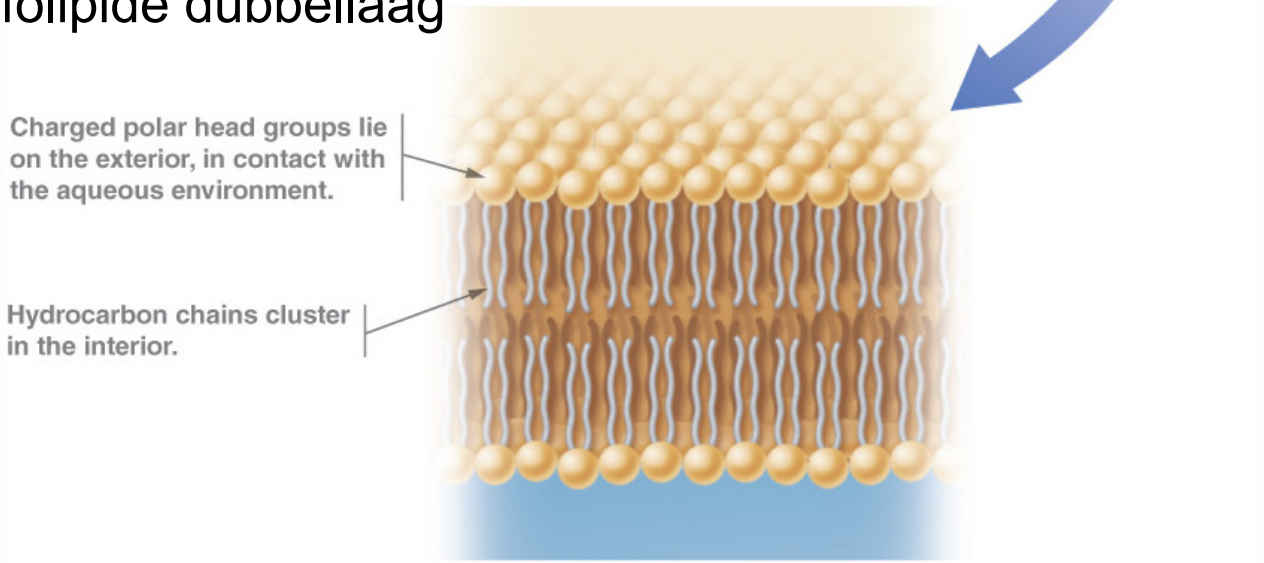
Lipiden en vorming cellulaire membranen

Fosfolipiden

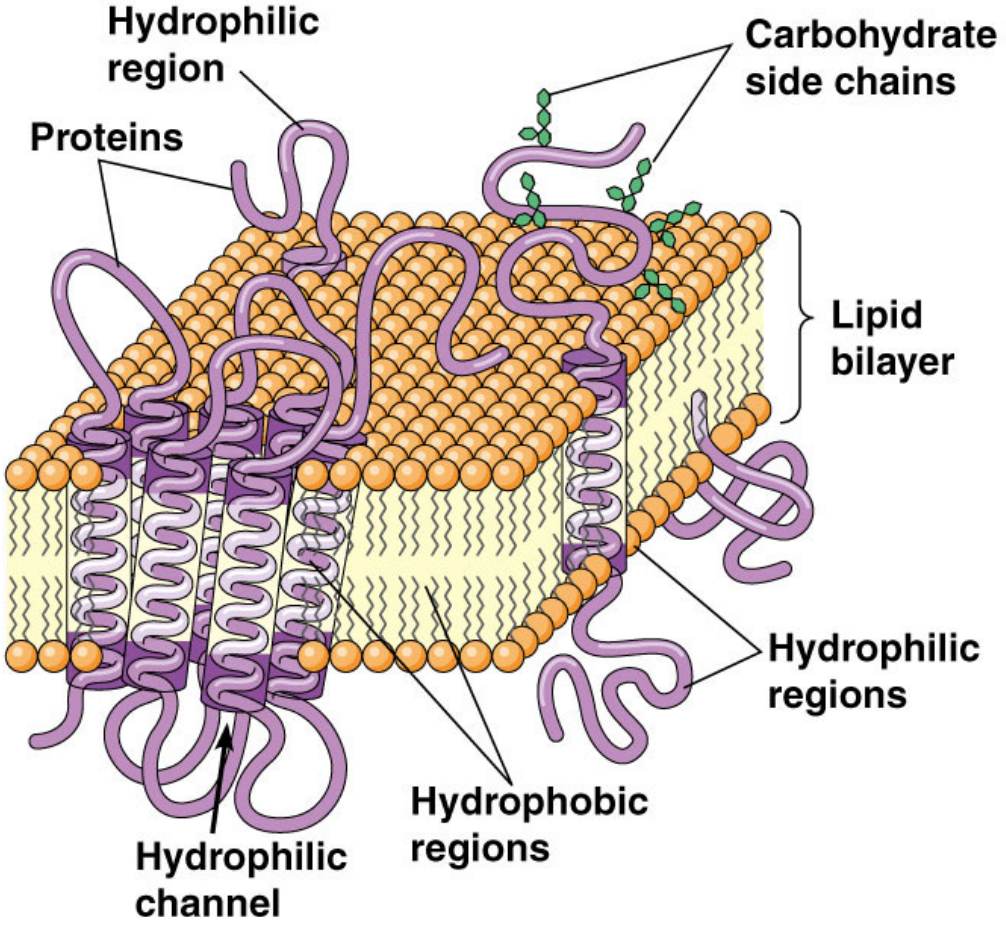
- Amfifiel of amfipatisch



- Vorming fosfolipide dubbellaag



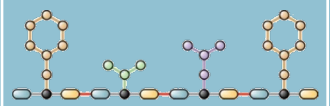
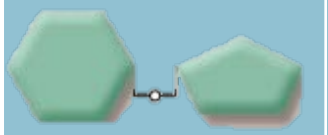
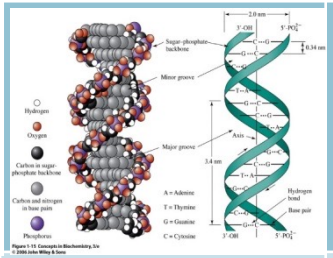
Lipiden en vorming cellulaire membranen



Model of a membrane as a lipid bilayer with proteins embedded in it

Macromoleculen opgebouwd uit kleinere bouwstenen

4 belangrijke groepen bio/macromoleculen

Biopolymeren		Bouwstenen	Monomeren
	Eiwiten, proteïnen		Aminozuren
	Polysacchariden, Koolhydraten, Carbohydraten, Suikers		Monosacchariden
	Nucleïnezuren = DNA/RNA		Nucleotide
	Lipiden		Vetzuren (in het geval van triglyceriden en fosfolipiden)

Biopolymeren

Een vrij beperkt aantal bouwstenen worden op diverse wijze gecombineerd waardoor een grote variatie aan grotere structuren kan worden geproduceerd

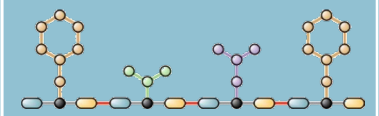
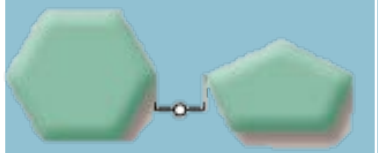
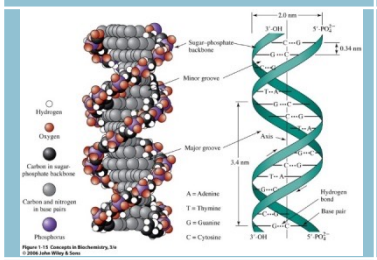
Voordelen:

1. Beperkte hoeveelheid aan ‘ruwe materialen’ nodig om te overleven

2. ‘Informatie’ zit vervat in de volgorde van de bouwstenen in een keten

Biomoleculen zeer divers in tegenstelling tot bouwstenen

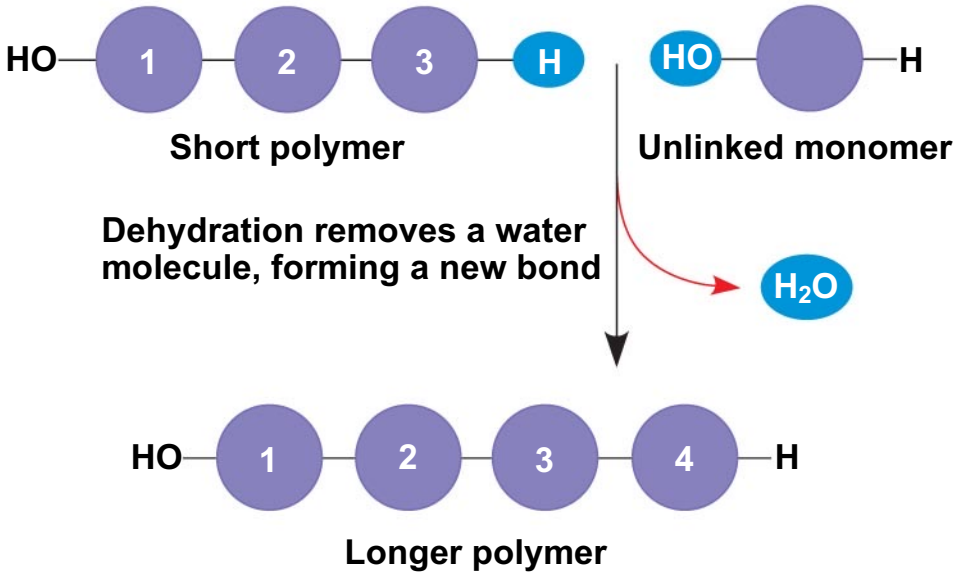
4 belangrijke groepen bio/macromoleculen

	**ZEER DIVERS**	>	**Bouwstenen**	**RELATIEF EENVOUDIG**
	Eiwiten, proteïnen			Aminozuren – **20**
	Polysacchariden, Koolhydraten, Carbohydraten, Suikers			Monosacchariden
	Nucleïnezuren = DNA/RNA			Nucleotide – **5**
	Lipiden			Bv. **3** voor fosfolipiden (bv. palmitinezuur $C_{16}H_{32}O_2$), glycerol en serine)

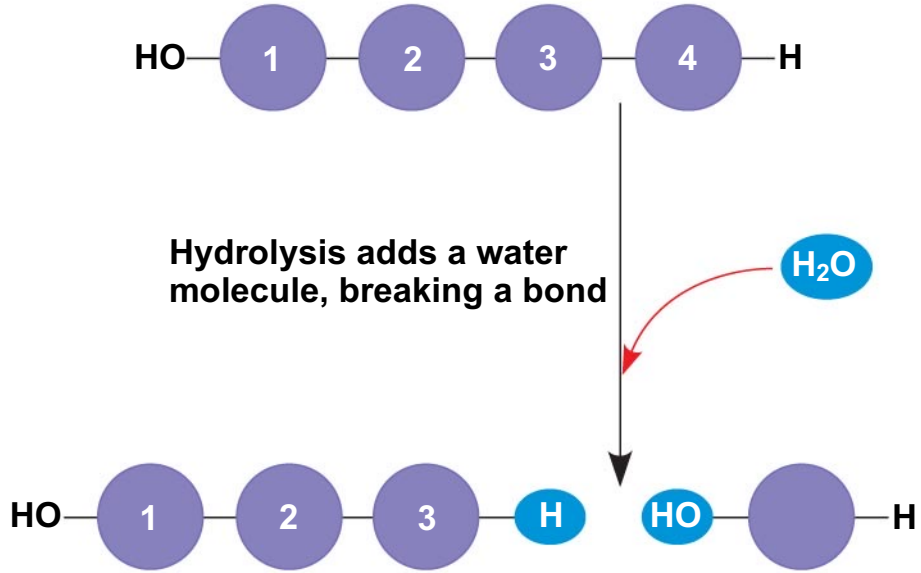
Synthese en hydrolyse biopolymeren

Chemische reacties voor synthese (= aanmaak) en hydrolyse (= afbraak) van biopolymeren:

- Een **condensatiereactie** of specifieker een **dehydratatiereactie** treedt op bij het aan elkaar hechten van twee monomeren door het verlies van een watermolecuul
- **Enzymen** zijn macromoleculen (eiwitten) die de snelheid van de dehydratatie versnellen
- Biopolymeren worden afgebroken tot monomeren door **hydrolyse** wat in wezen het omgekeerde is van de dehydratatiereactie

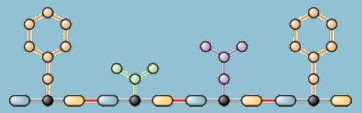
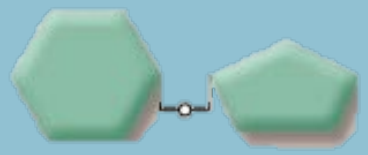
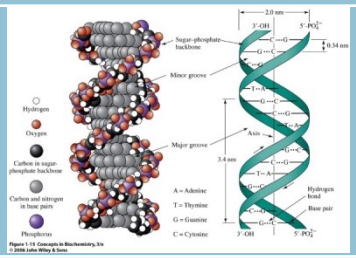


(a) Dehydration reaction in the synthesis of a polymer



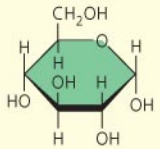
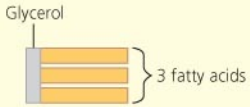
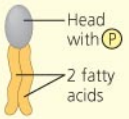
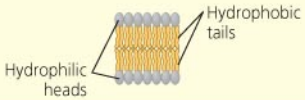
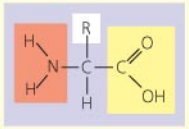
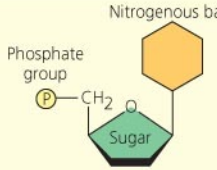
(b) Hydrolysis of a polymer

Bouwstenen worden via covalente bindingen gecombineerd tot biomoleculen

	Eiwiten, proteïnen	Peptide = amide	Aminozuren
	Polysacchariden, Koolhydraten, Carbohydraten, Suikers	Glycoside = ether	Monosaccharide
	Nucleïnezuren = DNA/RNA	Fosfodiester	Nucleotide
	Lipiden (Bv. triglyceriden)	Ester	Vetzuren

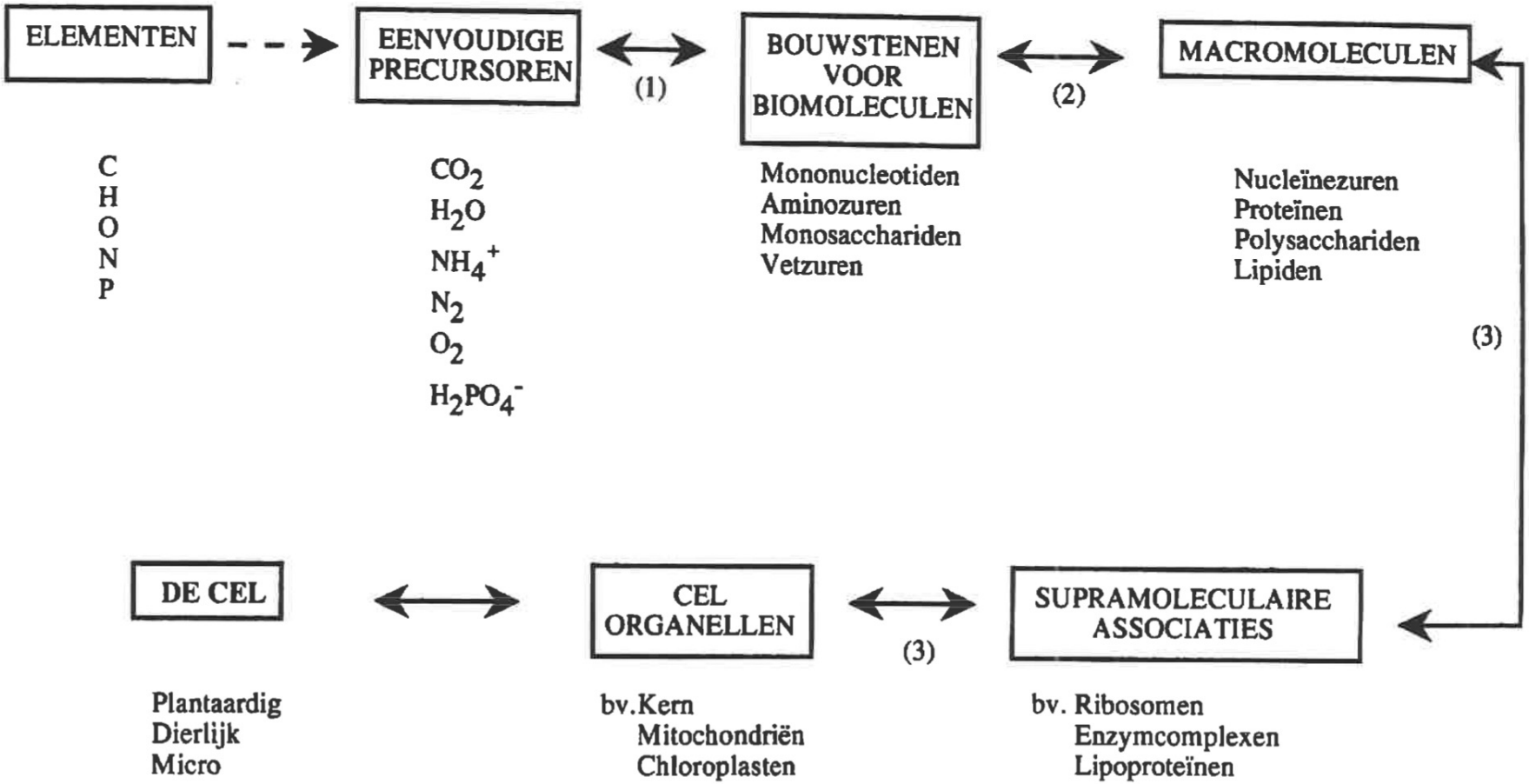
Samenvatting

MACRO-MOLECULAIRE BIO-MOLECULEN

Large Biological Molecules	Components	Examples	Functions
Concept 5.2 **Carbohydrates** serve as fuel and building material	 Monosaccharide monomer	Monosaccharides: glucose, fructose	Fuel; carbon sources that can be converted to other molecules or combined into polymers
		Disaccharides: lactose, sucrose	
		Polysaccharides: • Cellulose (plants) • Starch (plants) • Glycogen (animals) • Chitin (animals and fungi)	• Strengthens plant cell walls • Stores glucose for energy • Stores glucose for energy • Strengthens exoskeletons and fungal cell walls
Concept 5.3 **Lipids** are a diverse group of hydrophobic molecules and are not ~~macromolecules~~ polymers	 	Triacylglycerols (fats or oils): glycerol + 3 fatty acids	Important energy source 
	 	Phospholipids: phosphate group + 2 fatty acids	Lipid bilayers of membranes 
	 Steroid backbone	Steroids: four fused rings with attached chemical groups	• Component of cell membranes (cholesterol) • Signals that travel through the body (hormones)
Concept 5.4 **Proteins** have many structures, resulting in a wide range of functions	 Amino acid monomer (20 types)	• Enzymes • Structural proteins • Storage proteins • Transport proteins • Hormones • Receptor proteins • Motor proteins • Defensive proteins	• Catalyze chemical reactions • Provide structural support • Store amino acids • Transport substances • Coordinate organismal responses • Receive signals from outside cell • Function in cell movement • Protect against disease
Concept 5.5 Nucleic acids store and transmit hereditary information	 Nucleotide monomer	DNA: • Sugar = deoxyribose • Nitrogenous bases = C, G, A, T • Usually double-stranded	Stores all hereditary information
		RNA: • Sugar = ribose • Nitrogenous bases = C, G, A, U • Usually single-stranded	Carries protein-coding instructions from DNA to protein-synthesizing machinery

1.3 De Cel als Eenheid van Biologische Organisatie

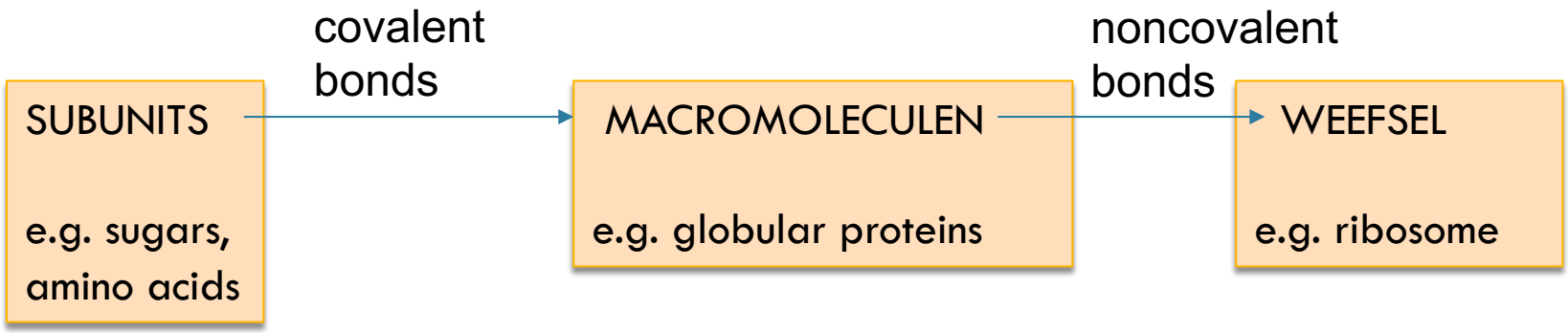
CHEMISCHE OPBOUW VAN CELMATERIAAL



(1) ingewikkelde metabolische processen
(2) snelle, geordende, specifieke reacties
(3) o.a. niet-covalente interacties spelen een belangrijke rol

Cellulaire hiërarchie

Macromoleculen vormen samen grotere, meer complexe structuren:



Niet-covalente 'zwakke' bindingen:
H-bruggen, hydrofobe interacties,
Van der Waals krachten

Precursoren uit de omgeving (CO_2, H_2O, N_2, . . .)

↓

Eigen laag moleculaire massa precursoren (zie boven)

↓

Monomeren (aminozuren, nucleotiden, suikers)

covalente bindingen →

↓

Macromoleculen (eiwitten, nucleïnezuren, polysacchariden, vetten)

niet-covalente bindingen →

↓

Supramoleculaire structuren (multi-enzym complexen, ribosomen, chromosomen, membranen, structuurelementen zoals celwand, . .)

↓

Organellen (kern, mitochondriën, chloroplasten, . .)

↓

Cellen → **micro-organisme**

↓

Weefsel

↓

Organen

↓

Stelsel

↓

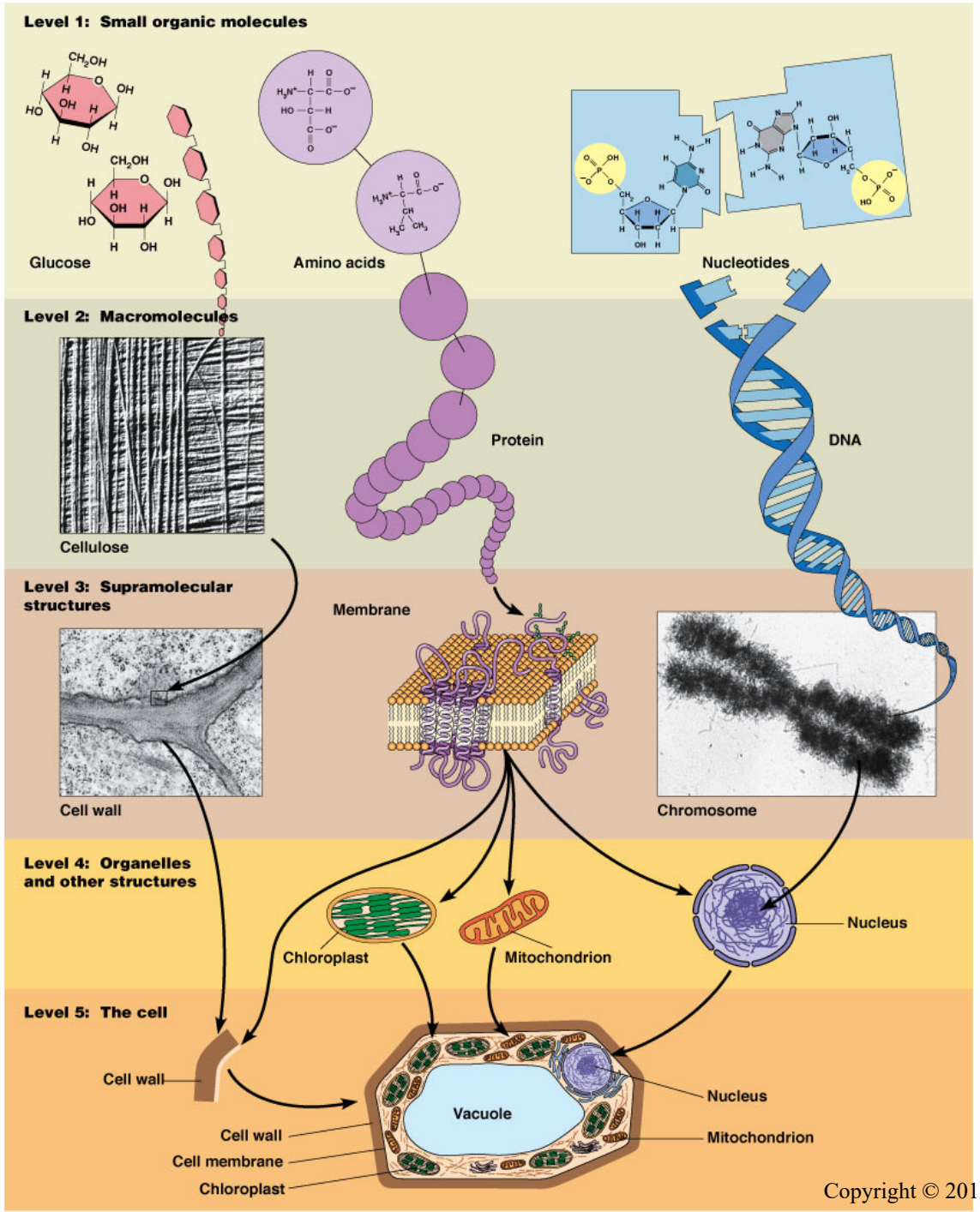
Organismen

Macromoleculen zijn overvloedig aanwezig in cellen

Chemische samenstelling van een bacteriële cel (samenstelling van een dierlijke cel is vergelijkbaar)

	Percent of Total Cell Weight	Types of Each Molecule
Water	70	1
Inorganic Ions	1	20
Sugars and precursors	1	250
Amino acids and precursors	0.4	100
Nucleotides and precursors	0.4	100
Fatty acids and precursors	1	50
Other small molecules	0.2	~300
Macromolecules (proteins, nucleic acids, and polysaccharides)	26	~3000

Cellulaire hiërarchie

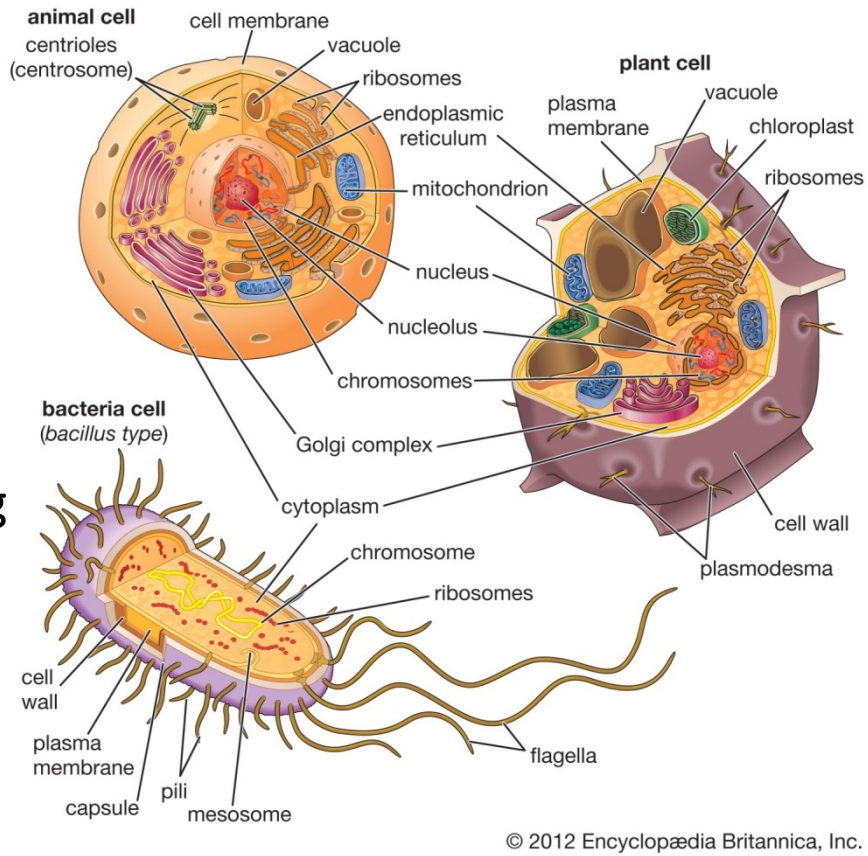


Biochemie als biologische wetenschap

Basiseenheid van alle leven = cel

Eukaryoten: eencellig (protista) of meercellig (dieren, planten, sommige schimm

Prokaryoten: eencellig



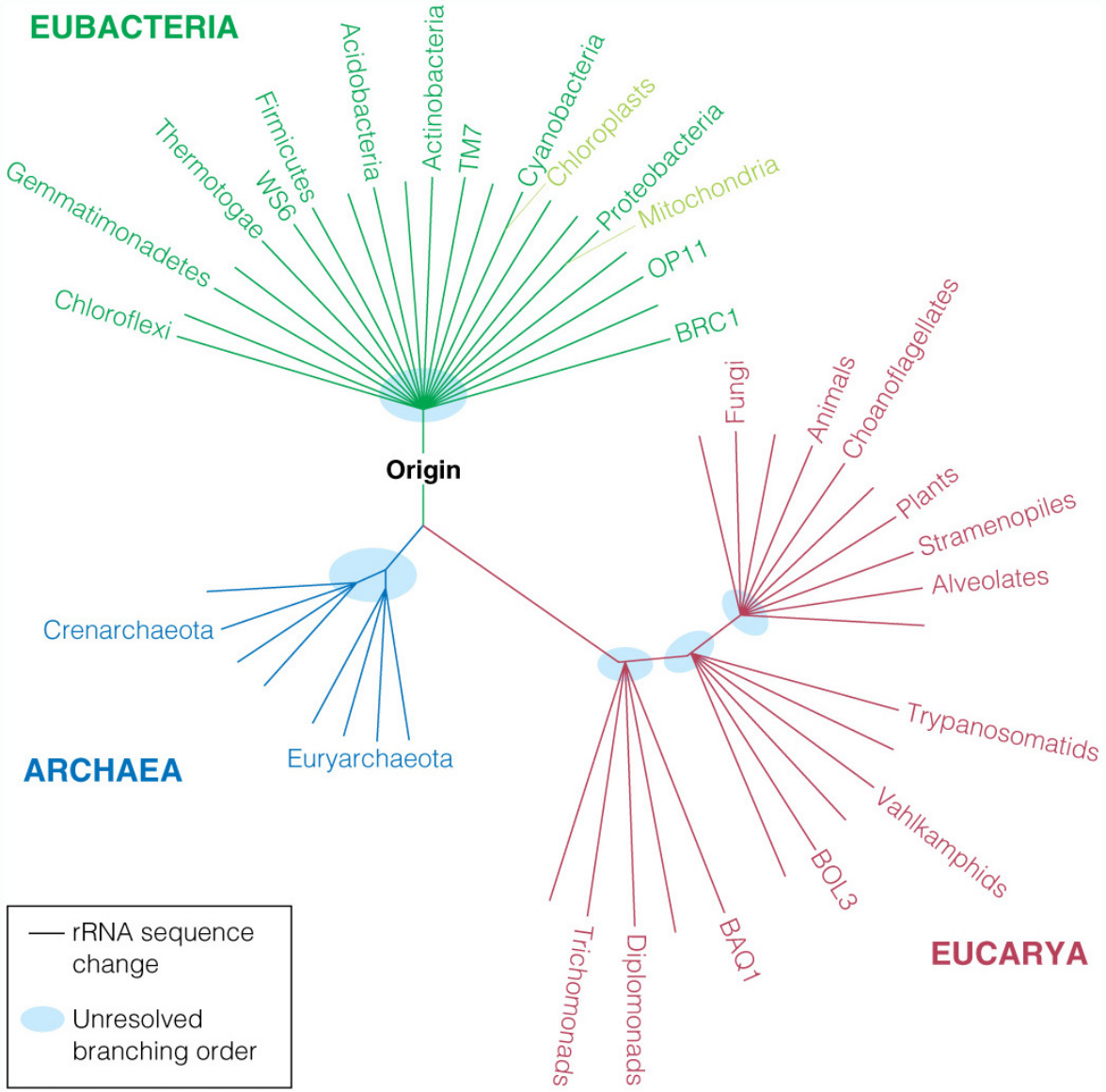
Biochemie als biologische wetenschap

Grote verschillen tussen celstructuren definiëren drie grote klassen van organismen: bacteriën, archaea en eukaryoten

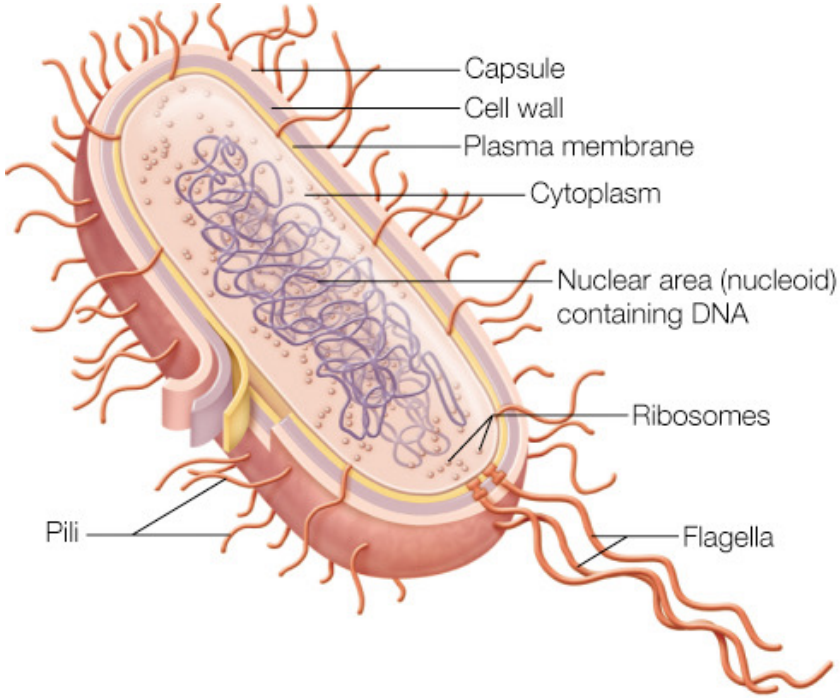
Eubacteria = true bacteria, always unicellular

Archaea = ancient group of organisms, always unicellular

Eukaryotes: uni- or multicellular



De eenheid van biologische organisatie: de prokaryote cel



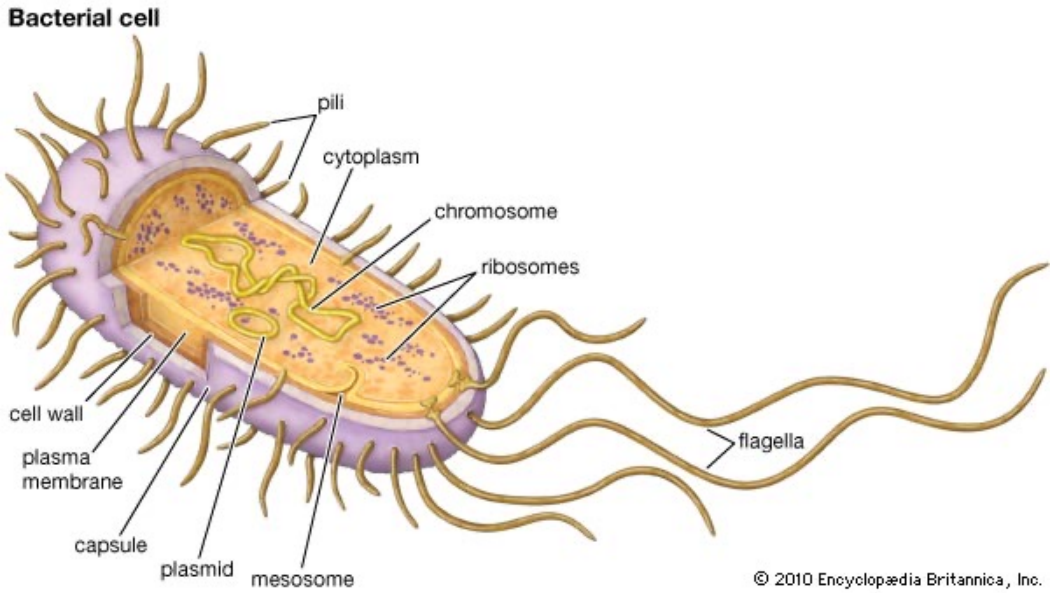
(a) Schematic view of a representative bacterial cell. The DNA molecule that constitutes most of the genetic material is coiled up in a region called the nucleoid, which shares the fluid interior of the cell (the cytoplasm) with ribosomes (which synthesize proteins), other particles, and a large variety of dissolved molecules. The cell is bounded by a plasma membrane, outside of which is usually a fairly rigid cell wall. Many bacteria also have a gelatinous outer capsule. Projecting from the surface may be pili, which attach the cell to other cells or surfaces, and one or more flagellae, which enable the cell to swim through a liquid environment.

(b) Scanning electron micrograph of *Salmonella*: rod-shaped Gram-negative enterobacteria that causes typhoid fever, paratyphoid fever, and food-borne illness.

Molecular composition and biological function of prokaryotic cell components

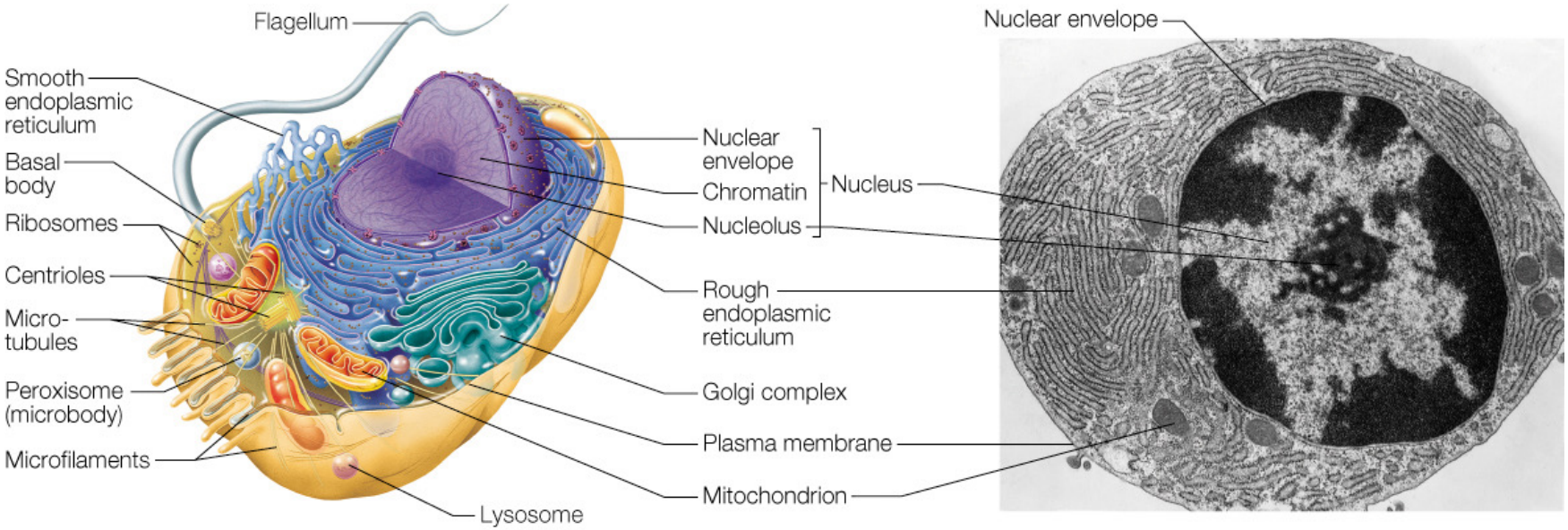
Structural Feature	Molecular Composition	Biological Function
Cell wall, pili, and flagella	Polysaccharide chains cross-linked by proteins; coated with lipopolysaccharide; pili and flagella are extensions of the cell wall	Protection against mechanical and hypertonic stress; flagella assist in movement; pili assist in sexual conjugation
Cell membrane, mesosome	Bilayer of 40% lipid, 60% protein, perhaps some carbohydrate; mesosome is infolded membrane	Permeable boundary that allows for entry and exit of nutrients, waste; mesosome may play role in DNA replication
Nucleoid region	Contains chromatin, a complex of chromosomal DNA and histone proteins	The genome; storage of genetic information; site of DNA replication
Ribosomes	Complexes of RNA (65%) and protein (35%)	Sites of protein synthesis
Vacuoles	Nutrients stored as small molecules or polymers	Storage of fuel molecules for energy metabolism
Cytoplasm	Small molecules, soluble proteins, enzymes, nutrients, inorganic salts; dissolved in aqueous solution	Region where many metabolic reactions occur

Table 1-1 Concepts in Biochemistry, 3/e



De eenheid van biologische organisatie: de eukaryote cel

Eukaryotische dierlijke cel

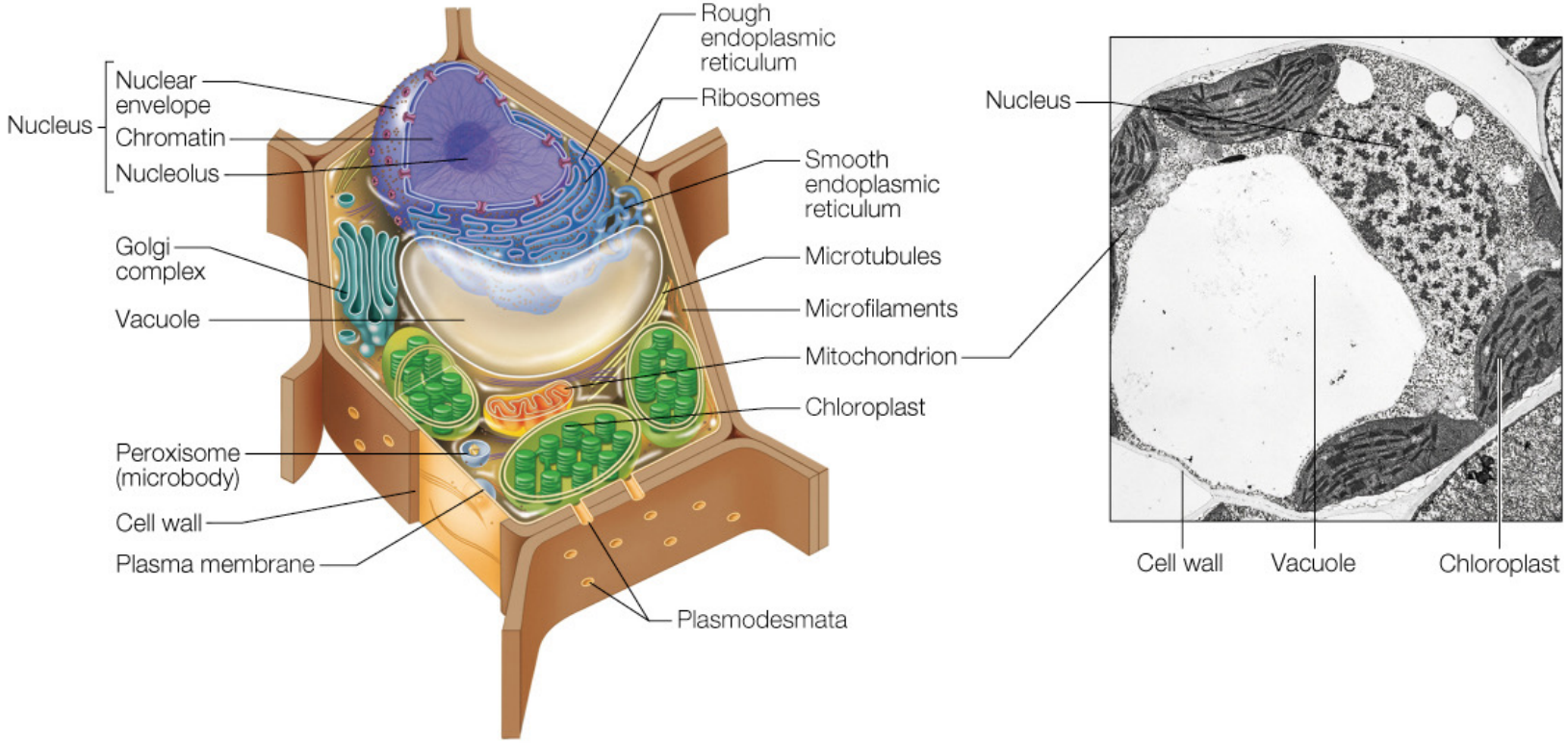


(a) Typical animal cell. The accompanying photograph is an electron micrograph of a representative animal cell, a white blood cell.

Eukaryotische cellen hebben door membranen omgeven structuren (organellen) binnen de cellulaire grens

De eenheid van biologische organisatie: de eukaryote cel

Eukaryotische plantencel

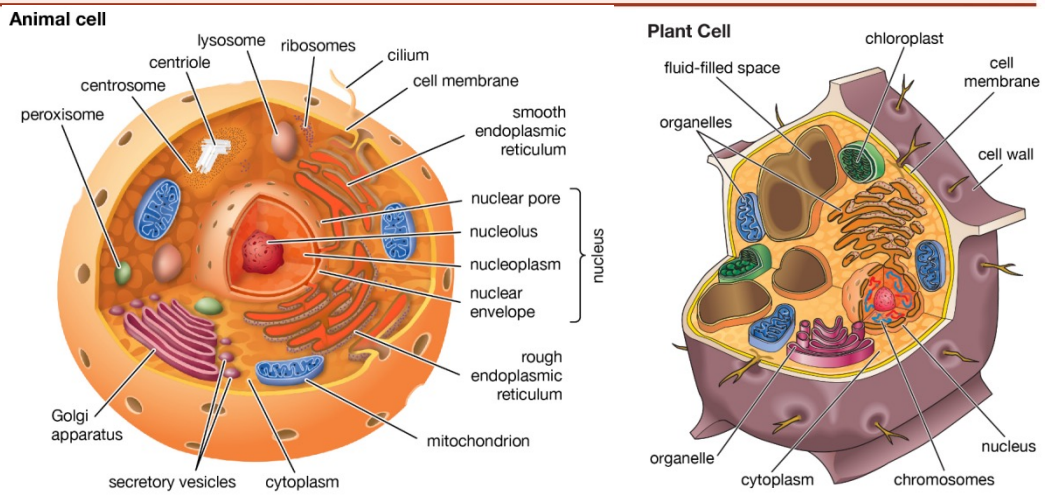


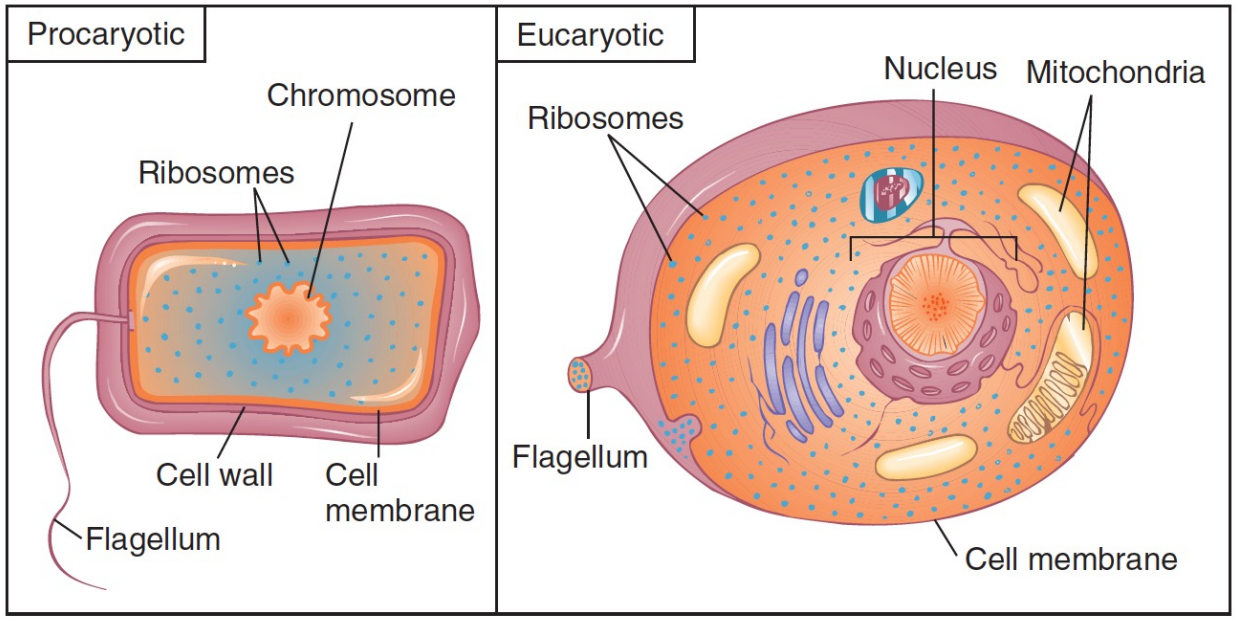
(b) Typical plant cell. The accompanying photograph is an electron micrograph of a representative plant cell, Timothy-grass (*Phleum pratense*).

Eukaryotic organelles, their constituent biomolecules, and biological function

Structural Feature	Molecular Composition	Biological Function
Cell membrane	Bilayer of proteins (50%) and lipids (50%) and some carbohydrate	Selectively permeable boundary for entry and exit of nutrients and waste; some important enzyme activities; location of receptors for signaling
Nucleus	Contains genomic DNA, and histone proteins as chromatin; RNA	Storage of genetic information; site of DNA replication and transcription to RNA
Endoplasmic reticulum with ribosomes	Flat, single-membraned vesicles of lipid and protein; ribosomes consist of RNA and proteins	Surfaces on which ribosomes bind for protein synthesis
Golgi apparatus	Flattened vesicles of lipid, protein, and polysaccharide	Secretion of cell waste products; site of protein processing
Mitochondria	Double-membraned with protein and lipids; interior (matrix) contains soluble and insoluble enzymes, RNA, and DNA	Site of energy metabolism and synthesis of high-energy ATP
Lysosomes (animal)	Single-membraned vesicles containing enzymes for hydrolysis	Metabolism of materials ingested by endocytosis
Peroxisomes (animal) or glyoxysomes (plant)	Single-membraned vesicles containing catalase and other oxidative enzymes	Oxidative metabolism of nutrients using O_2 to generate H_2O_2
Chloroplasts (plant)	Double-membraned organelles containing protein, lipid, chlorophyll, RNA, DNA, and ribosomes	Sites of photosynthesis; convert light energy into chemical energy (ATP)
Cytoplasm	Cytoskeleton made of proteins; small molecules, soluble proteins, enzymes, nutrients, and salts in aqueous solution	Provides shape to cell; region where many metabolic reactions occur

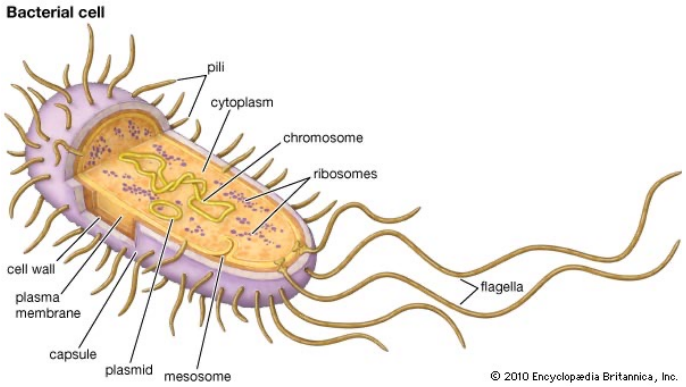
Table 1-2 Concepts in Biochemistry, 3/e

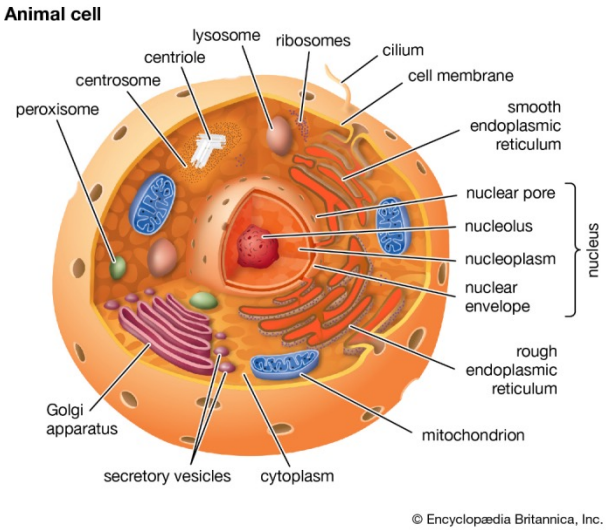


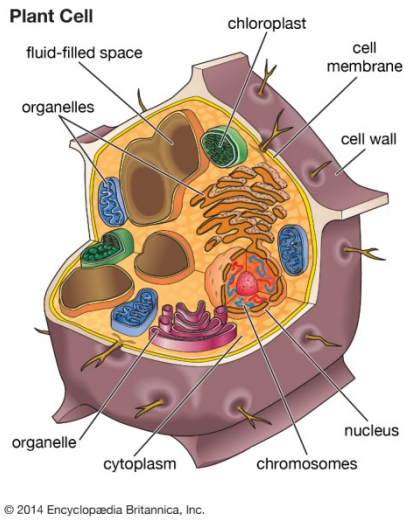


Microbial cells are of the small, relatively simple procaryotic variety (left) or the larger, more complex eucaryotic type (right).

Prokaryote cel	Eukaryote cel
1-10 µm	5-100 µm
Nucleoid, geen kernmembraan => 'Pro karyos'	Nucleus (celkern) met kernmembraan
Geen organellen (door membranen omgeven)	Mitochondriën, chloroplast, ER, Golgi, lysosoom
Geen cytoskelet	Microtubuli, contractiele systemen
Circulair chromosoom & plasmiden	Lineaire chromosomen
Eenvoudige deling	Mitose (somatische cel) /meiose (gameten)

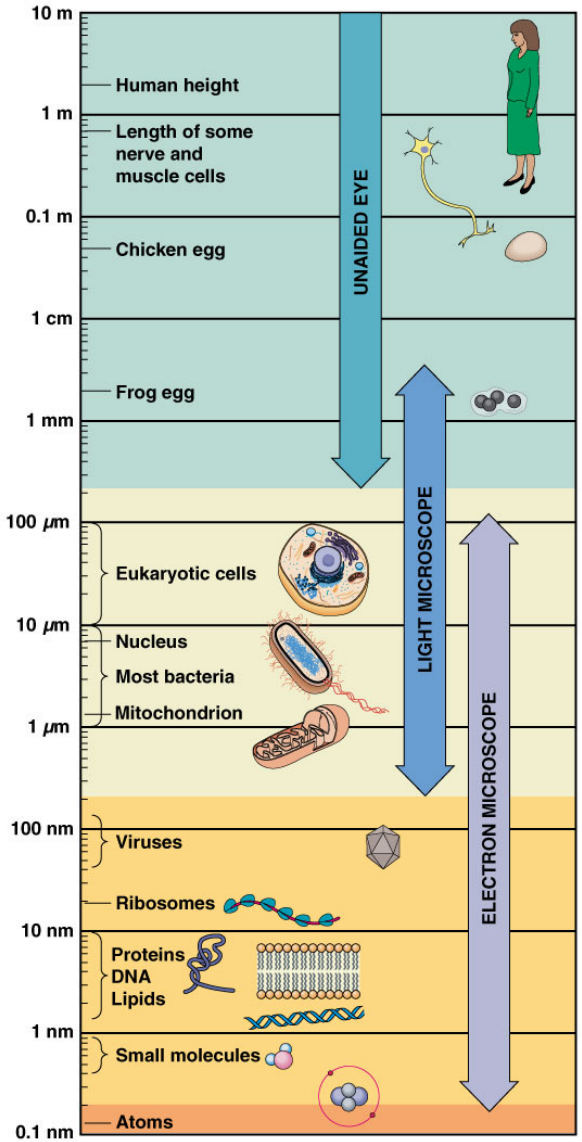


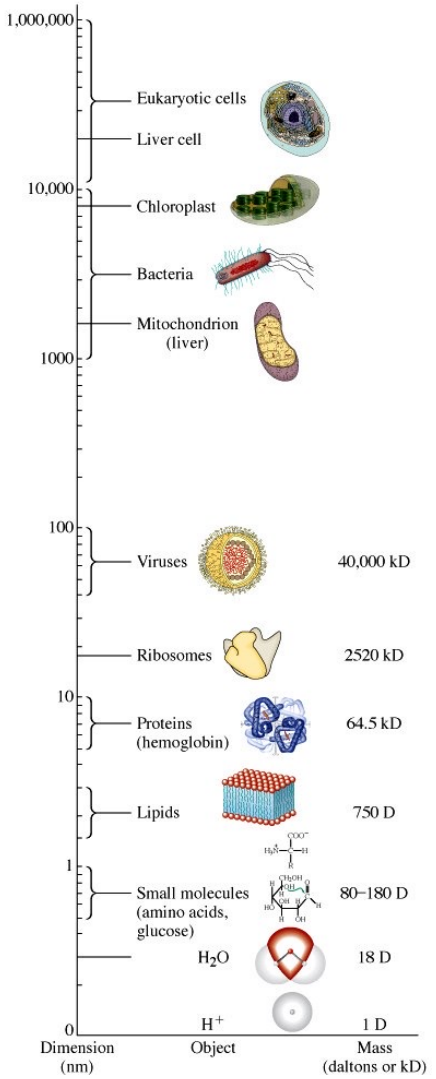




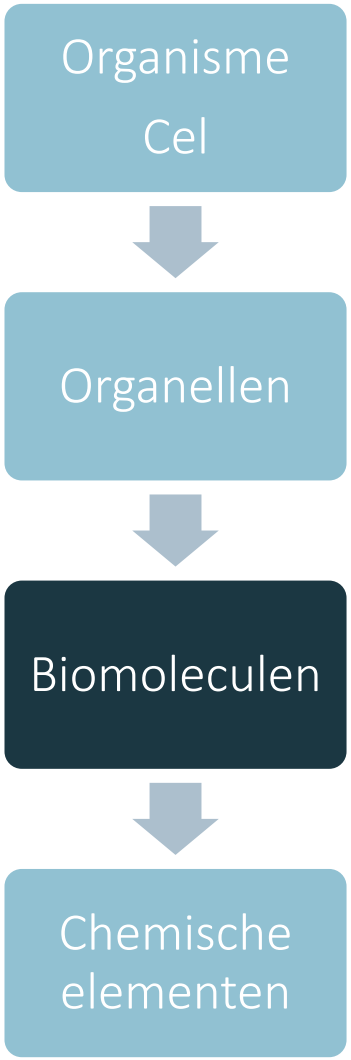
Celstructuur		Prokaryote cel	Plant: 10-100 µm	Dier: 5-30 µm
	Celwand	X	X	
	Celmembraan	X	X	X
Organellen	Nucleus		X	X
	Mitochondriën		X	X
	Chloroplasten		X	
	Golgi apparaat		X	X
	ER		X	X
	Vacuole	(X)	X	(X)
Supra-moleculaire assemblages	Ribosomen	X	X	X
	Enzyme complexen	X	X	X
	Cytoskelet		X	X

Biochemie werkt op verschillende niveaus





Unnumbered figure pg 24 Concepts in Bio
© 2006 John Wiley & Sons

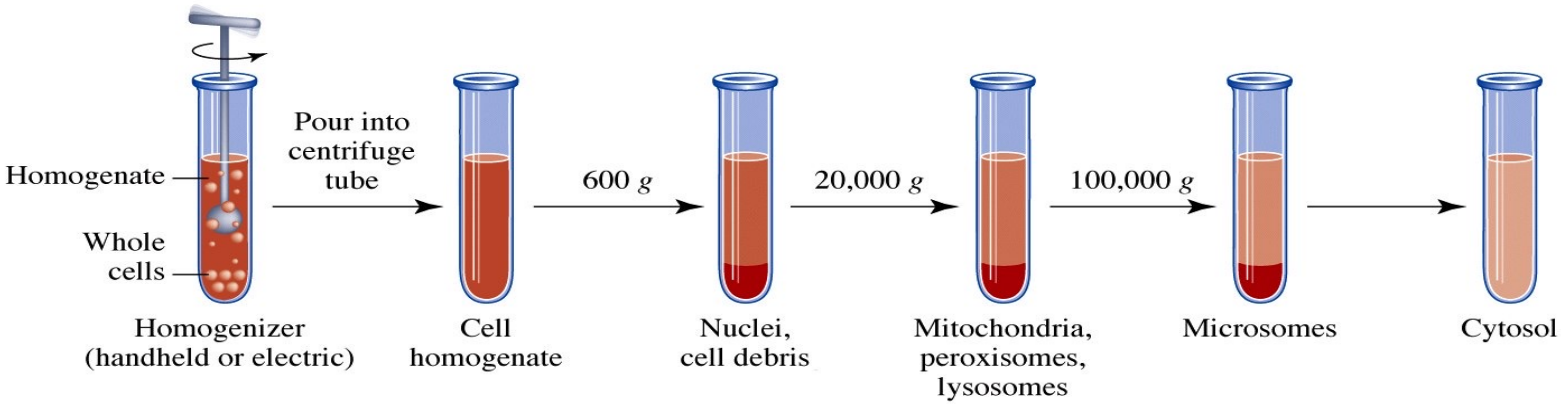


BIOCHEMIE

= Experimentele wetenschap

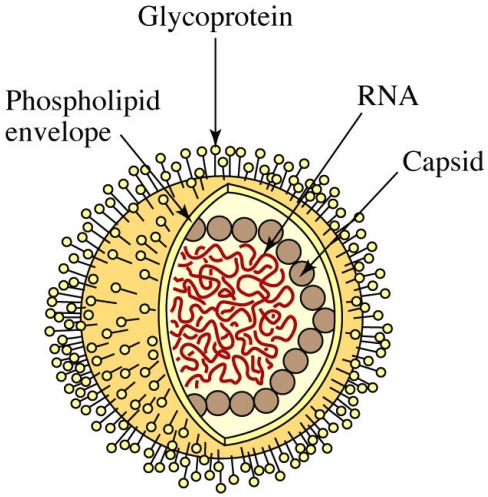
- Voor uitvoeren experiment: isolatie van cellen, organellen & biomoleculen via centrifugatie
- Gebaseerd op eigenschappen van biomoleculen: gewicht, grootte, dichtheid & vorm

Unnumbered figure pg 31a Concepts in Biochemistry, 3/e



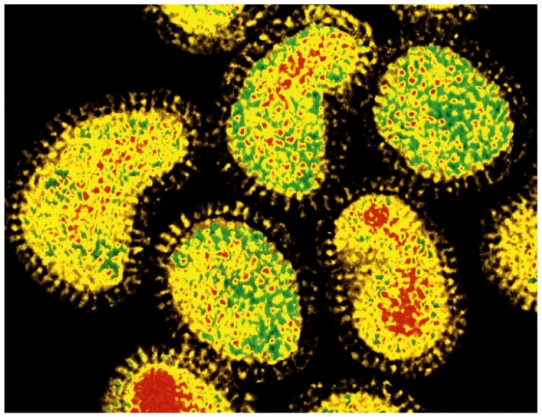
Unnumbered figure pg 31b Concepts in Biochemistry, 3/e

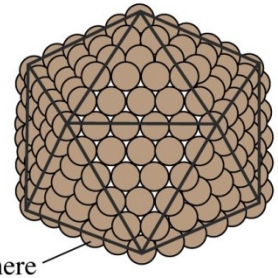
BIOCHEMIE & VIRUSSEN?



(a) Influenza virus (globular)

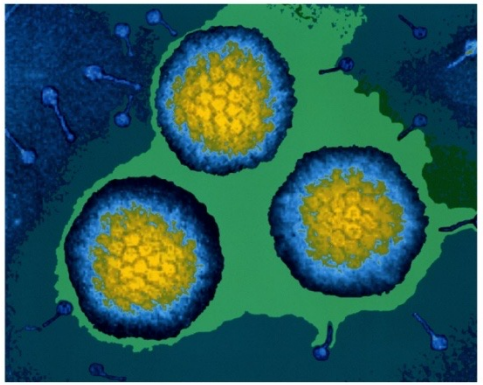
Figure 1-7a Concepts in Biochemistry, 3/e



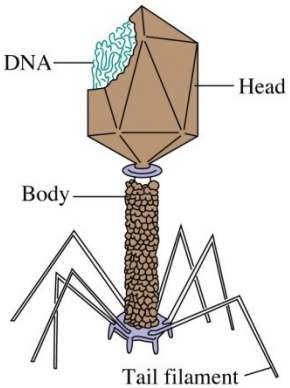


(b) Adenovirus (polyhedral)

Figure 1-7b Concepts in Biochemistry, 3/e

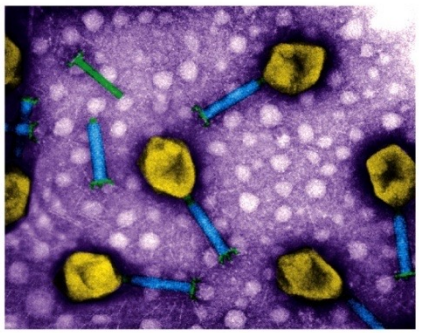


- Niet levend, maar bestaan uit biomoleculen
- ss DNA of RNA molecule in eiwitmantel
- Parasieten – geen metabolisme of reproductie zonder gastheer
- Reden vele plant- & dierlijke ziektes



(d) Bacteriophage (complex shape)

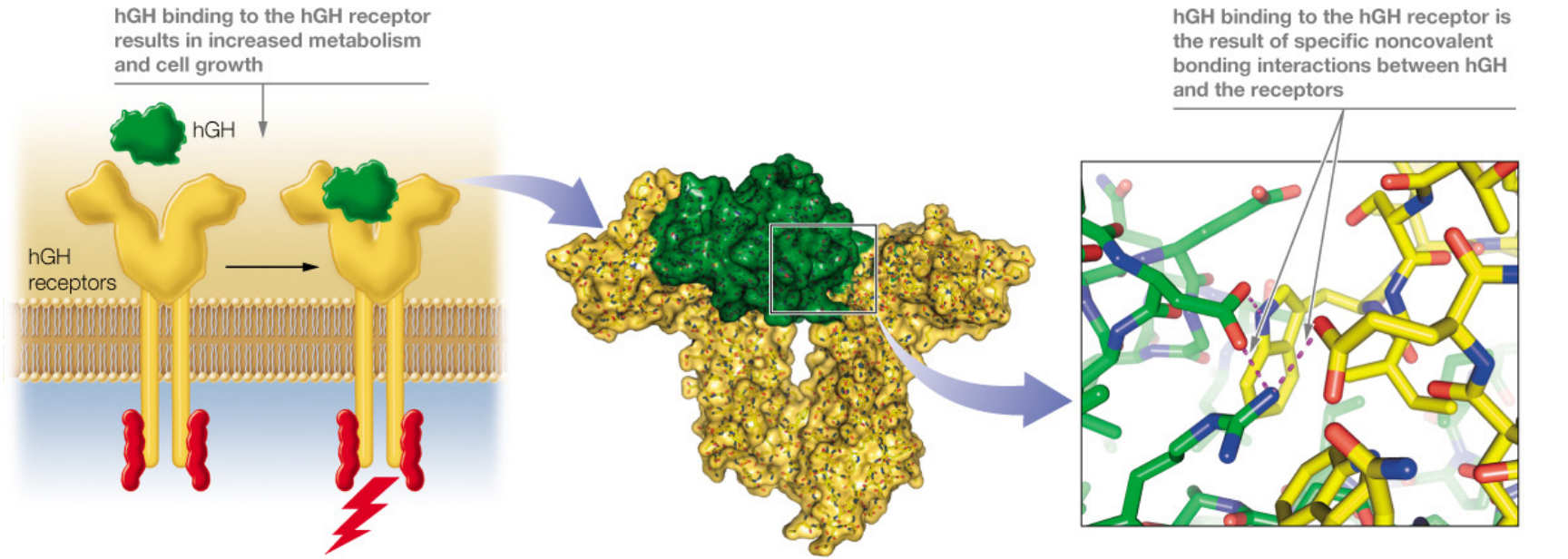
Figure 1-7d Concepts in Biochemistry, 3/e



1.4 Niet-covalente Bindingen in Biomoleculen

Belang van niet-covalente interacties in de biochemie

- Niet-covalente interacties bepalen structuur en functie van biomoleculen

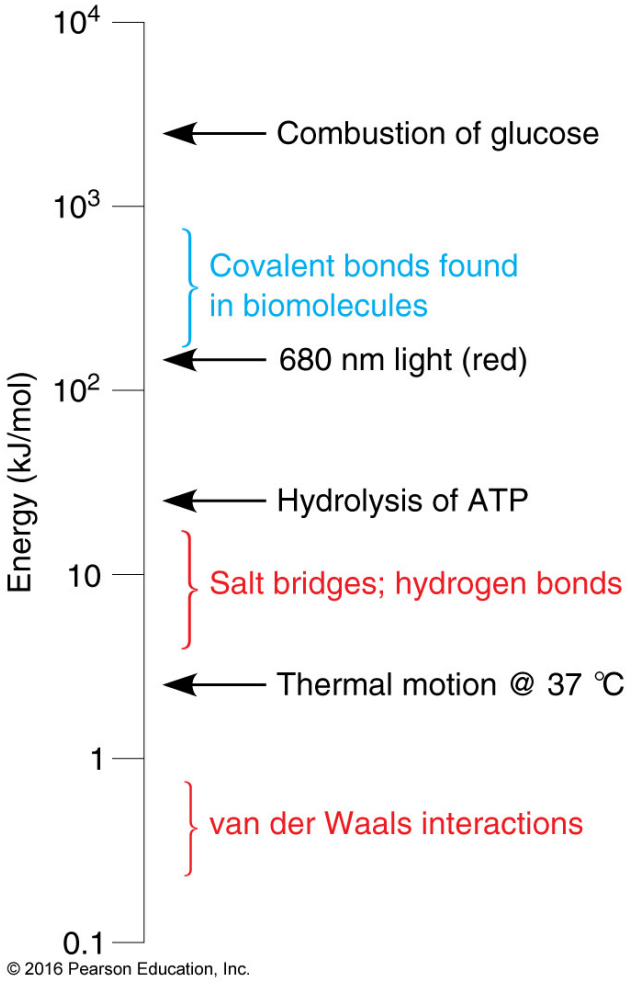


(a) The binding of human growth hormone (hGH) to its receptor transmits a signal across the cell membrane which, in turn, stimulates cell growth (indicated by lightning bolt).

(b) The X-ray crystal structure of the hGH-receptor complex shows the complementary binding surfaces (interfaces) between these proteins.

(c) A zoom into the interface between hGH and the receptor shows highly specific noncovalent bonding interactions (magenta-colored dashed lines). Here, O atoms are colored red, N atoms are blue, and C atoms are either green (on hGH) or yellow (on the receptor).

Belang van niet-covalente interacties in de biochemie



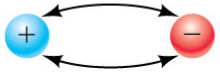
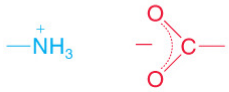
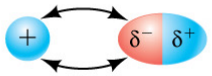
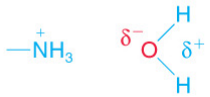
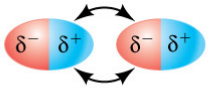
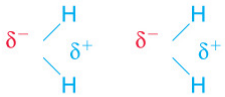
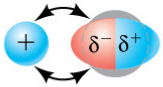
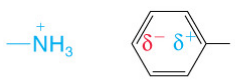
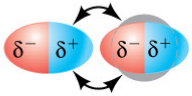
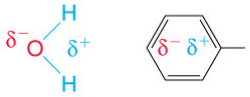
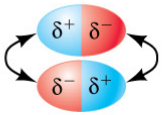
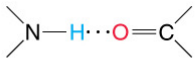
- Niet-covalente bindingen zijn zwak, en kunnen dus voortdurend worden verbroken en hervormd

TABLE 2.1 Energies of some noncovalent interactions in biomolecules

Type of Interaction	Approximate Energy (kJ/mol)
Charge–charge	13 to 17
Hydrogen bond	2 to 21
van der Waals	0.4 to 0.8

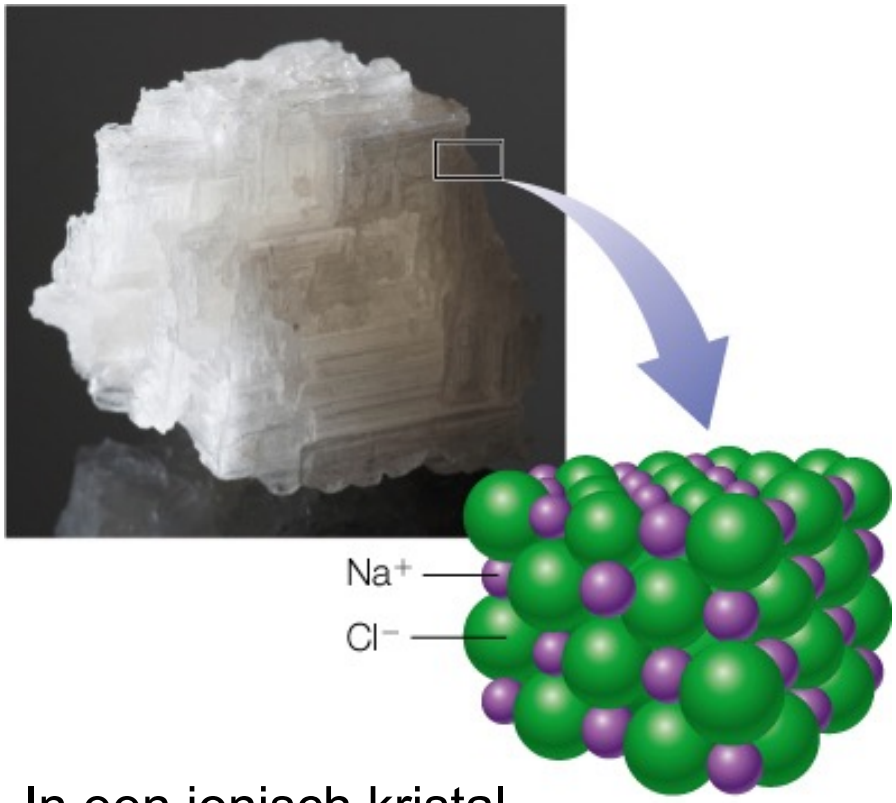
Source: Data from S. K. Burley and G. A. Petsko, Weakly polar interactions in proteins, *Advances in Protein Chemistry* (1988) 39:125–189.

Soorten niet-covalente interacties

Type of Interaction	Model	Example	Dependence of Energy on Distance
(a) Charge–charge			$1/r$
(b) Charge–dipole			$1/r^2$
(c) Dipole–dipole			$1/r^3$
(d) Charge–induced dipole			$1/r^4$
(e) Dipole–induced dipole			$1/r^5$
(f) Dispersion (van der Waals)			$1/r^6$
(g) Hydrogen bond	 Donor Acceptor		Bond length is fixed

Lading-lading interacties

- Alle niet-covalente interacties zijn **elektrostatisch** van aard
- De eenvoudigste elektrostatische interacties zijn die tussen een paar geladen deeltjes, een **zoutbrug** genoemd



In een ionisch kristal

Lading-lading interacties

- De aantrekkingskracht van de tegengesteld geladen ionen wordt geregeld door de **wet van Coulomb**:

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

met F = kracht, q = lading, en r = afstand tussen de ladingen

- De wet van Coulomb geldt in een vacuüm

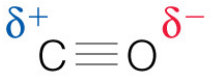
Lading-lading interacties

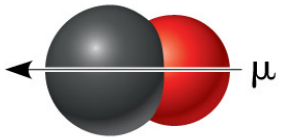
- In een cel worden ladingen in oplossing afgeschermd door het medium dat zich tussen de ladingen bevindt
- De afschermende werking van een medium wordt weergegeven door **ε, de diëlektrische constante** (water heeft een hoge diëlektrische constante, 80) die aanleiding geeft tot de vergelijking:

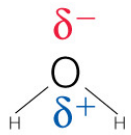
$$F = k\frac{q_1 q_2}{\varepsilon r^2}$$

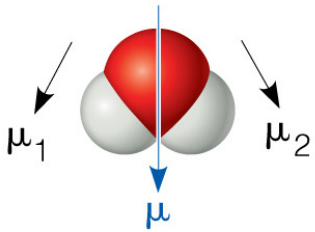
=> **F zwakt af**

Dipoolinteracties



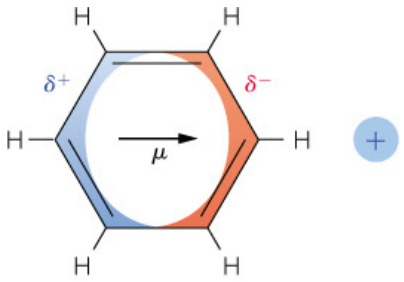






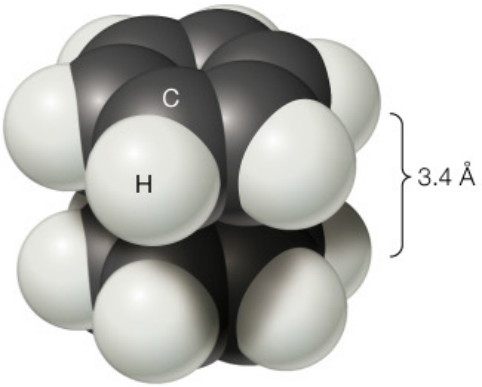
Water: the partial negative charge on O together with the partial positive charge on each H produces two dipole moments, μ_1 and μ_2, directed along the O—H bonds. Their vector sum (μ, shown in blue) represents the net dipole moment of the molecule.

Permanent dipoles



(a) Benzene has neither a net charge nor a permanent dipole moment, but a nearby charge can induce a redistribution of electrons within the benzene ring, producing an induced dipole moment (arrow).

(b) Planar molecules like benzene have a strong tendency to stack because fluctuations in the electron clouds of the stacked rings give rise to mutually attractive induced dipoles (van der Waals interactions).



(c) Although the molecules approach closely, they do not interpenetrate.

Induced dipoles

van der Waals interactie van 2 moleculen

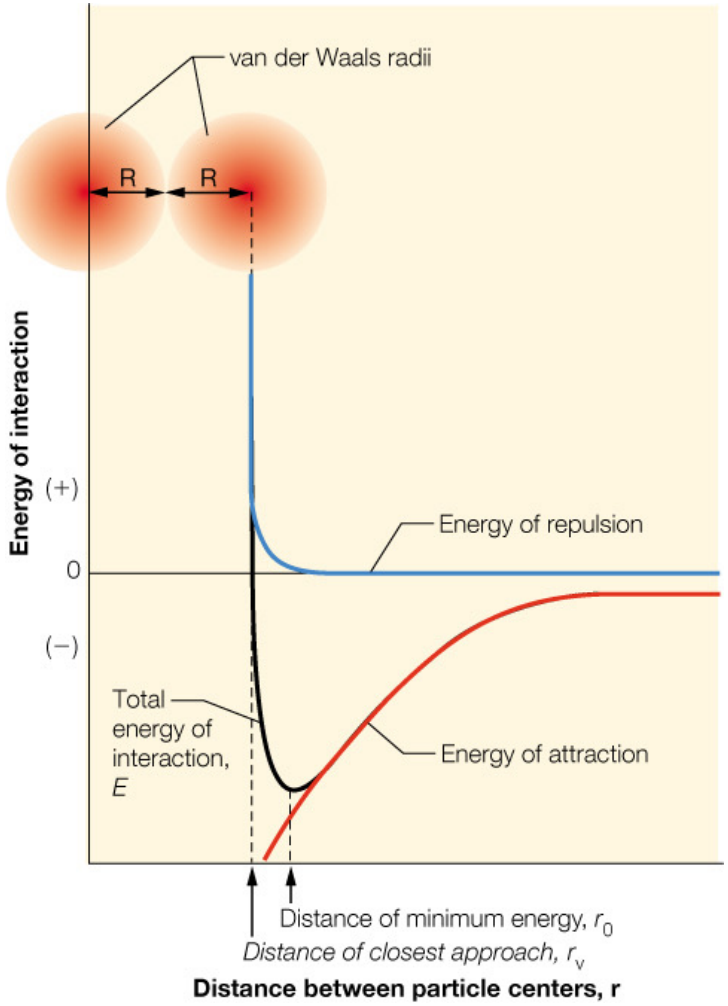


TABLE 2.2 van der Waals radii of some atoms and groups of atoms

	R (Å)
Atoms	
H	1.2
O	1.4
N	1.5
C	1.7
S	1.8
P	1.9
Groups	
—OH	1.4
—NH_2	1.5
—CH_2—	2.0
—CH_3	2.0
Half-thickness of aromatic ring	1.7

Waterstofbindingen (H-bruggen)

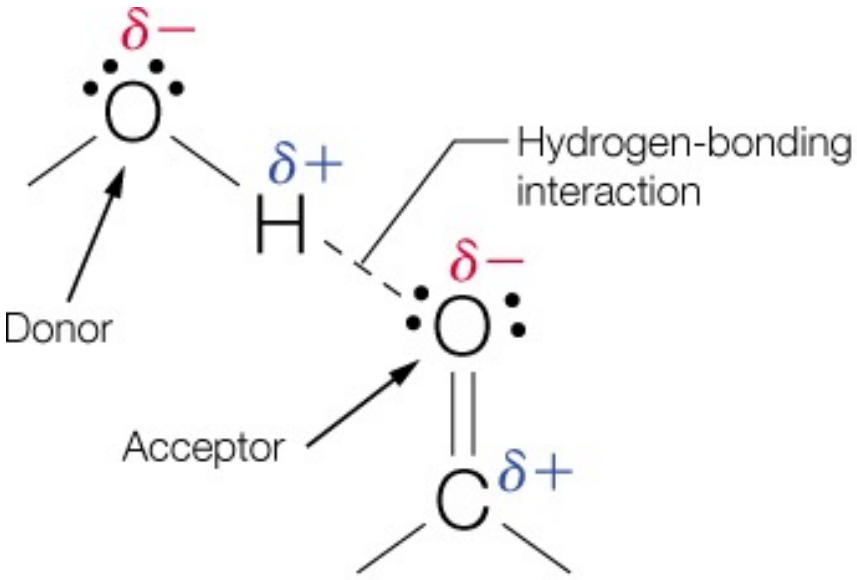
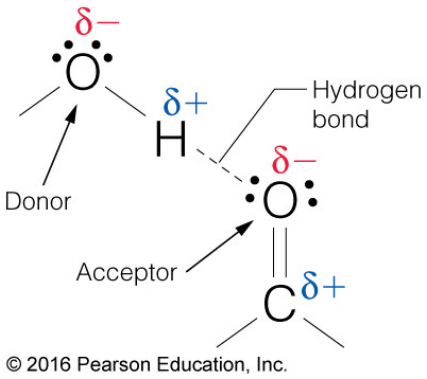


TABLE 2.3 Major types of hydrogen bonds found in biomolecular interactions

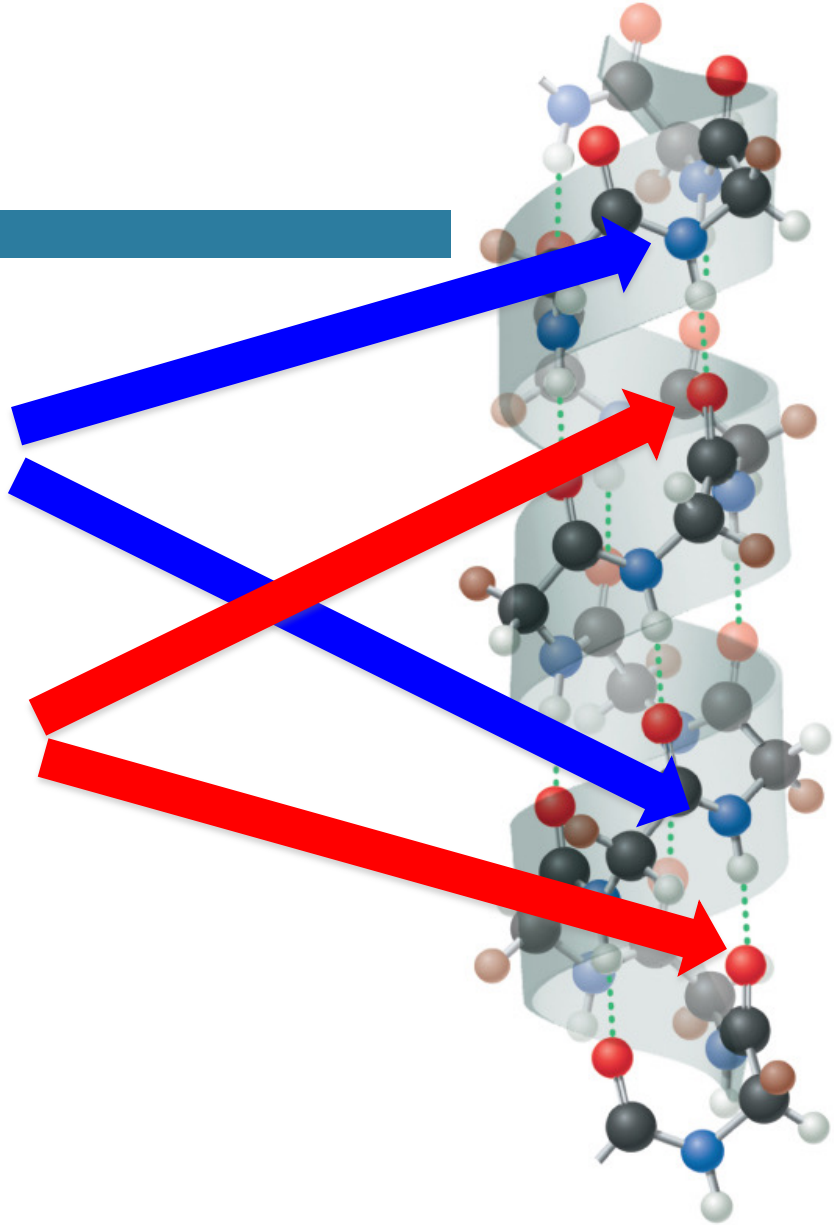
Donor . . . Acceptor	Distance between Donor and Acceptor (Å)	Comment
—O—H ··· O(H)	2.8 ± 0.1	H bond formed in water
—O—H ··· O=C	2.8 ± 0.1	Bonding of water to other molecules often involves these
N—H ··· O(H)	2.9 ± 0.1	
N—H ··· O=C	2.9 ± 0.1	Very important in protein and nucleic acid structures
N—H ··· N	3.1 ± 0.2	
N—H ··· S	3.7	Relatively rare; weaker than above

Waterstofbindingen



H-bond donors

H-bond acceptors



Hydrofobe interacties

- Hydrofobe of apolaire moleculen zijn moeilijk oplosbaar in water
- Interactie met elkaar in waterige omgeving = hydrofobe interactie

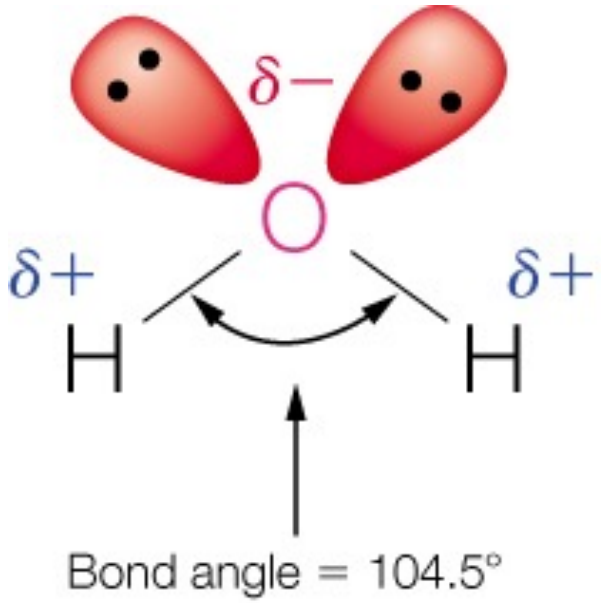
1.5 Structuur en Eigenschappen van Water

Structuur en Eigenschappen van water

Water heeft verschillende unieke eigenschappen.

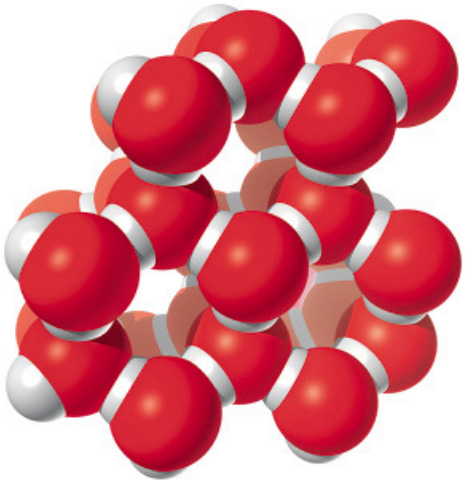
Het heeft:

1) twee **H-bindingsdonor**plaatsen en
   twee **H-bindingsacceptor**plaatsen
2) een **permanente dipool**
3) een **hoge warmtecapaciteit**
4) een grotere **dichtheid** in vloeistof
5) een relatief hoge **diëlektrische constante**

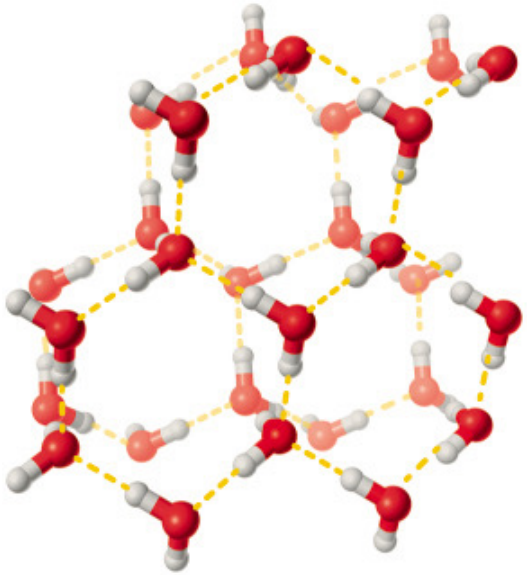


Structuur en Eigenschappen van water

Water als moleculair rooster

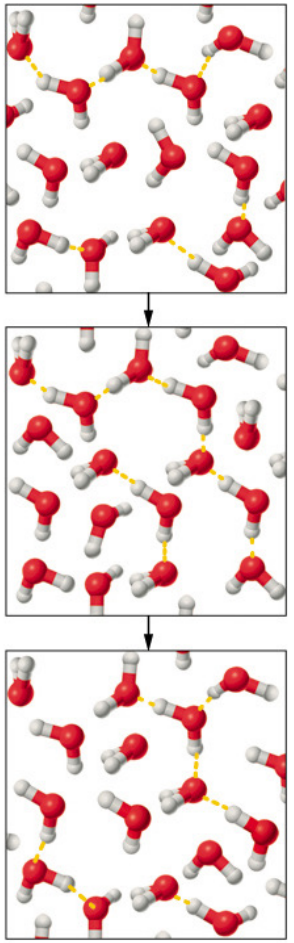


(a) A space-filling model of the structure of ice. Ice is a molecular lattice formed by indefinite repetition of a tetrahedral hydrogen-bonding pattern. Each molecule acts as a hydrogen-bond donor to two others and as an acceptor from two others. Because of the length of the hydrogen bonds, the structure is a relatively open one, which accounts for the low density of ice.



(b) A stick model of the ice lattice. Hydrogen bonds are shown as dashed yellow lines.

Solid



Liquid

(c) The structure of liquid water. When ice melts, the regular tetrahedral lattice is broken, but substantial portions of it remain, especially at low temperatures. In liquid water, flickering clusters of molecules are held together by hydrogen bonds that continually break and re-form. In this schematic "motion picture," successive frames represent changes occurring in picoseconds (10^{-12} s).

Structuur en Eigenschappen van water

TABLE 2.4 Properties of water compared to those of some other hydrogen-containing, low-molecular-weight compounds

Compound	Molecular Weight	Melting Point (°C)	Boiling Point (°C)	Heat of Vaporization (kJ/mol)
CH_4	16.04	−182	−164	8.16
NH_3	17.03	−78	−33	23.26
H_2O	18.02	0	+100	40.71
H_2S	34.08	−86	−61	18.66

Structuur en Eigenschappen van water

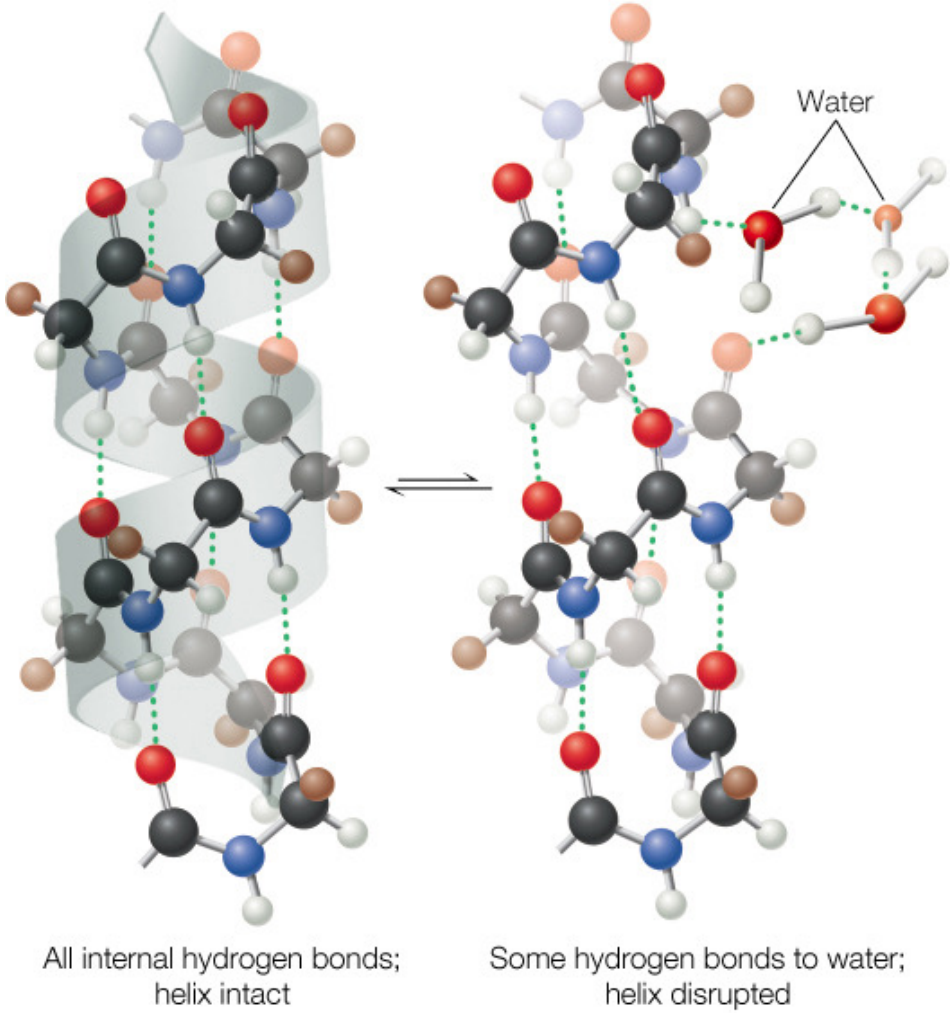
TABLE 2.5 Important properties of liquid water compared with those of *n*-pentane, a nonpolar, nonhydrogen-bonding liquid[a]

Property	Water	*n*-Pentane
Molecular weight (g/mol)	18.02	72.15
Density (g/cm^3)	0.997	0.626
Boiling point (°C)	100	36.1
Dielectric constant	78.3	1.84
Viscosity ($g/cm \cdot s$)	0.890×10^{-2}	0.228×10^{-2}
Surface tension (dyne/cm)	71.97	17

[a]All data are for 25 °C. (Note the higher dielectric constant for water compared to that at 37 °C.)

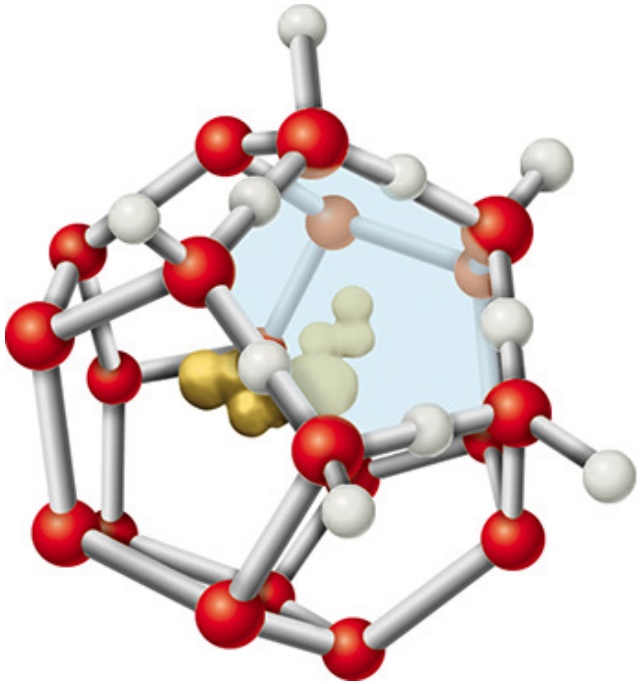
Water als solvent van organische moleculen

- Hydrofiele moleculen in waterige oplossing



Water als solvent van organische moleculen

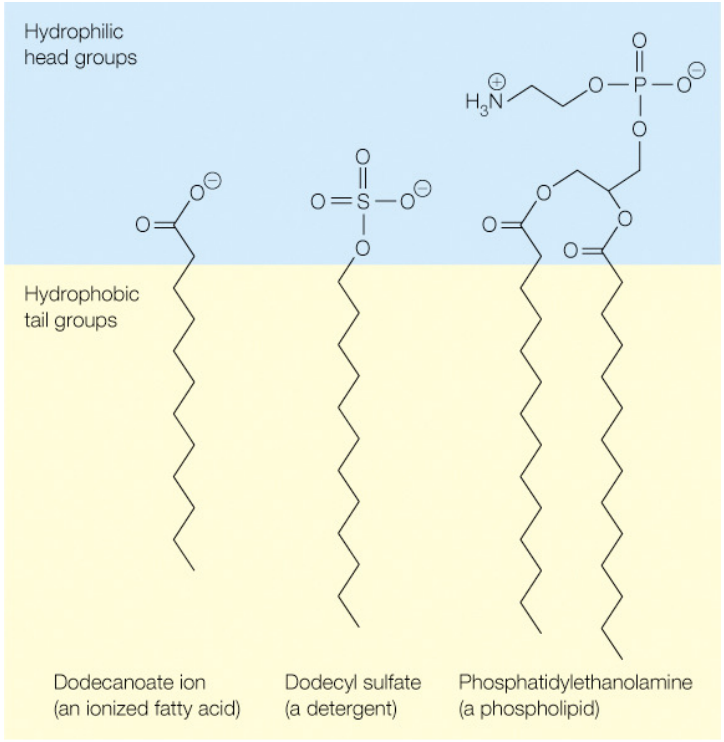
- Hydrofobe moleculen in waterige oplossing
- Hydrofobe effect

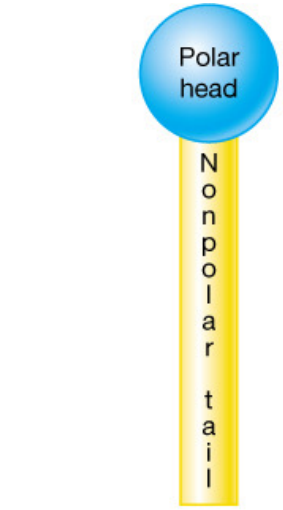


Een eenheid van de clathraatstructuur rond een hydrofoob molecuul (geel)

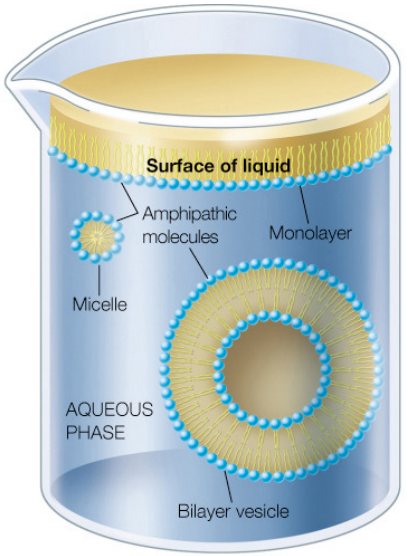
Water als solvent van organische moleculen

- Amfipathische moleculen in waterige oplossing





A simplified representation of an amphipathic lipid molecule



(a) Structures formed in water. Structures that can form when amphipathic substances are mixed with water include a monolayer on the water surface, a micelle, and a bilayer vesicle, a hollow sphere with water both inside and out. In each case, the hydrophilic head groups are in close contact with the aqueous phase, whereas the hydrophobic tails associate with one another.

Een amfipathische stof kan een monolaag, een micel of een bilaag vormen

De fosfolipidenbilaag is de primaire component van membranen

1.6 Biochemie en de Informatie-explosie

Bioinformatica

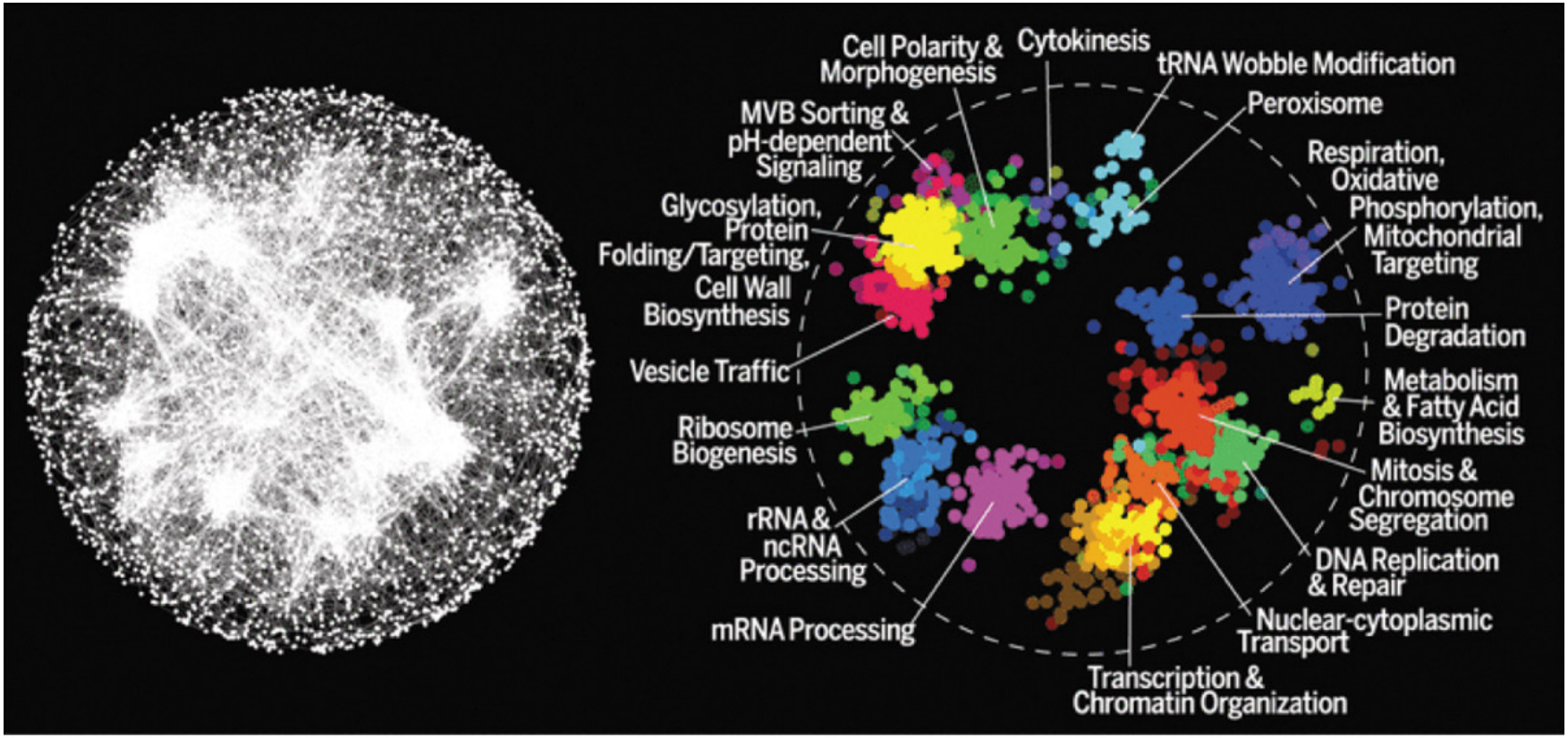
- Nieuwe wetenschappelijke hulpmiddelen en technieken kunnen toenemende hoeveelheid biochemische en moleculair biologische informatie genereren en analyseren
- **Bio-informatica** kan worden beschouwd als informatica die wordt toegepast in de biologie, voorbeelden zijn:
  1. wiskundige analyse van DNA-sequentiegegevens
  2. computersimulatie van metabole routes
  3. analyse van potentiële geneesmiddelendoelen (enzymen of receptoren) voor op structuur gebaseerd geneesmiddelenontwerp

Omics

- **Genetica** houdt zich bezig met de locatie, expressie en functie van individuele genen of kleine groepen genen
- **Genomics** breidt de genetica-benadering uit en houdt zich bezig met het hele genoom, het geheel van genetische informatie in een organisme
- Sommige van de bredere doelen van genomics zijn
  1. bepaal de nucleotidesequentie van hele genoom (van een organisme)
  2. beoordeel de expressie en functie van elk gen
  3. de evolutionaire relaties tussen genen in hetzelfde genoom en met genomen van verschillende organismen begrijpen

Omics

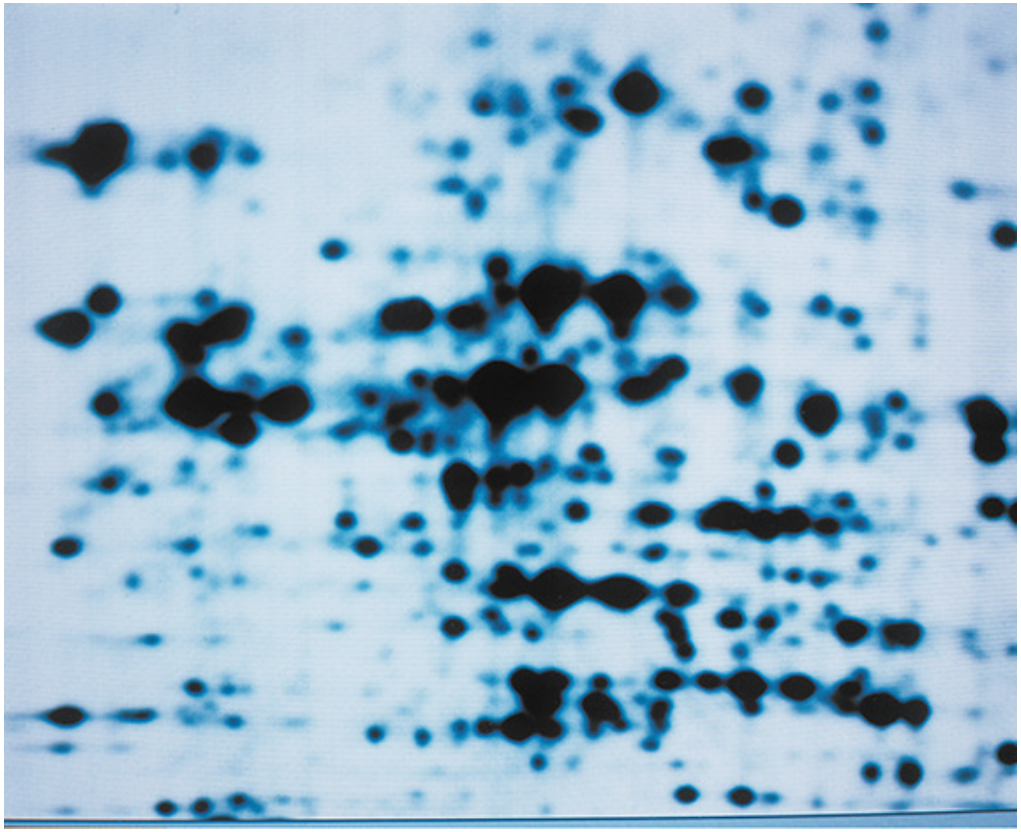
- **Genomics**: the genetic landscape of a yeast cell



Omics

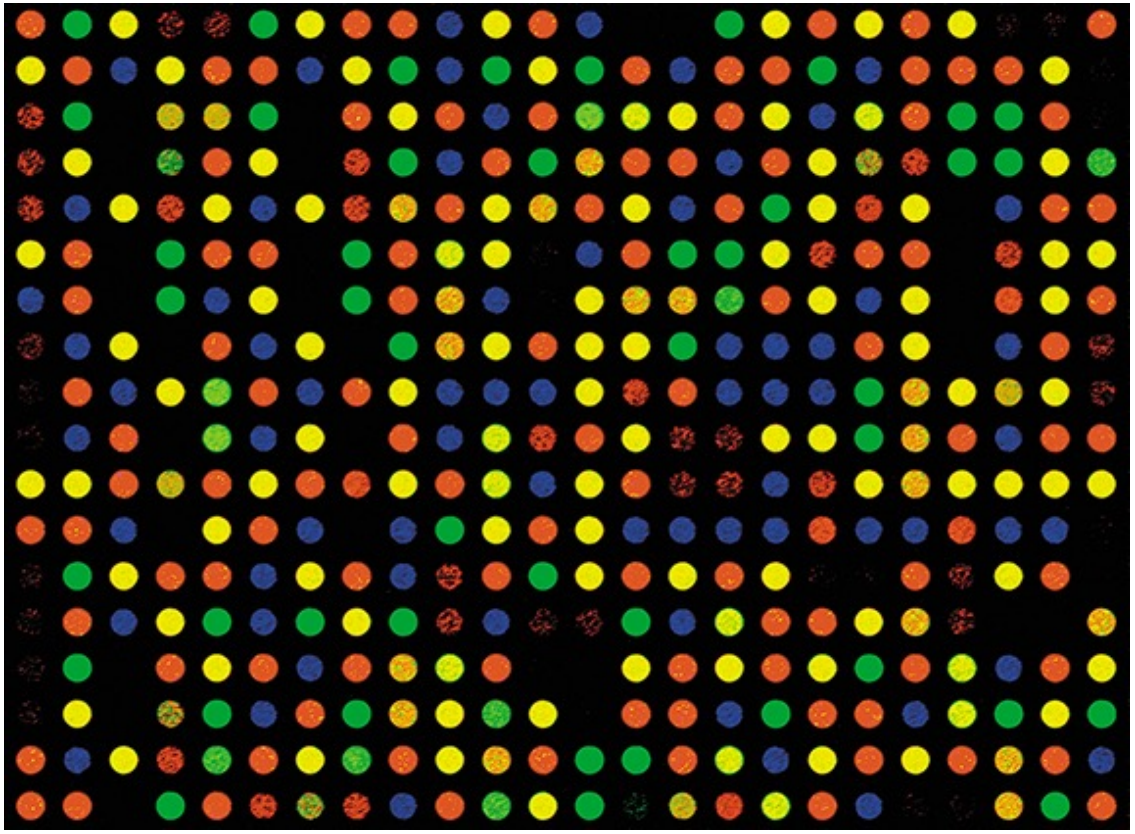
- Voorbeelden van andere gevestigde "Omics" zijn **Proteomics**, **Transcriptomics**, **Metabolomics** en **Interactomics**

- **Proteomics**: scheiding van groot aantal eiwitten uit cellulaire extract door tweedimensionale gelelektroforese



Omics

- **Transcriptomics**: de overvloed aan genspecifieke mRNA's aangegeven door microarrays



1.7 Hoofdstuk 1 Samengevat

Hoofdstuk 1 Samengevat

- Het doel van biochemie is om levende systemen in moleculaire termen te begrijpen en te verklaren
- Biochemie overbrugt biologische en chemische wetenschappen op het niveau van moleculen in levende systemen
- Levende systemen zijn samengesteld uit cellen, die kunnen worden onderverdeeld in drie hoofdtypen: bacterieel, archaeaal en eukaryotisch
- Biochemie is een experimentele wetenschap en maakt gebruik van verschillende hulpmiddelen en technieken, waarvan sommige een grote hoeveelheid informatie genereren

- Met je eigen woorden kunnen uitleggen wat biochemie is en wat het doel van biochemie is.
- Hoe zijn levende cellen structureel georganiseerd?
- De macromoleculen kennen + welke daarvan zijn biopolymeren en waarom?
  Functies van de macromoleculen?
  Bouwstenen?
  Linkage?
- Voorbeelden van toepassingsdomeinen kunnen geven.