

Lebenswissenschaftliches Kolleg 09/2013

Biophysik und biophysikalische Chemie

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Experimental Physics I, University of Bayreuth



Zentrale Fragestellungen dieser Woche

Dynamische Phänomene lebender Materie

Beobachtung, Quantifizierung, Modelle

Spontane Bildung von Mustern und Strukturen (z.B. im Embryo)

Beobachtung, Quantifizierung, Modelle

Physik auf der Skala der Zelle

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Ablauf

Montag

eingführende Vorlesungen & Vorlesung/Übung zu Mikroskopie

Dienstag

2 Vorlesungen (H. Kress) zu Kraftmessungen in der Zelle
Vorlesung/Übung zu Mikrotubuli & molekularen Motoren

Mittwoch

Vorlesungen/Übungen zu FRAP und FCS

Donnerstag

2 Vorlesungen zur Musterbildung in Zellen/Geweben
Posterzusammenstellung & Feedback-Runde

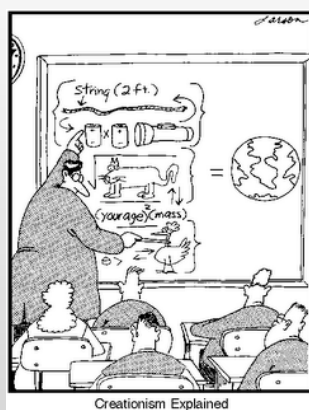
Freitag

Vorlesung zur Lichtblattmikroskopie
Posterpräsentation

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I. Lebende Materie aus Physikersicht...



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Überblick über die eukaryontische Zelle

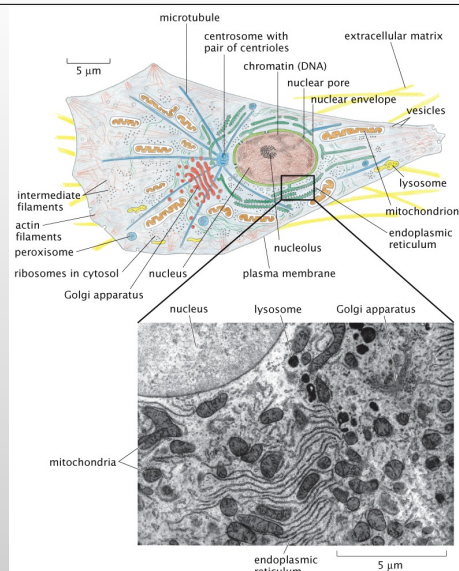


Figure 2.23 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Verlockend ist der äuß're Schein,
der Weise dringet tiefer ein.
(Wilhelm Busch)

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Wasser – DAS Lösungsmittel des Lebens

viele Sichten auf Wasser

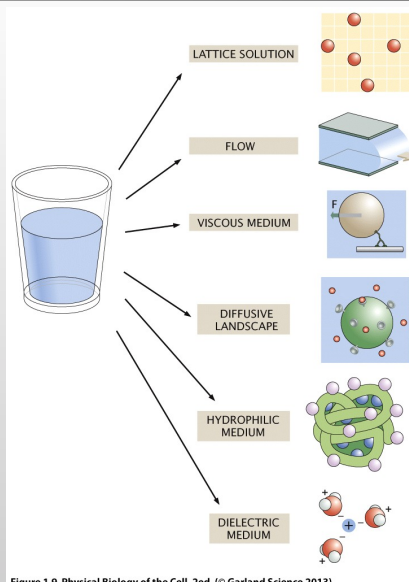
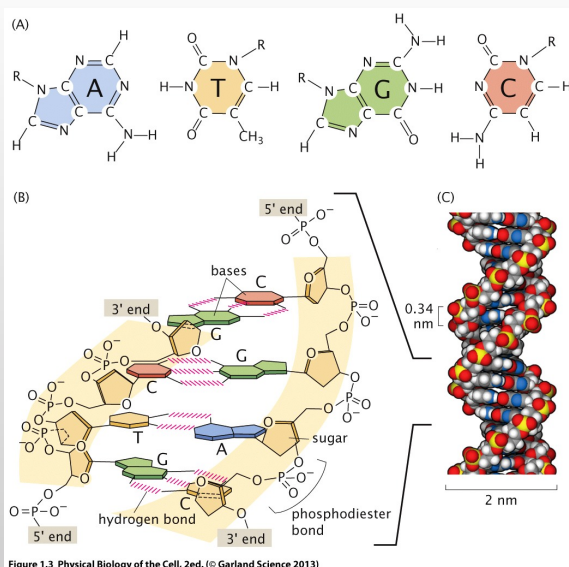


Figure 1.9 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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Elementare Bausteine – DNA



Polares Filament

stark neg. geladen

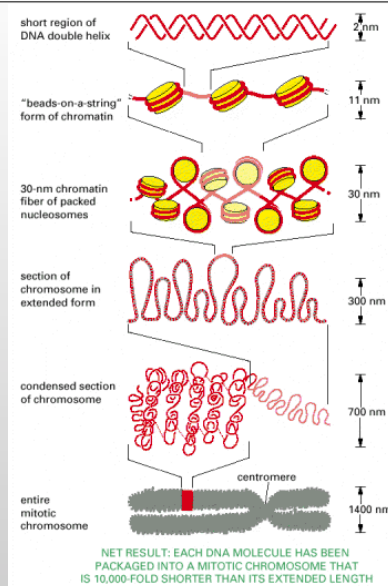
DNA-Strukturen auf vielen Größenskalen

- Doppelhelix
- 30nm-Faser
- Chromosomen

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DNA-Konformation – Multiskalenproblem



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Elementare Bausteine – Aminosäuren

20 natürliche Aminosäuren
(je 3 Basen $\Rightarrow 3^4=81$ möglich)

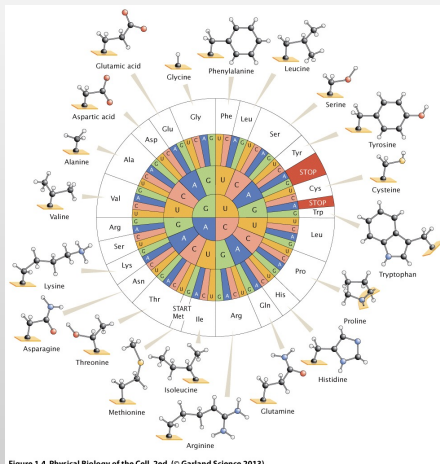


Figure 1.4 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

AMINO ACID	SIDE CHAIN	AMINO ACID	SIDE CHAIN
Aspartic acid	Asp D negative	Alanine	Ala A nonpolar
Glutamic acid	Glu E negative	Glycine	Gly G nonpolar
Arginine	Arg R positive	Valine	Val V nonpolar
Lysine	Lys K positive	Leucine	Leu L nonpolar
Histidine	His H positive	Isoleucine	Ile I nonpolar
Asparagine	Asn N uncharged polar	Proline	Pro P nonpolar
Glutamine	Gln Q uncharged polar	Phenylalanine	Phe F nonpolar
Serine	Ser S uncharged polar	Methionine	Met M nonpolar
Threonine	Thr T uncharged polar	Tryptophan	Trp W nonpolar
Tyrosine	Tyr Y uncharged polar	Cysteine	Cys C nonpolar

POLAR AMINO ACIDS

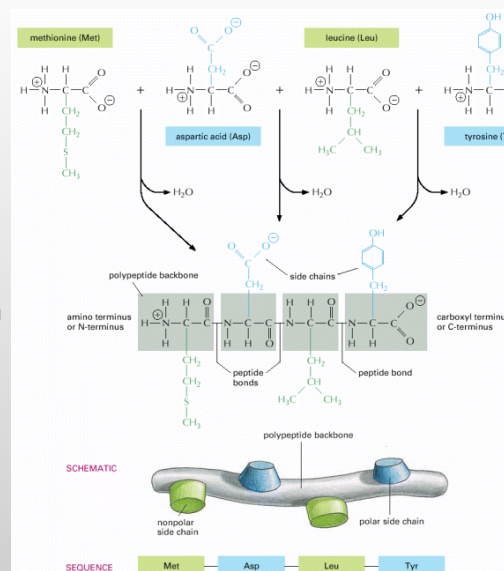
NONPOLAR AMINO ACIDS

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Proteine – Polymere von Aminosäuren

verbinde Aminosäuren
per Peptidbindung



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Komplexität aus einfachen Bausteinen

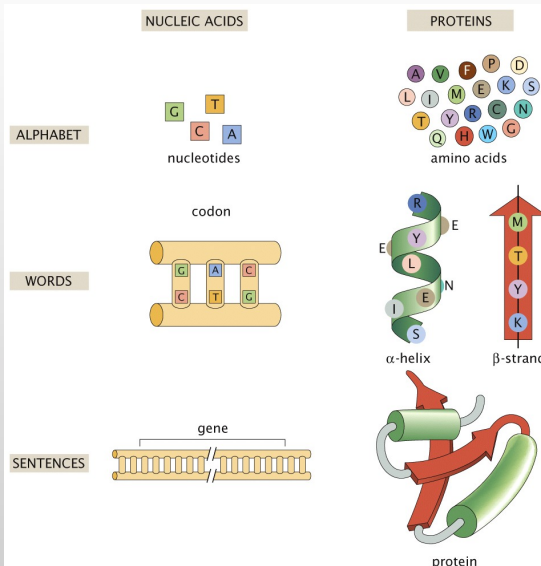


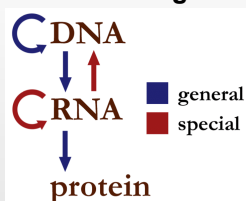
Figure 1.2 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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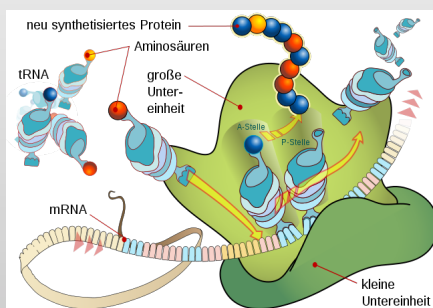


Von der DNA zum Protein

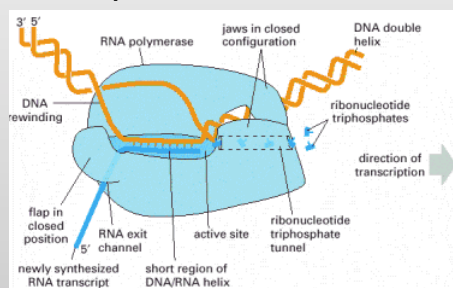
Central Dogma



Translation der mRNA



Transkription der ssDNA



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Ein Protein – viele Interpretationen

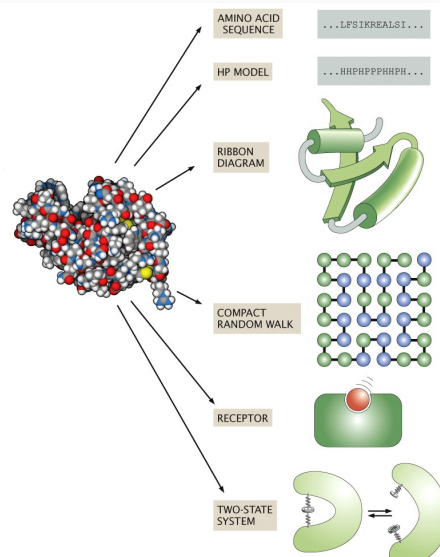
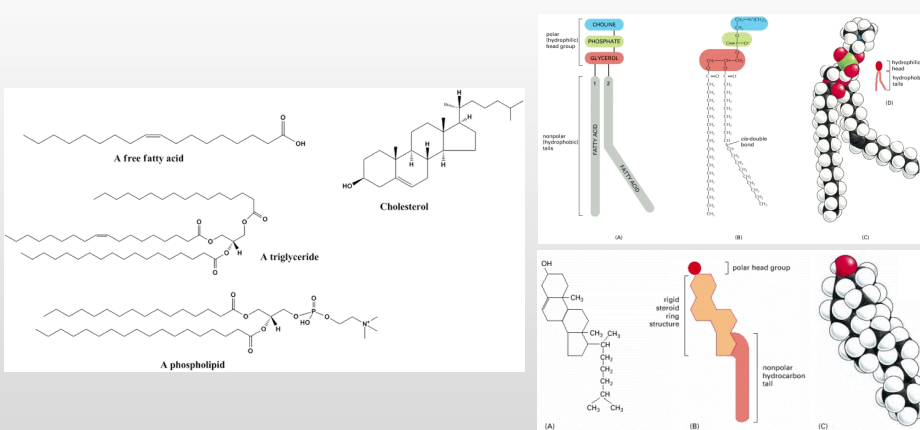


Figure 1.6 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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Elementare Bausteine – Lipide

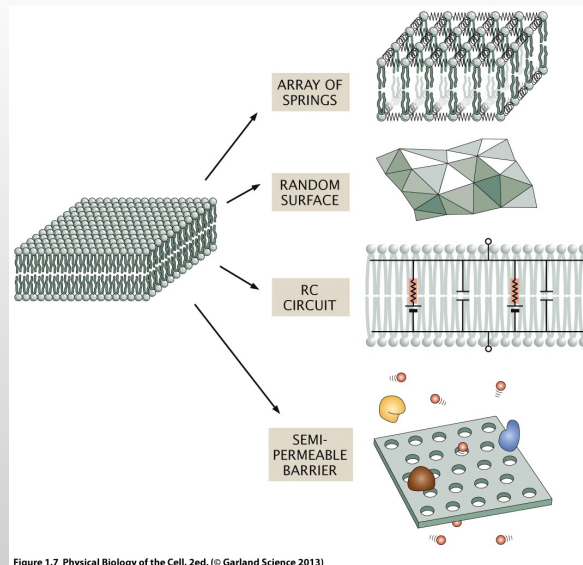


Riesiger Zoo von Lipiden (versch. Kopfgruppen und Fettsäuren)

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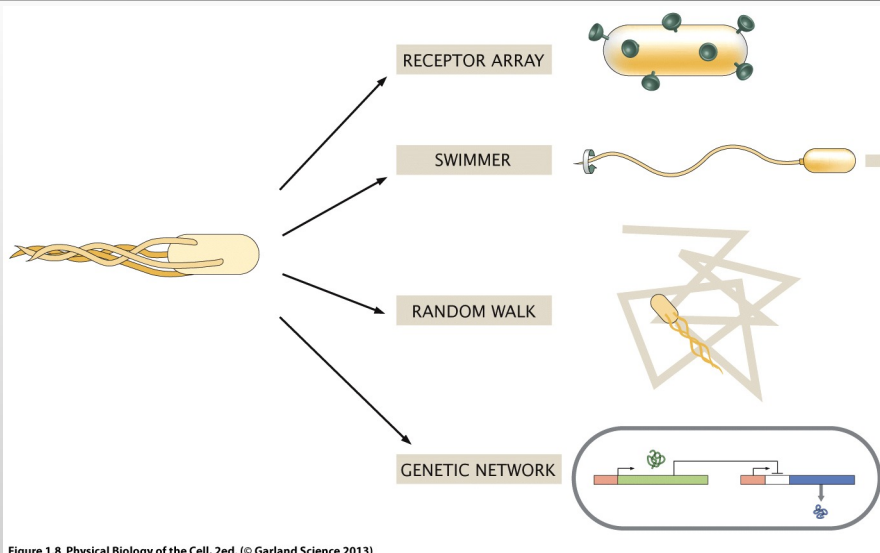
Verschiedene Aspekte von Membranen



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Viele Sichten auf ein Bakterium



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Einige Hausnummern #1

Table 1.1: Rules of thumb for biological estimates.

Quantity of interest	Symbol	Rule of thumb
<i>E. coli</i>		
Cell volume	$V_{E. coli}$	$\approx 1 \mu\text{m}^3$
Cell mass	$m_{E. coli}$	$\approx 1 \text{ pg}$
Cell cycle time	$t_{E. coli}$	$\approx 3000 \text{ s}$
Cell surface area	$A_{E. coli}$	$\approx 6 \mu\text{m}^2$
Macromolecule concentration in cytoplasm	$c_{E. coli}^{\text{macromol}}$	$\approx 300 \text{ mg/mL}$
Genome length	$N_{E. coli}^{\text{bp}}$	$\approx 5 \times 10^6 \text{ bp}$
Swimming speed	$v_{E. coli}$	$\approx 20 \mu\text{m/s}$
Yeast		
Volume of cell	V_{yeast}	$\approx 60 \mu\text{m}^3$
Mass of cell	m_{yeast}	$\approx 60 \text{ pg}$
Diameter of cell	d_{yeast}	$\approx 5 \mu\text{m}$
Cell cycle time	t_{yeast}	$\approx 200 \text{ min}$
Genome length	$N_{\text{yeast}}^{\text{bp}}$	$\approx 10^7 \text{ bp}$
Organelles		
Diameter of nucleus	d_{nucleus}	$\approx 5 \mu\text{m}$
Length of mitochondrion	l_{mito}	$\approx 2 \mu\text{m}$
Diameter of transport vesicles	d_{vesicle}	$\approx 50 \text{ nm}$
Water		
Volume of molecule	$V_{\text{H}_2\text{O}}$	$\approx 10^{-2} \text{ nm}^3$
Density of water	ρ	1 g/cm^3
Viscosity of water	η	$\approx 1 \text{ centipoise}$ (10^{-2} g/(cm s))
Hydrophobic embedding energy	$\approx E_{\text{hydr}}$	$2500 \text{ cal/(mol nm}^2\text{)}$

Table 1.1 (part 1 of 2) Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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Einige Hausnummern #2

Table 1.1: Rules of thumb for biological estimates.

Quantity of interest	Symbol	Rule of thumb
DNA		
Length per base pair	l_{bp}	$\approx 1/3 \text{ nm}$
Volume per base pair	V_{bp}	$\approx 1 \text{ nm}^3$
Charge density	λ_{DNA}	$2 e/0.34 \text{ nm}$
Persistence length	ξ_{p}	50 nm
Amino acids and proteins		
Radius of "average" protein	r_{protein}	$\approx 2 \text{ nm}$
Volume of "average" protein	V_{protein}	$\approx 25 \text{ nm}^3$
Mass of "average" amino acid	M_{aa}	$\approx 100 \text{ Da}$
Mass of "average" protein	M_{protein}	$\approx 30,000 \text{ Da}$
Protein concentration in cytoplasm	c_{protein}	$\approx 150 \text{ mg/mL}$
Characteristic force of protein motor	F_{motor}	$\approx 5 \text{ pN}$
Characteristic speed of protein motor	v_{motor}	$\approx 200 \text{ nm/s}$
Diffusion constant of "average" protein in cytoplasm	D_{protein}	$\approx 10 \mu\text{m}^2/\text{s}$
Lipid bilayers		
Thickness of lipid bilayer	d	$\approx 5 \text{ nm}$
Area per molecule	A_{lipid}	$\approx \frac{1}{2} \text{ nm}^2$
Mass of lipid molecule	m_{lipid}	$\approx 800 \text{ Da}$

Table 1.1 (part 2 of 2) Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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Einige Hausnummern #3

Table 2.1: Observed macromolecular census of an *E. coli* cell. (Data from F. C. Neidhardt et al., *Physiology of the Bacterial Cell*, Sinauer Associates, 1990 and M. Schaechter et al., *Microbe*, ASM Press, 2006.)

Substance	% of total dry weight	Number of molecules
Macromolecules		
Protein	55.0	2.4×10^6
RNA	20.4	
23S RNA	10.6	19,000
16S RNA	5.5	19,000
5S RNA	0.4	19,000
Transfer RNA (4S)	2.9	200,000
Messenger RNA	0.8	1,400
Phospholipid	9.1	22×10^6
Lipopolysaccharide (outer membrane)	3.4	1.2×10^6
DNA	3.1	2
Murein (cell wall)	2.5	1
Glycogen (sugar storage)	2.5	4,360
Total macromolecules	96.1	
Small molecules		
Metabolites, building blocks, etc.	2.9	
Inorganic ions	1.0	
Total small molecules	3.9	

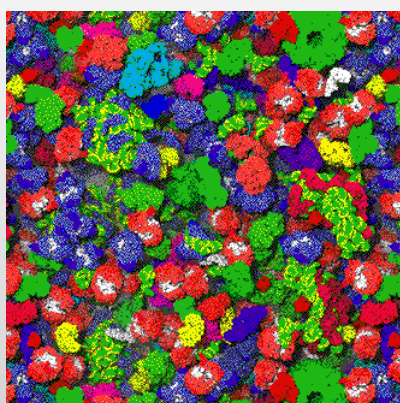
Table 2.1 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

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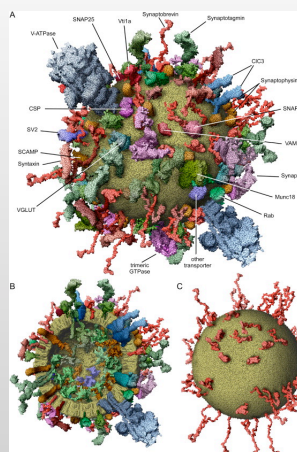
Und so sieht's wirklich aus...

Zytoplasma



McGuffee & Elcock, PLOS Comp. Biol (2010)

Membranen



Takamori *et al*, Cell (2006)

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