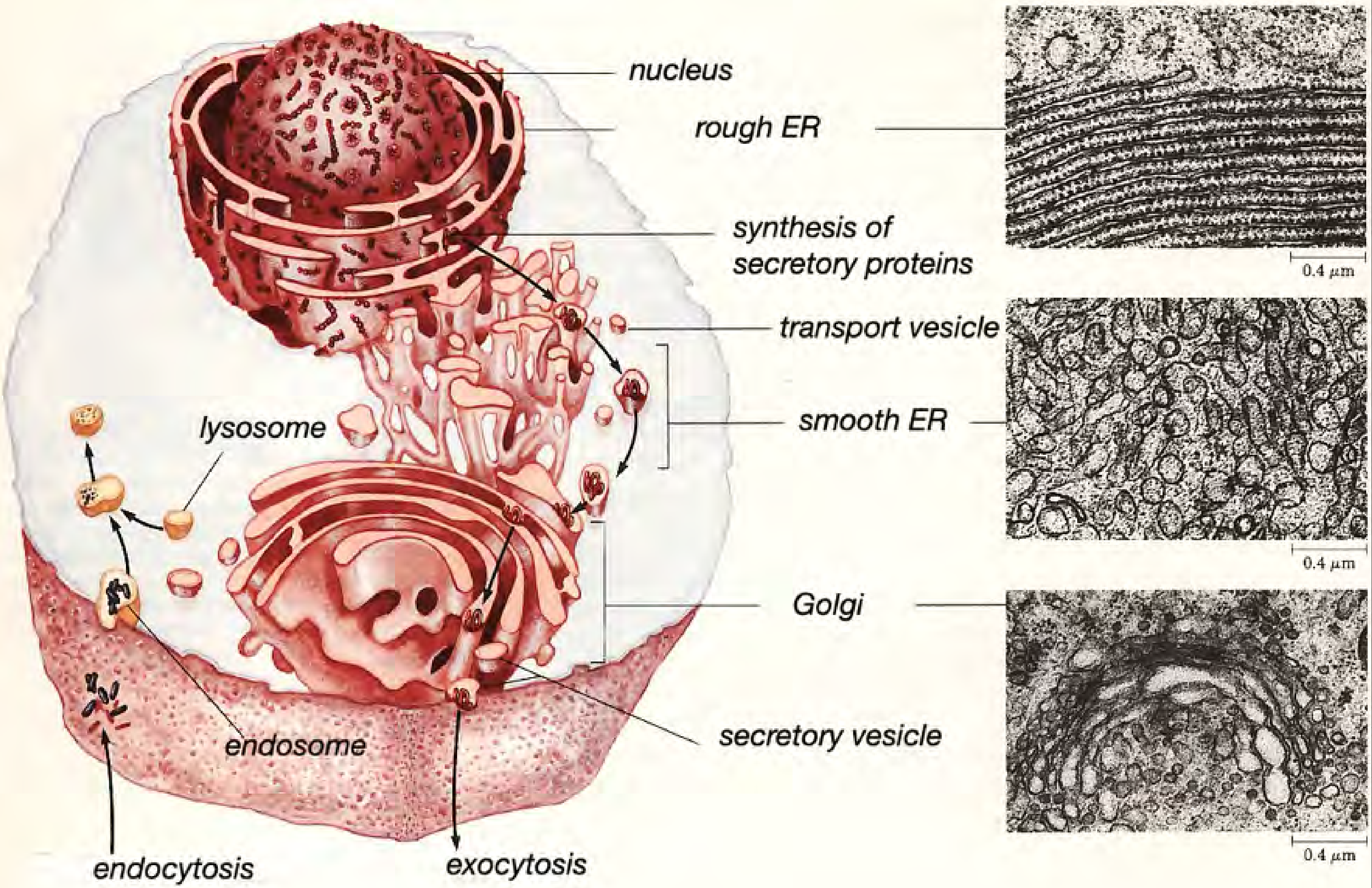
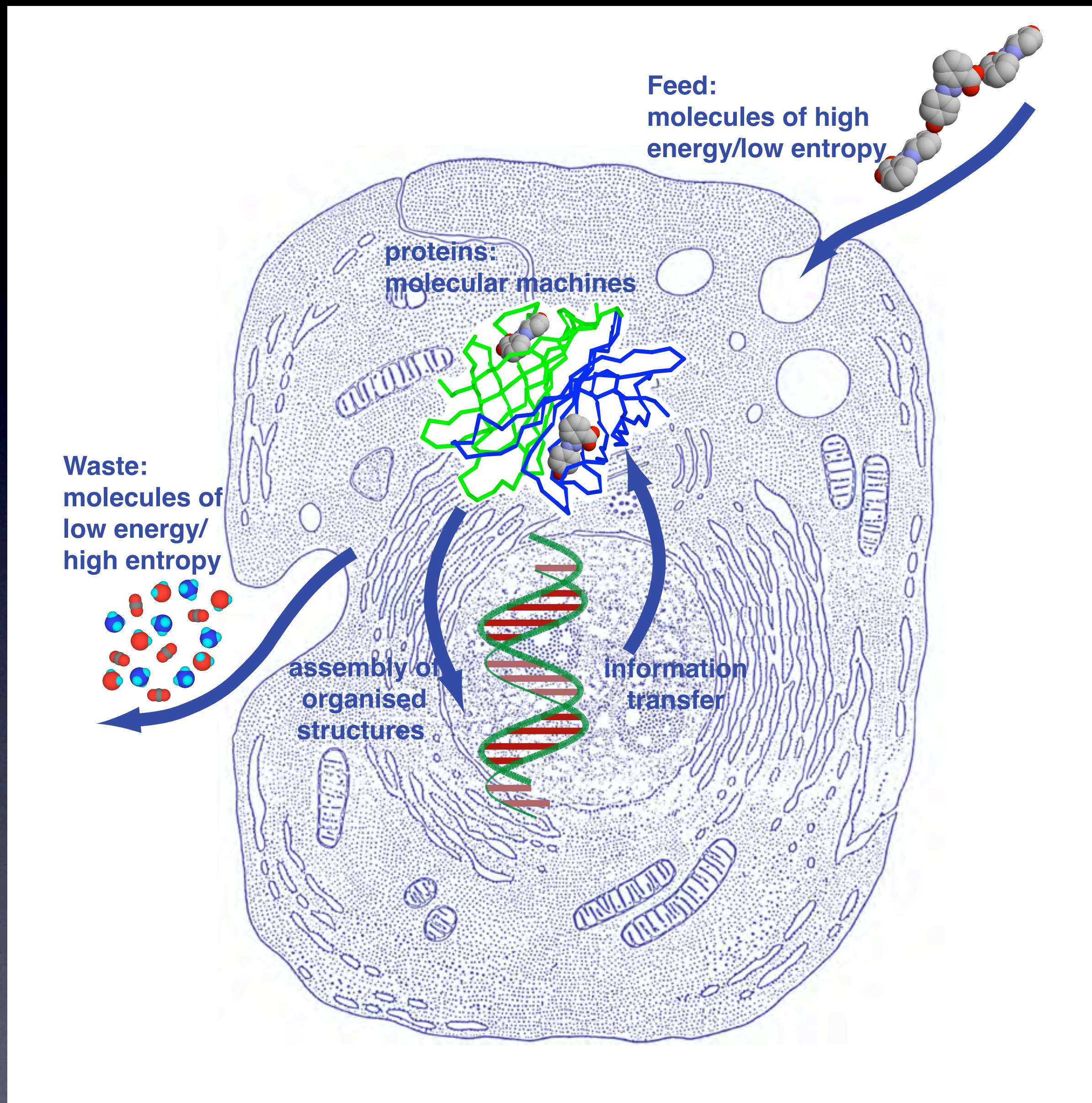
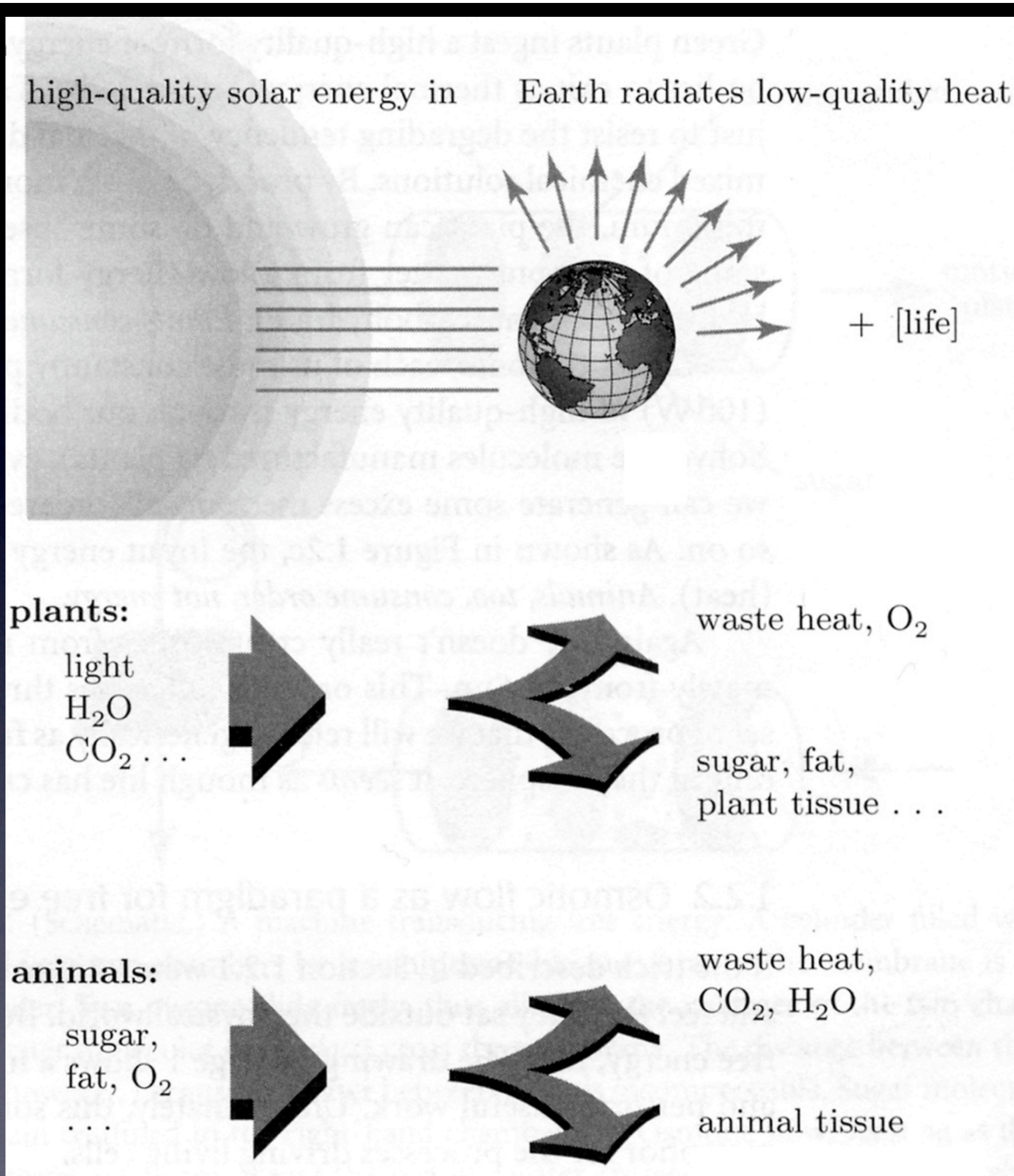


adapted from *Lehninger, Nelson & Cox – Principles of Biochemistry*


Feed:
molecules of high
energy/low entropy
proteins:
molecular machines
Waste:
molecules of
low energy/
high entropy
assembly of
organised
structures
information
transfer



adapted from *Nelson – Biological Physics*

order created via energy throughput in a dissipative system:
sand ripples created by wind

adapted from *Nelson – Biological Physics*

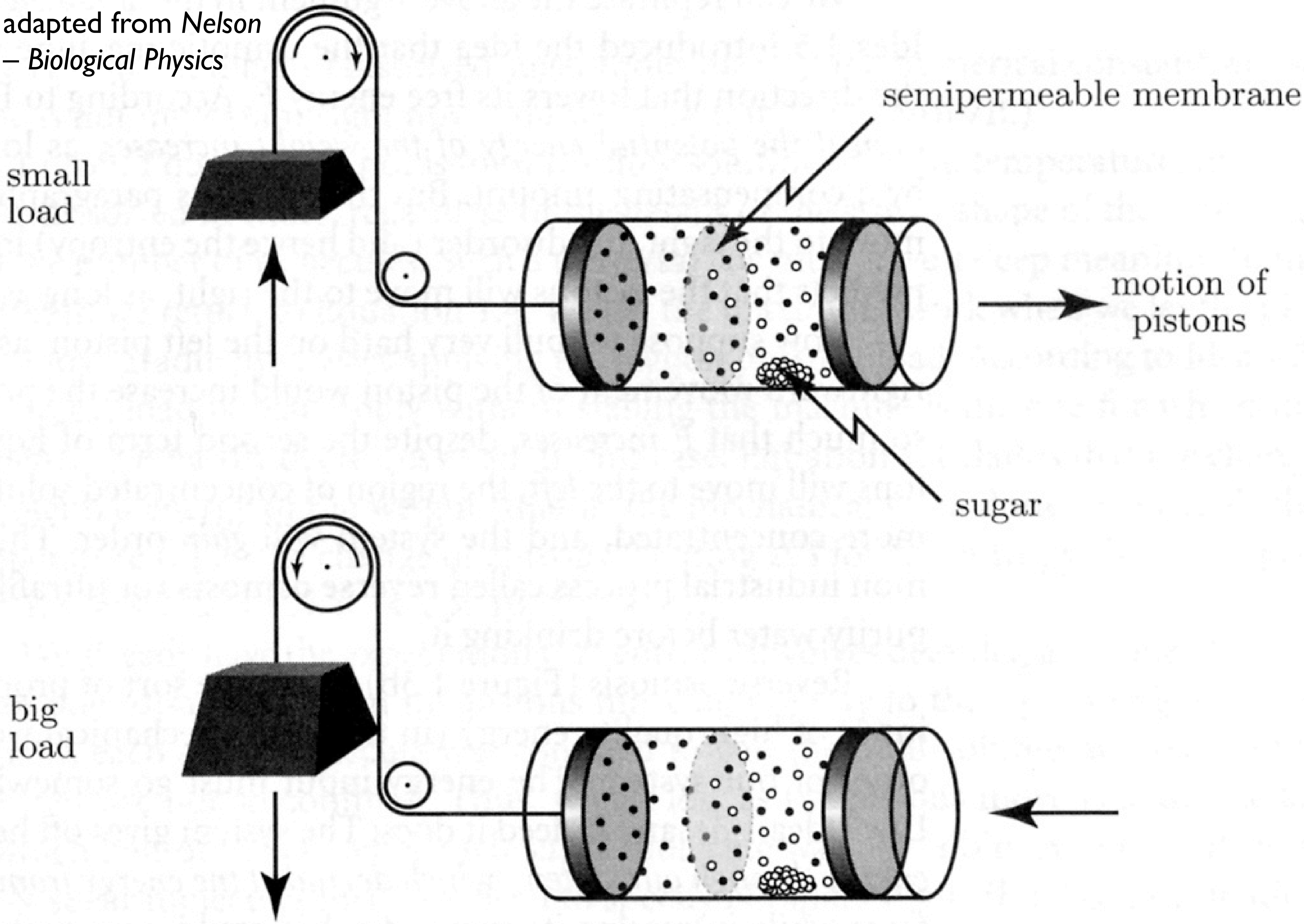
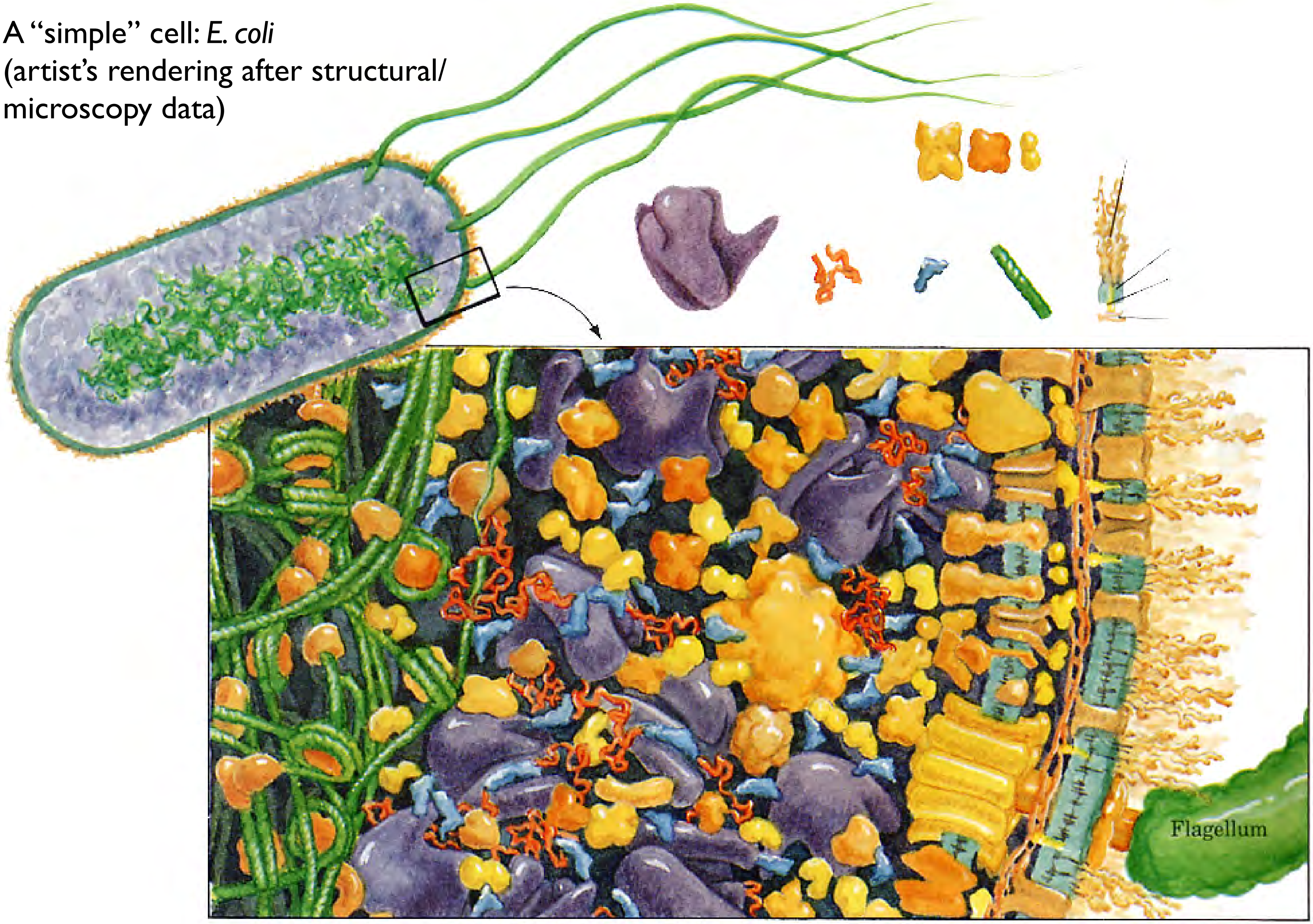
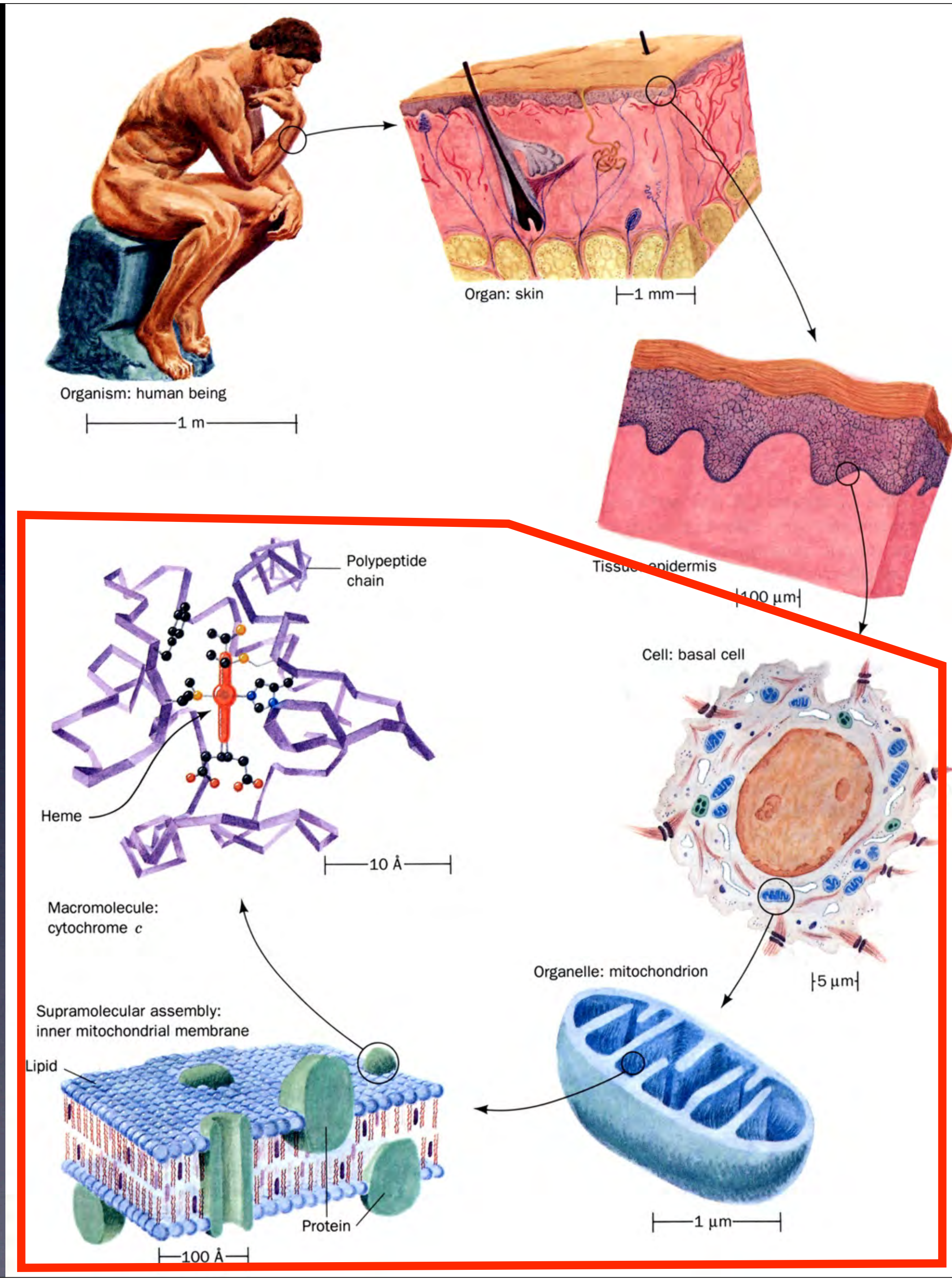


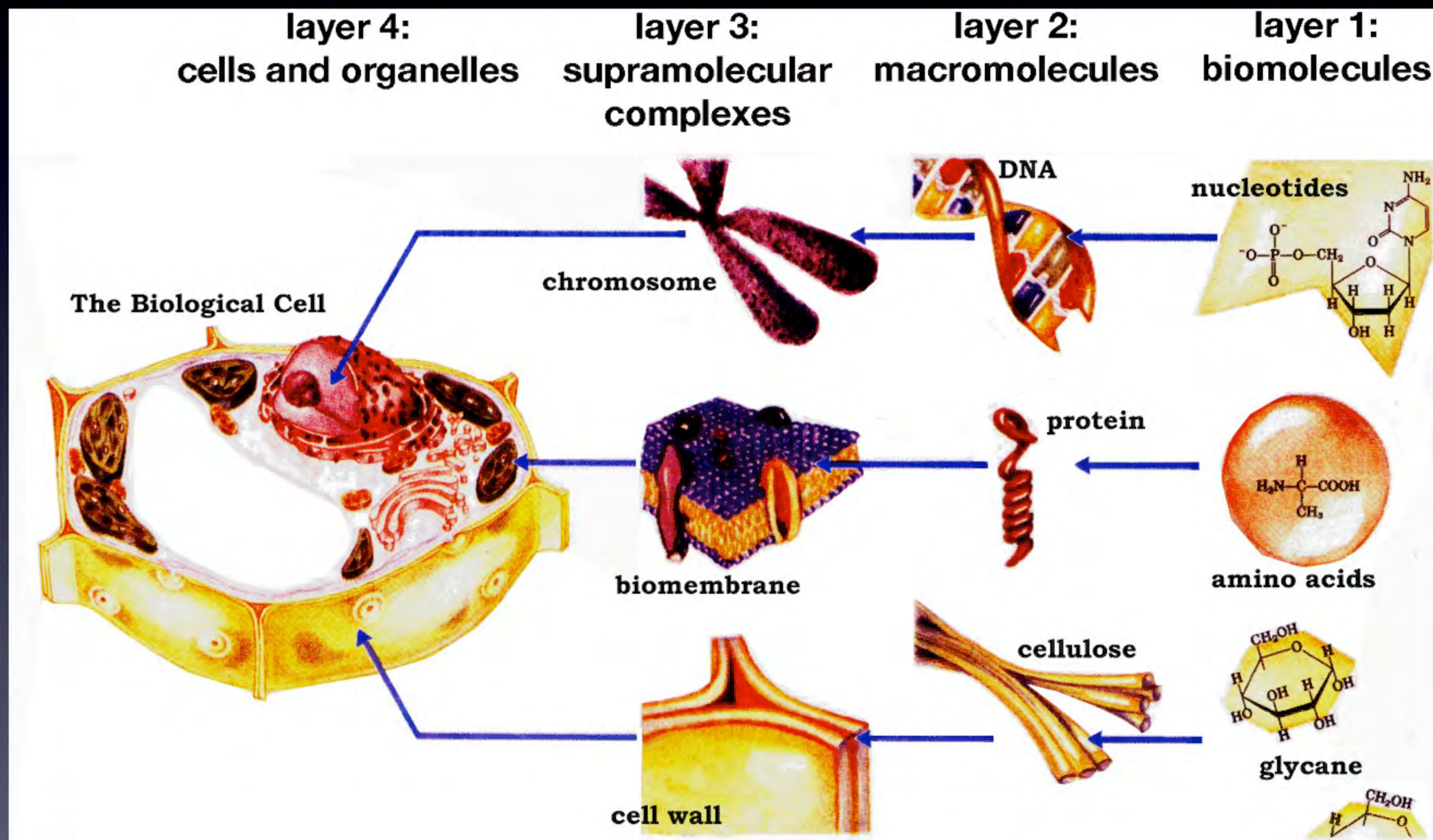
Figure 1.3: (Schematic.) A machine transducing free energy.

A "simple" cell: *E. coli*
(artist's rendering after structural/
microscopy data)

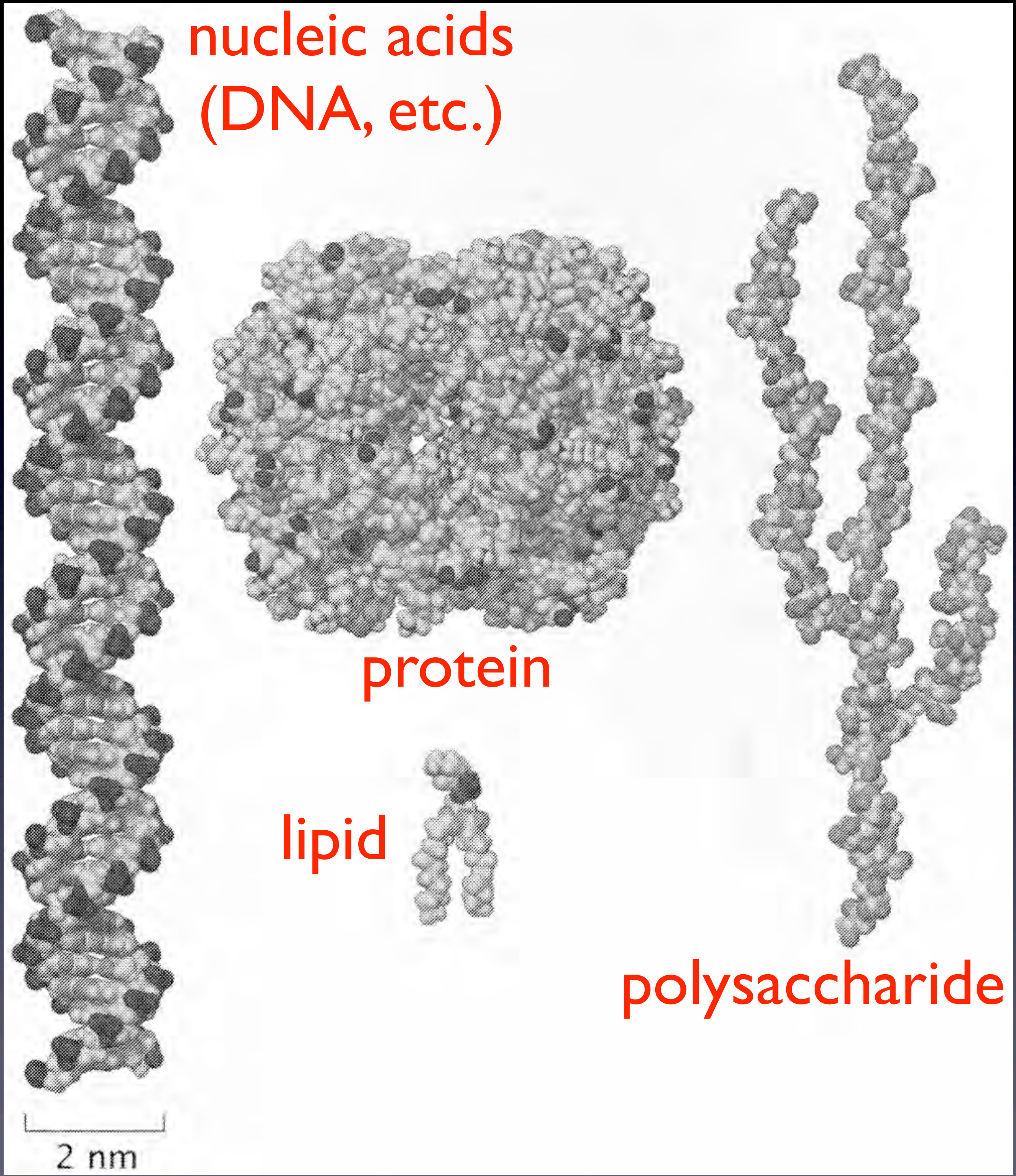




adapted from *Lehninger, Nelson & Cox – Principles of Biochemistry*

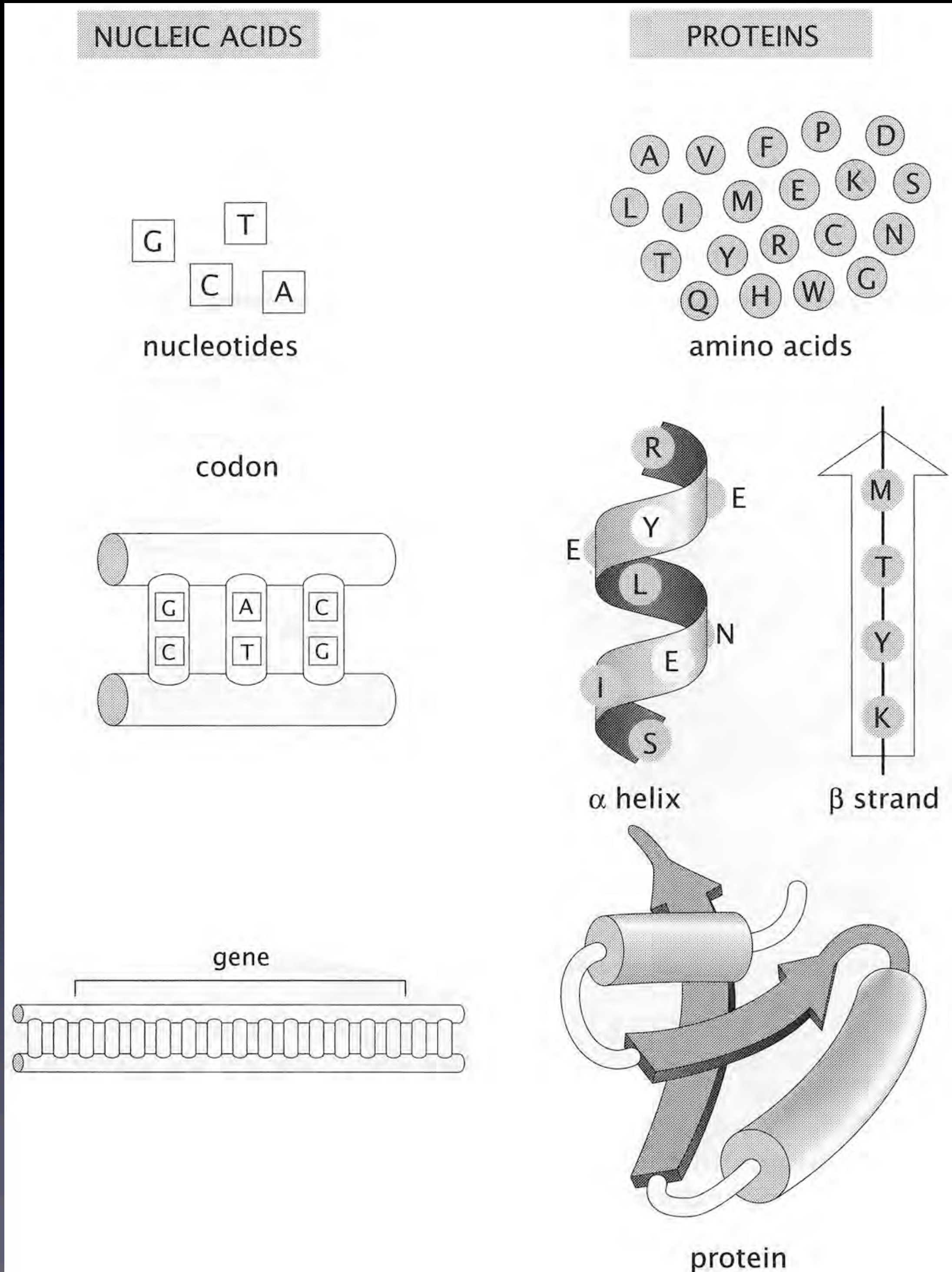


layer 4:
cells and organelles
layer 3:
supramolecular
complexes
layer 2:
macromolecules
layer 1:
biomolecules
DNA
nucleotides
chromosome
The Biological Cell
protein
biomembrane
amino acids
cellulose
glycane
cell wall



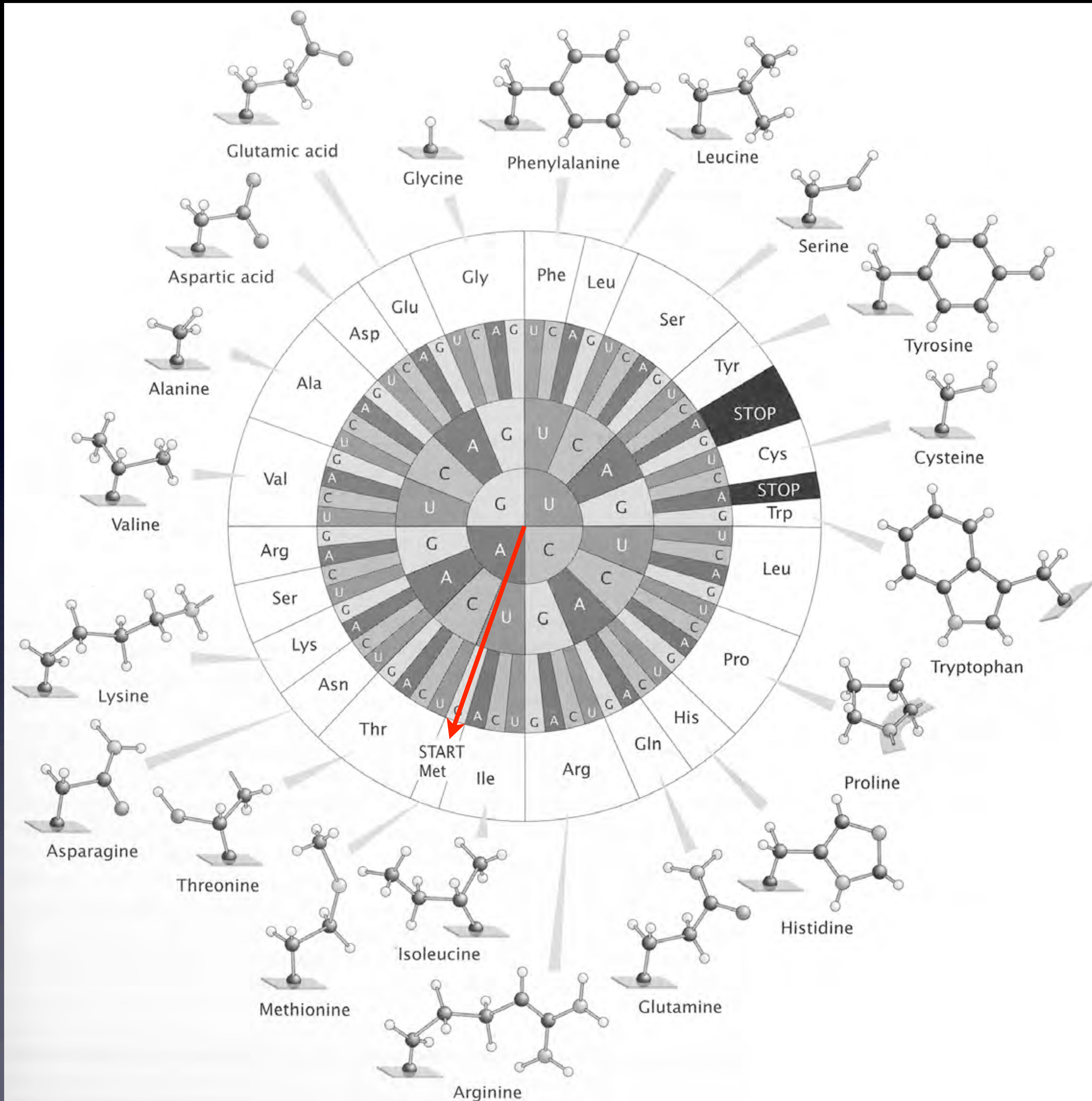
... only four classes of
biomolecules!

adapted from *Phillips et al.* –
Physical Biology of the Cell



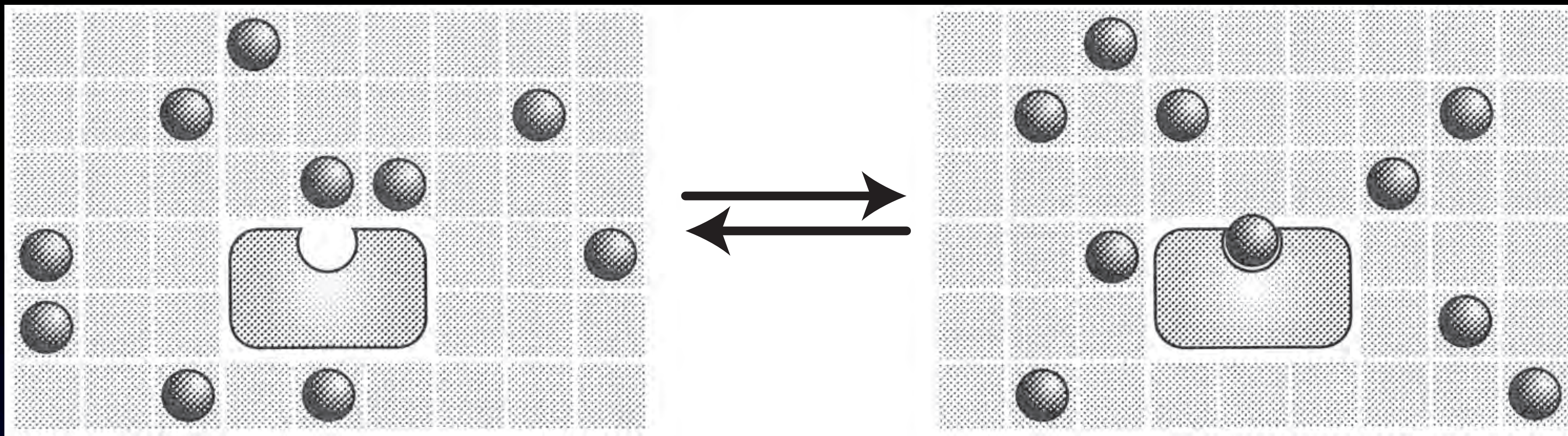
Two "*polymer languages*"
are important in biology

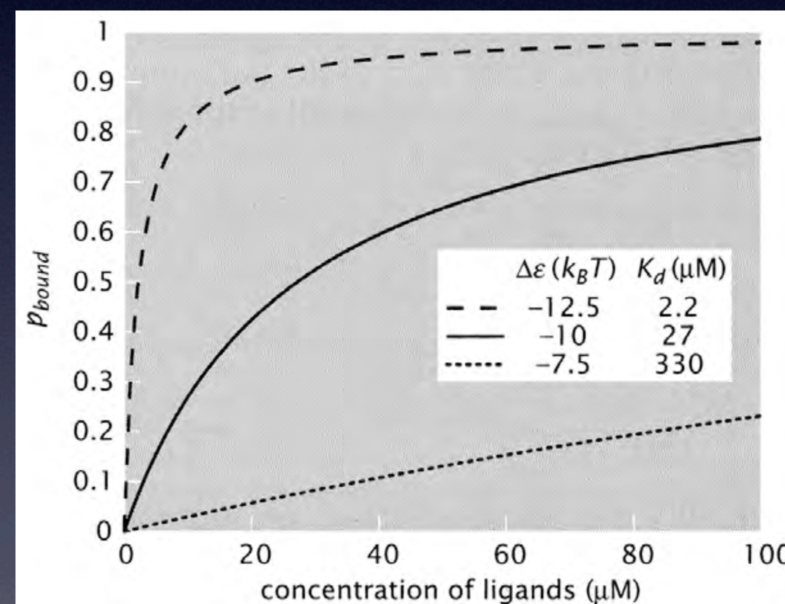
adapted from *Phillips et al.* – *Physical Biology of the Cell*



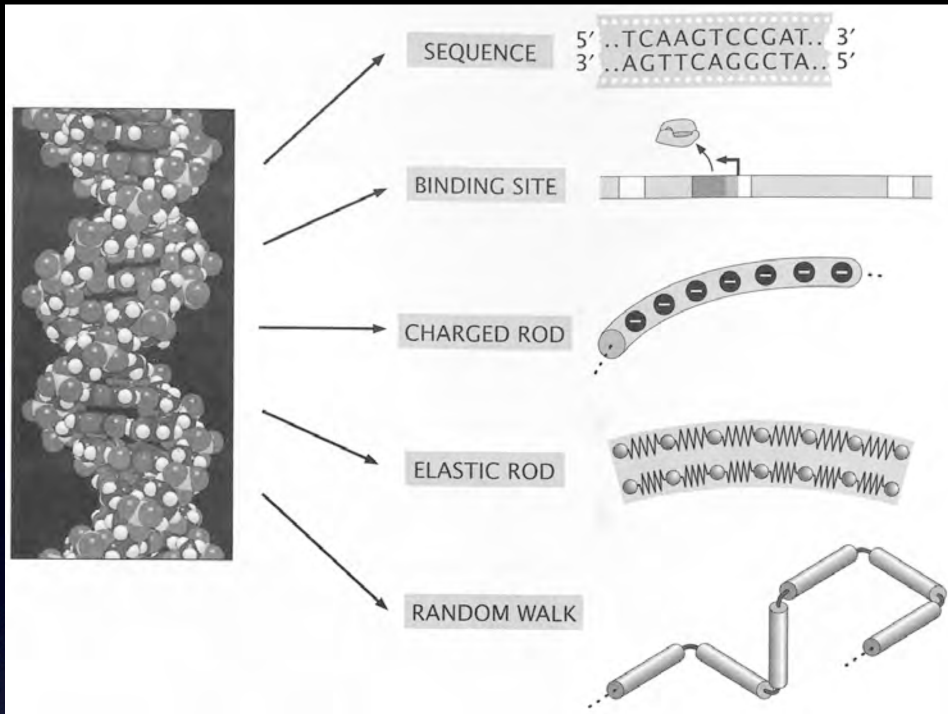
Translation between the "polymer languages": The *Genetic Code*

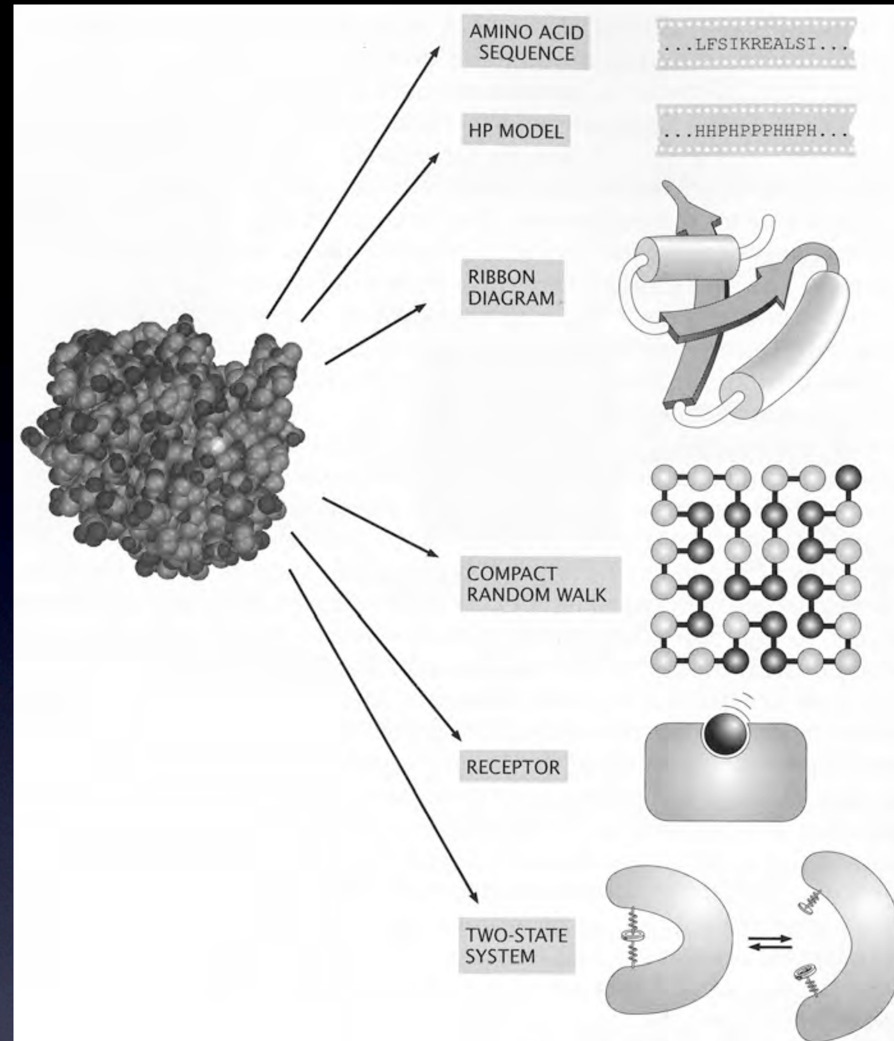
adapted from *Phillips et al. Physical Biology of the Cell*





adapted from *Phillips / Kondev / Theriot – Physical Biology of the Cell*





model building in biophysics: biological *cartoons* represent *idealizations* of different aspects of relevance in different contexts

adapted from *Phillips et al.* – *Physical Biology of the Cell*

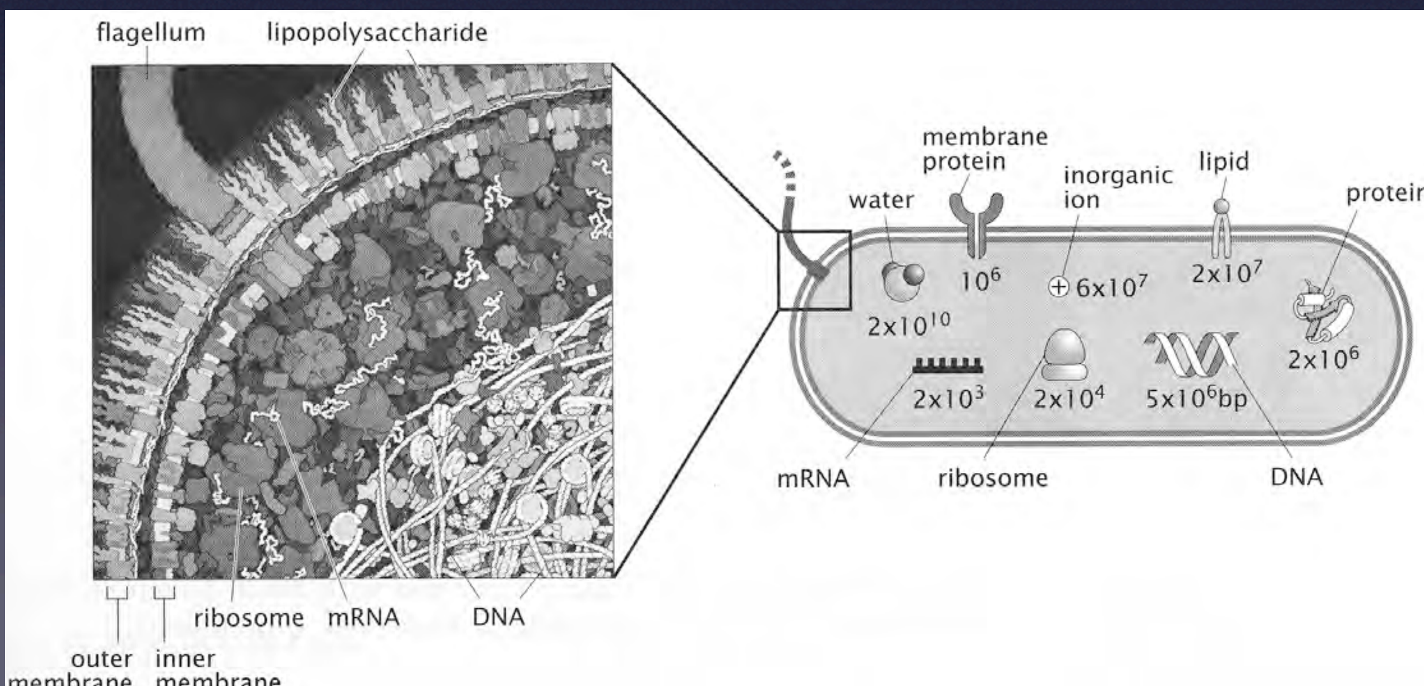
E. coli

adapted from *Phillips et al.* – *Physical Biology of the Cell*

cell volume	$V_{\text{E coli}}$	1 μm^3
cell mass	$m_{\text{E coli}}$	1 pg
repl cycle time	$t_{\text{E coli}}$	3,000 s
surface area	$A_{\text{E coli}}$	6 μm^2
genome length	$N_{\text{E coli}}$	5×10^6 bp
swimming speed	$v_{\text{E coli}}$	20 μm/s

biology by numbers:

order-of-magnitude estimates are *essential* for model building!

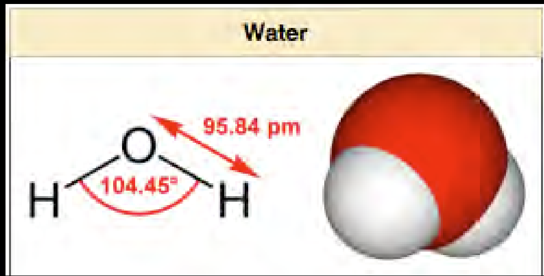


double-stranded DNA

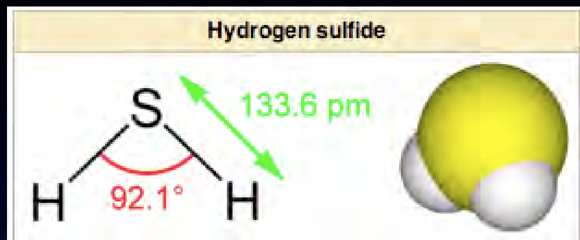
length per bp	l_{bp}	0.34 nm
volume per bp	V_{bp}	1 nm^3
charge density per unit length	λ_{DNA}	2 e/0.34 nm
persistence length	ξ_{DNA}	50 nm

amino acids and proteins

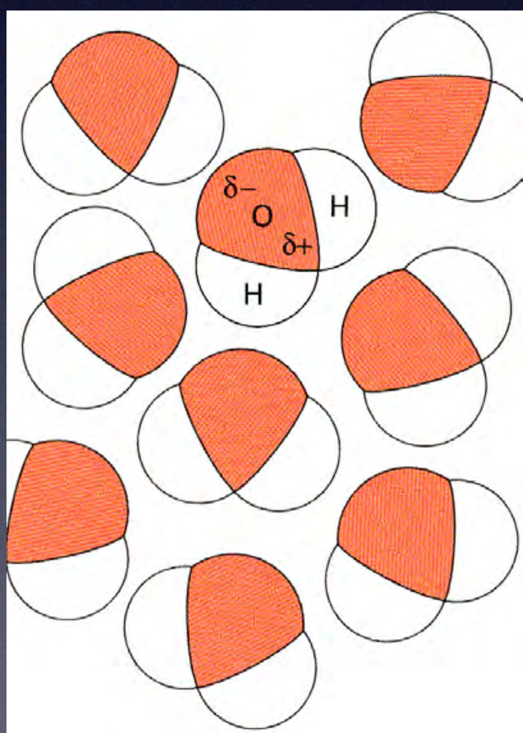
typical diameter	$d_{protein}$	4–5 nm
typical volume	$V_{protein}$	25 nm^3
avrg. mass of AA	M_{AA}	100 Da
typ. protein mass	$M_{protein}$	30 kDa
protein conc in cell	$c_{protein}$	300 mg/mL
diffusion const in water	$D_{protein}$	100 $\mu m^2/s$

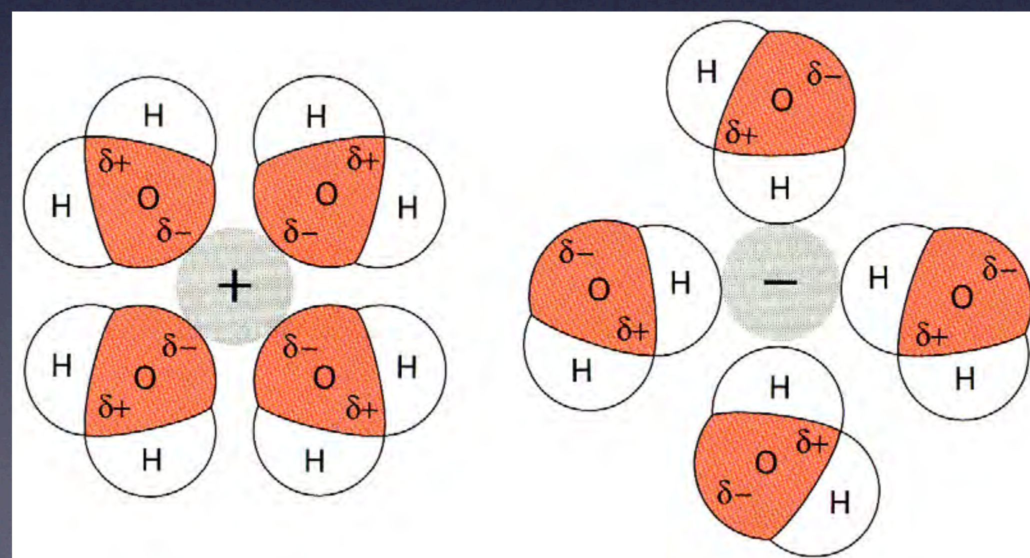


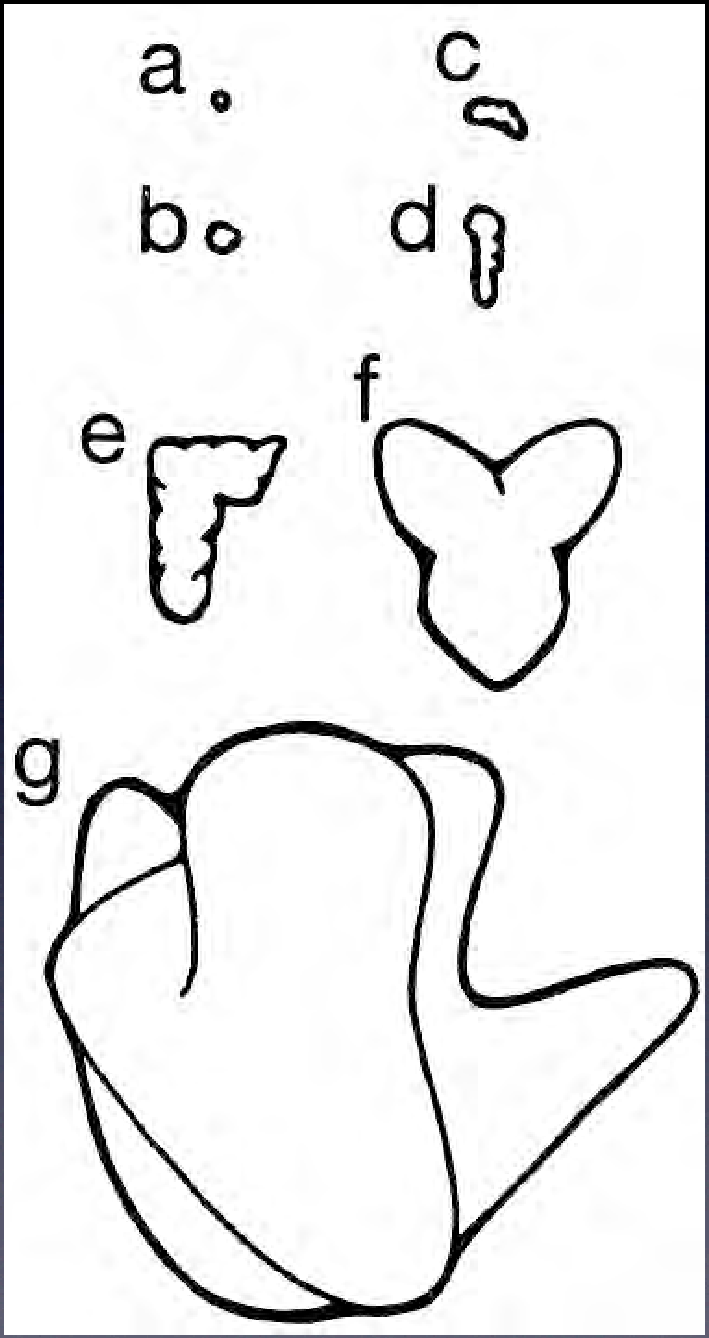
dipole moment: $e \cdot \vec{r}$ = 1.85 D (1 D = 3.33×10^{-30} Cm)
→ water dielectric constant $\epsilon \sim 80$ (room temp)
→ boiling point: T_B = 373 K (extraordinarily high!)

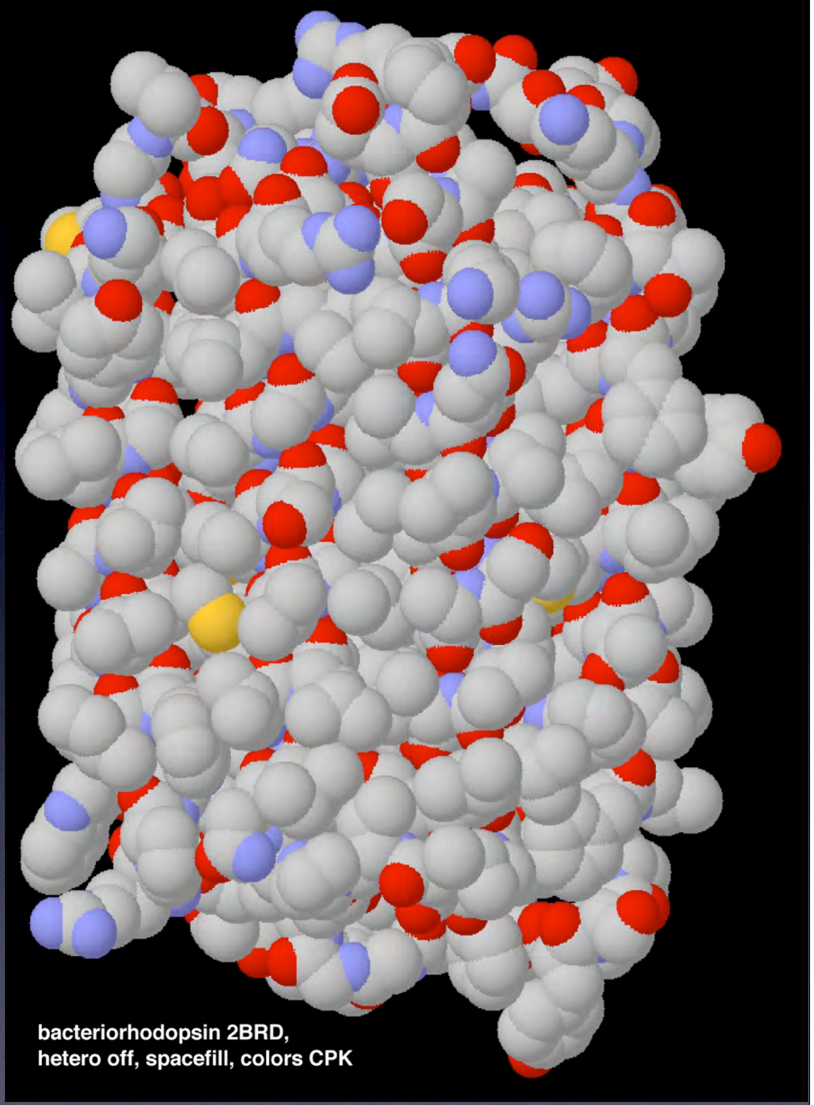


dipole moment: $e \cdot \vec{r}$ = 0.97 D
→ boiling point: T_B = 213 K

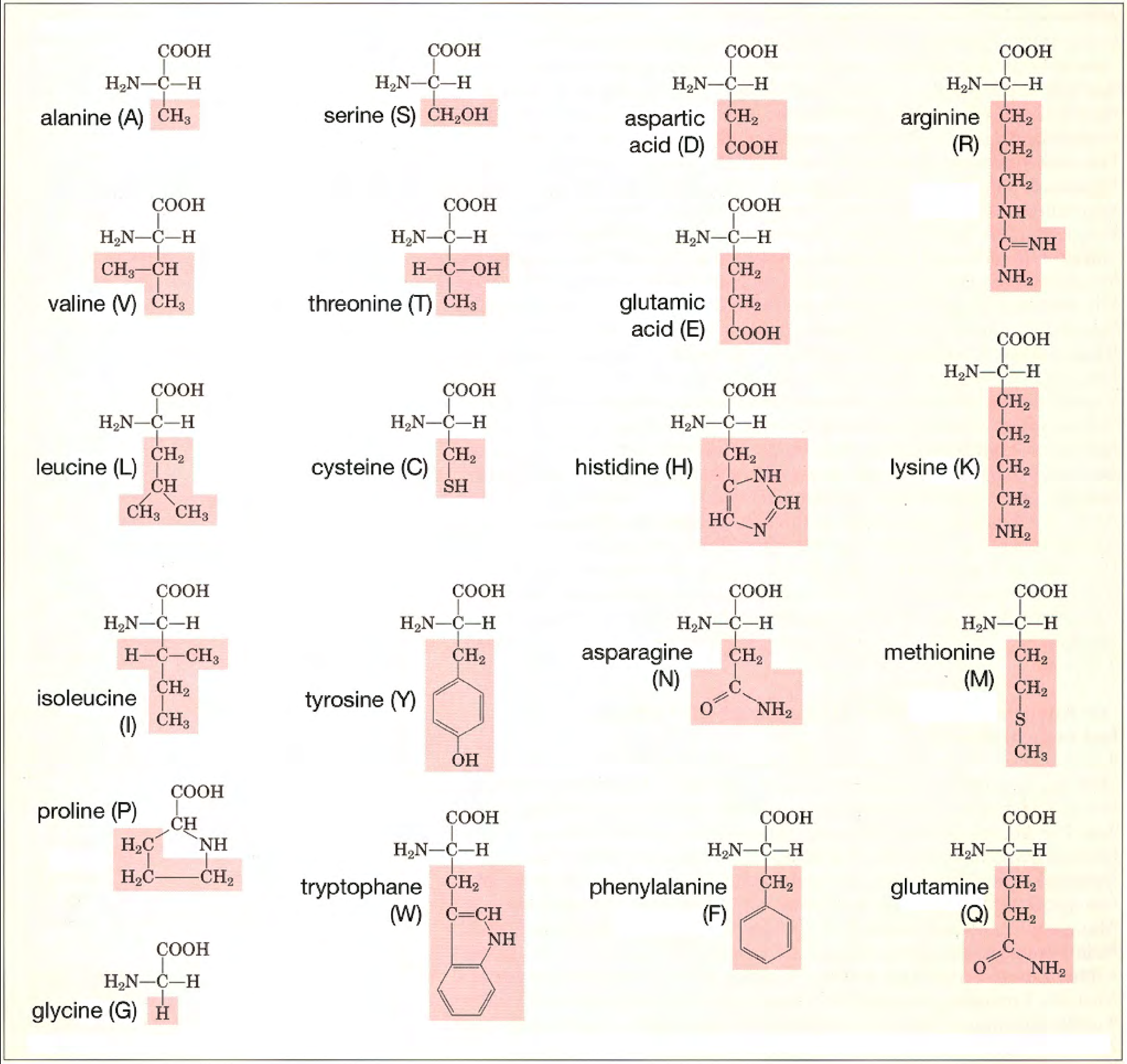


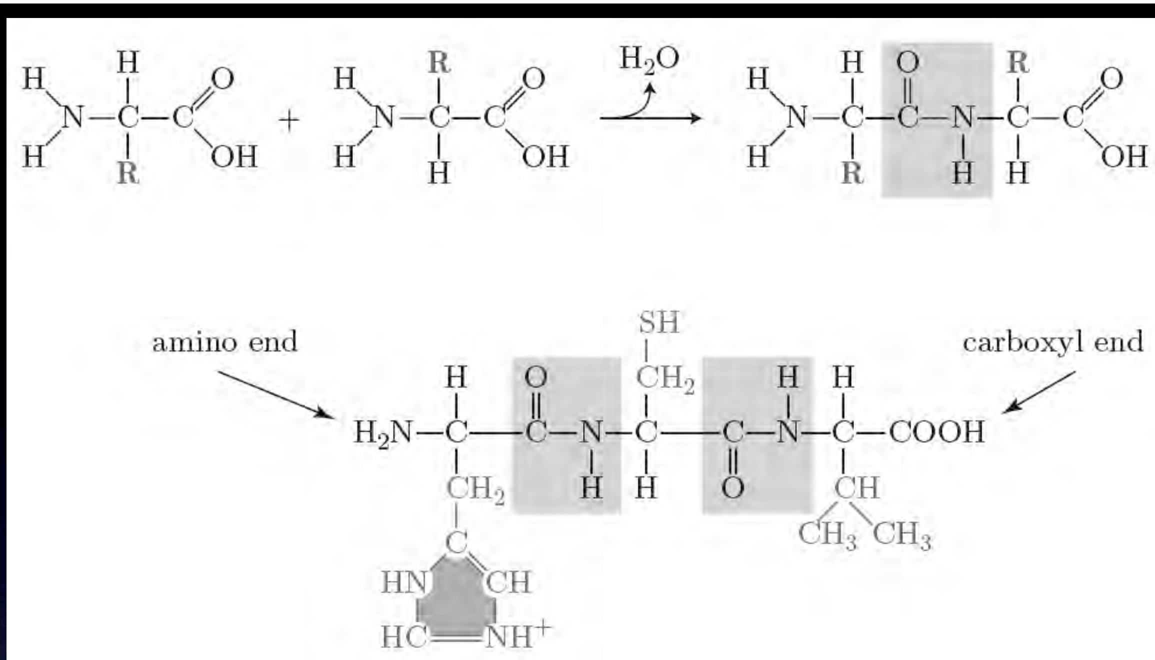


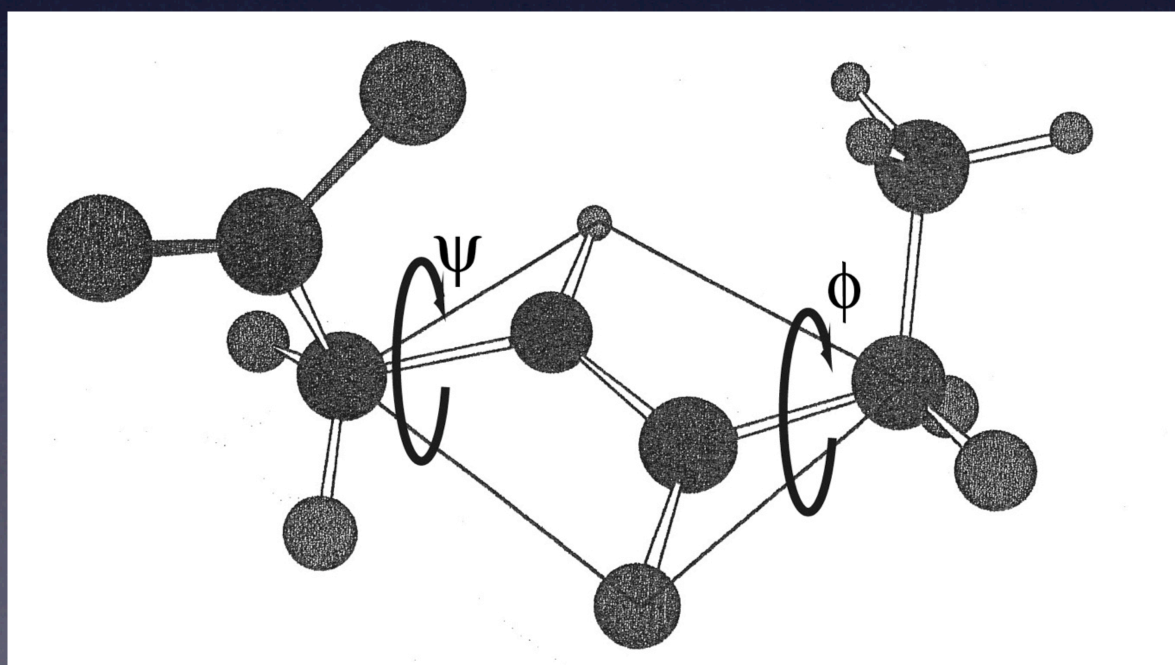




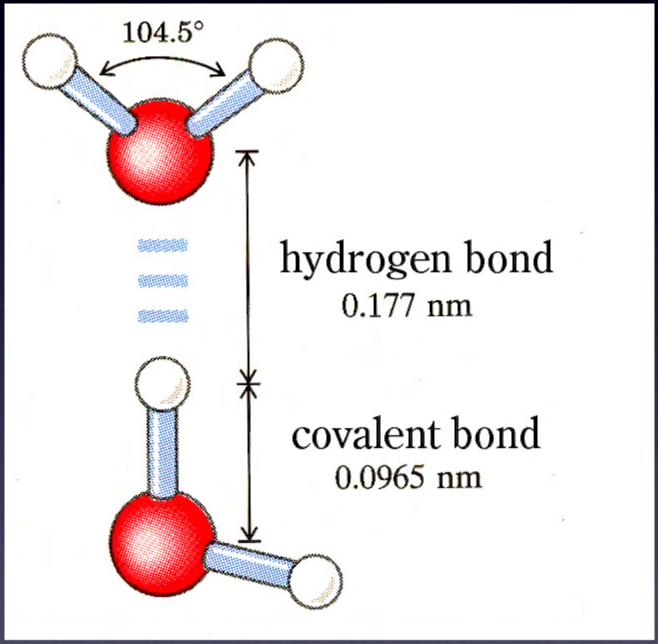
adapted from *Nelson – Biological Physics*

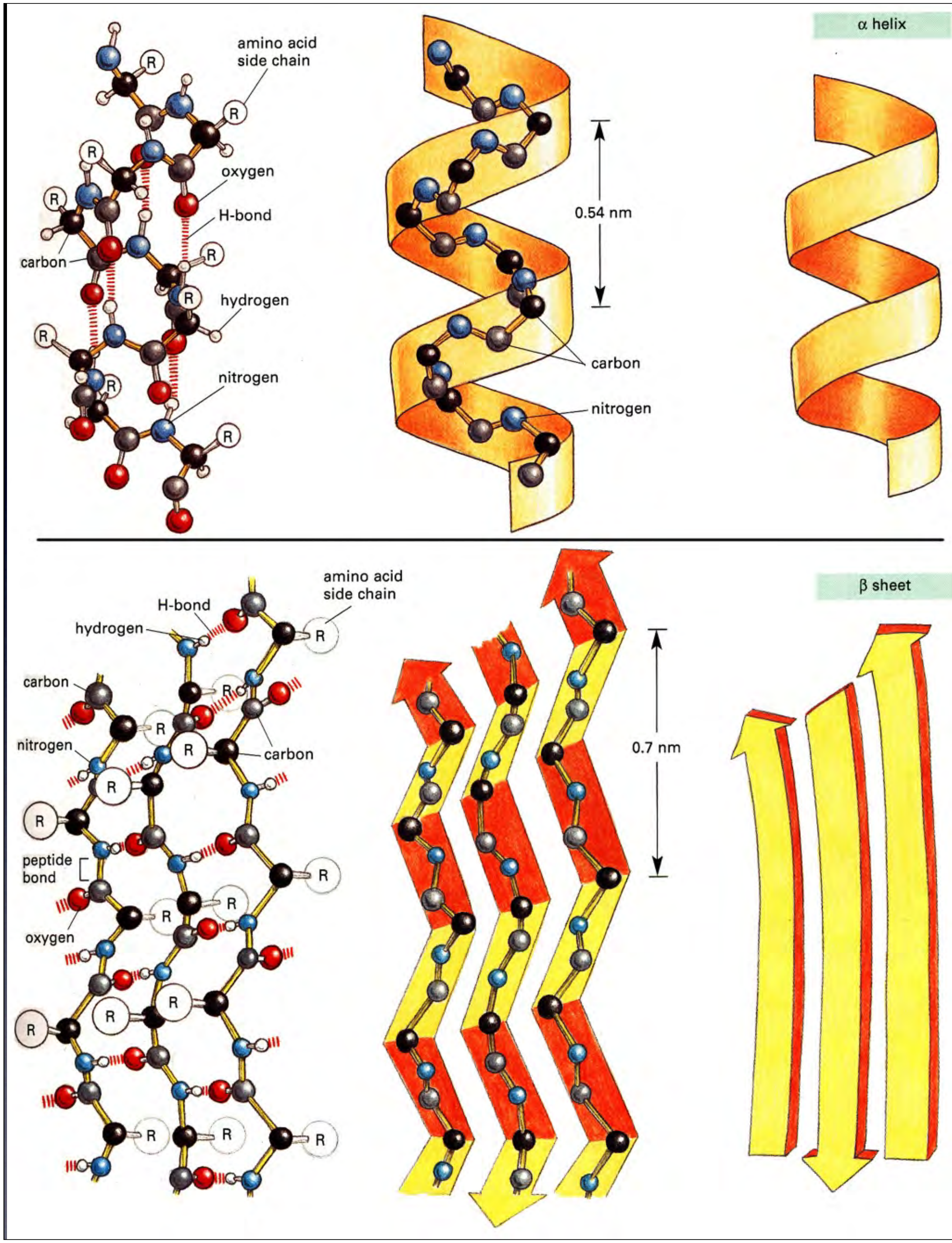

alanine (A)
serine (S)
aspartic acid (D)
arginine (R)
valine (V)
threonine (T)
glutamic acid (E)
leucine (L)
cysteine (C)
histidine (H)
lysine (K)
isoleucine (I)
tyrosine (Y)
asparagine (N)
methionine (M)
proline (P)
glycine (G)
tryptophane (W)
phenylalanine (F)
glutamine (Q)

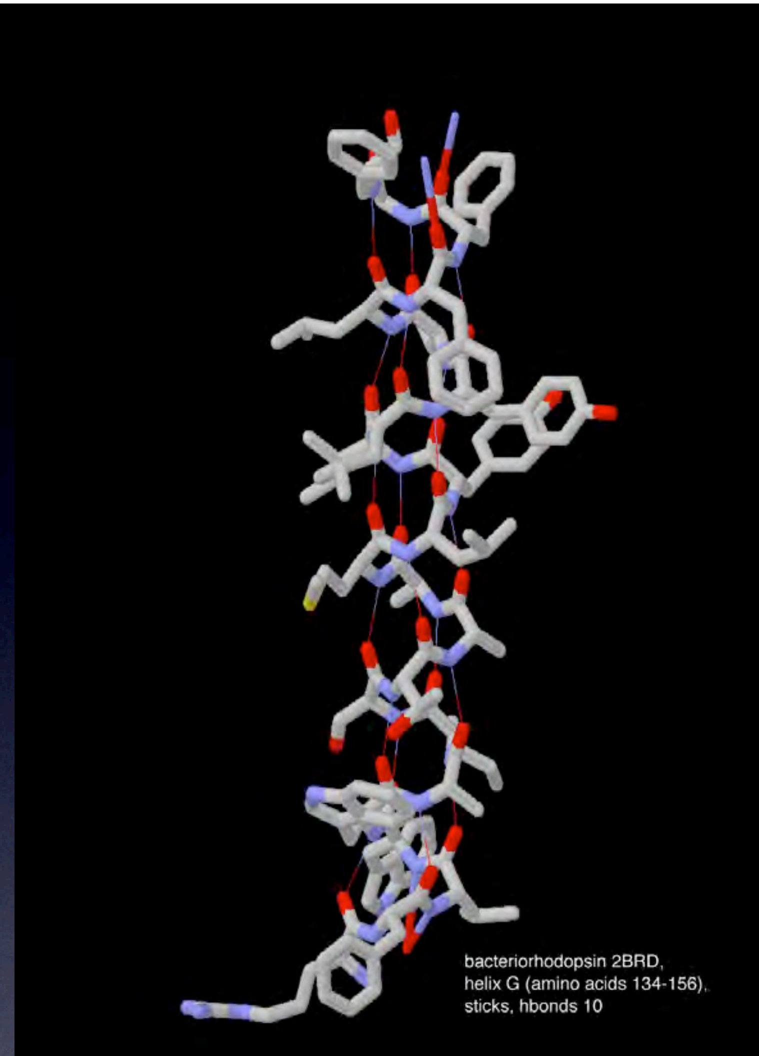




adapted from *Nelson*
– Biological Physics

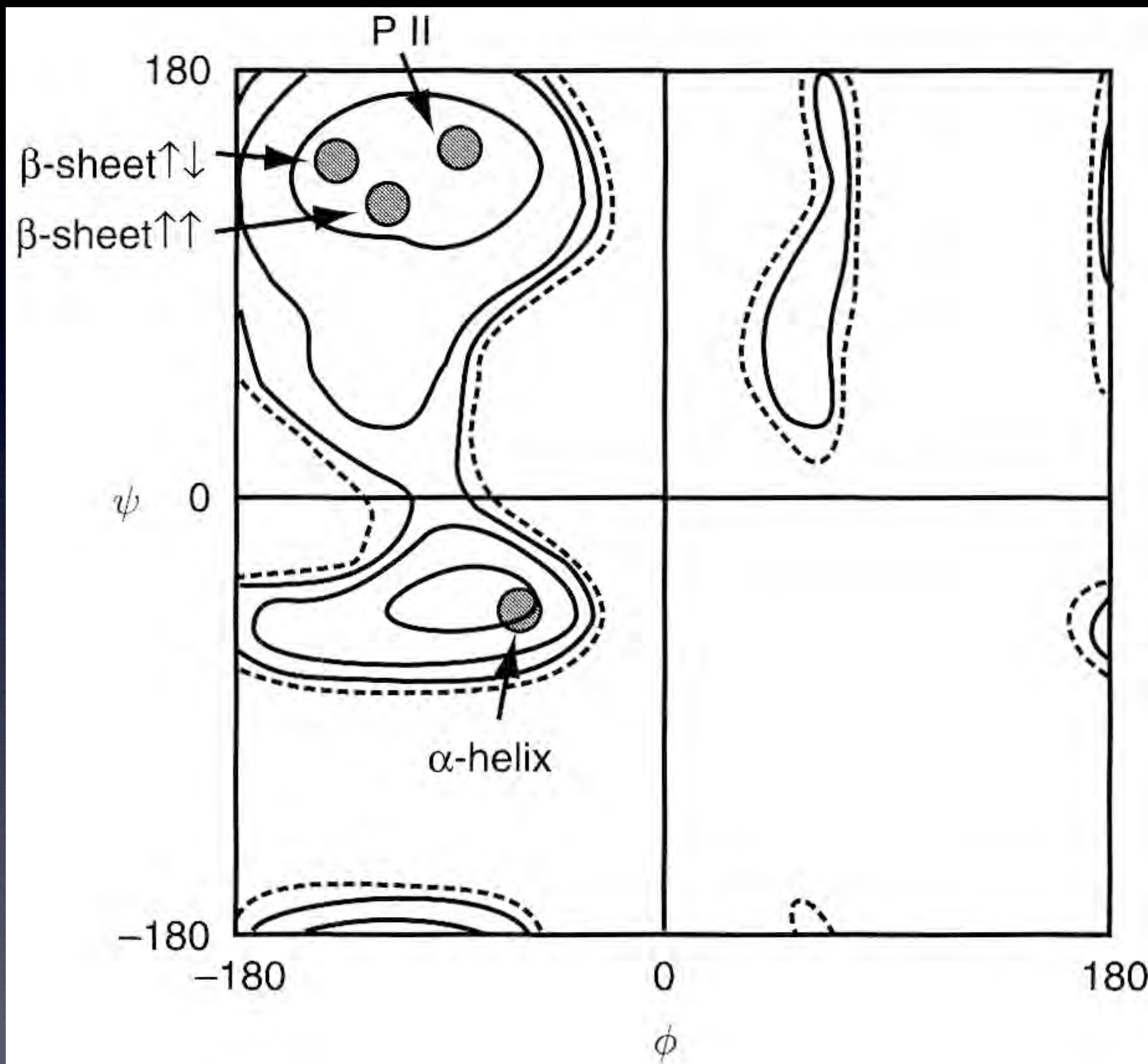

104.5°
hydrogen bond
0.177 nm
covalent bond
0.0965 nm

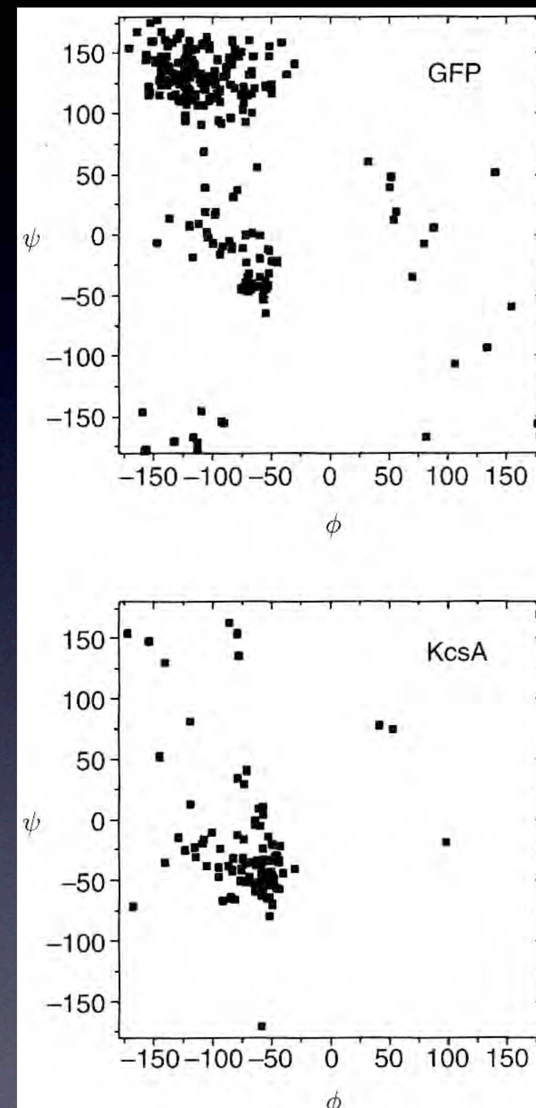




adapted from *Alberts et al.* –
Molecular Biology of the Cell

limitations to dihedral angles: Ramachandran diagram

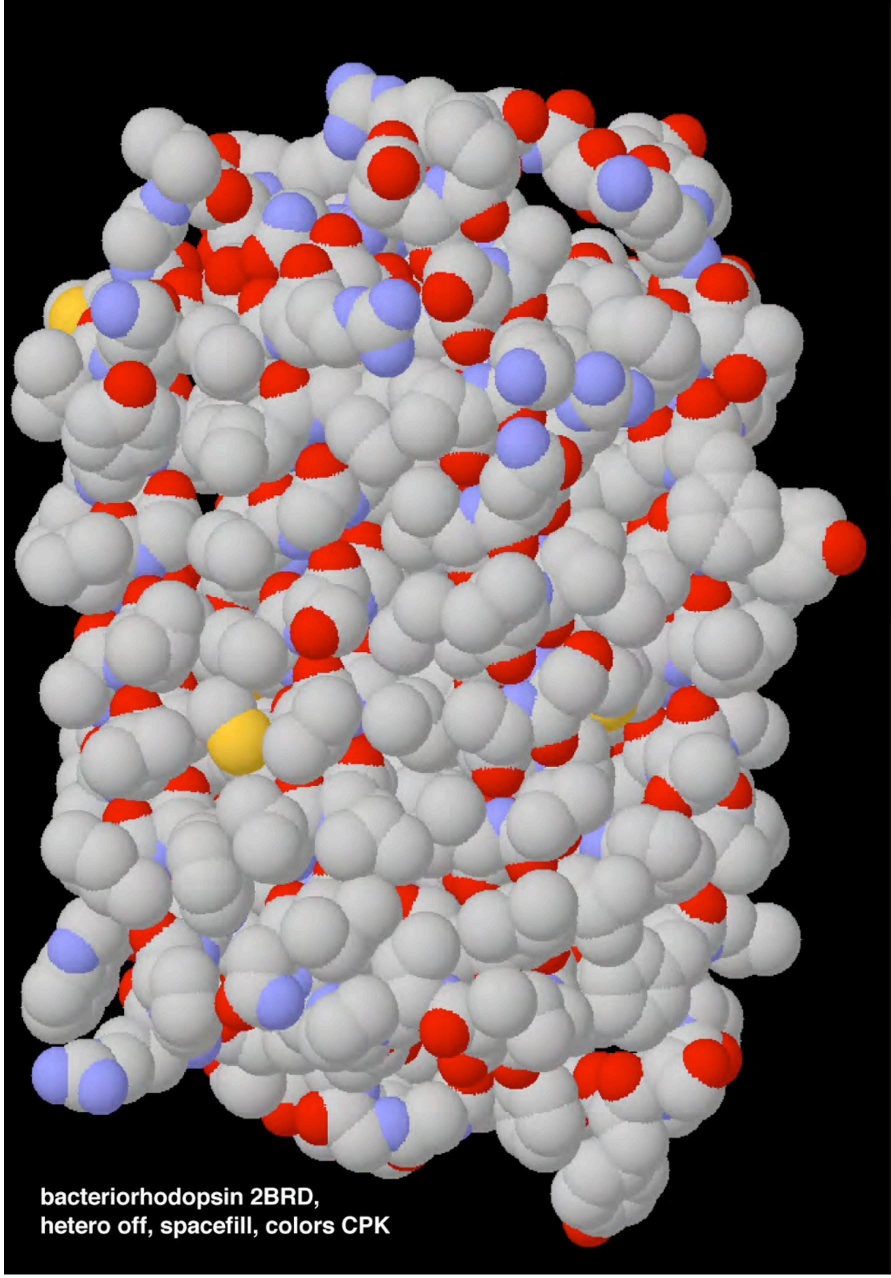


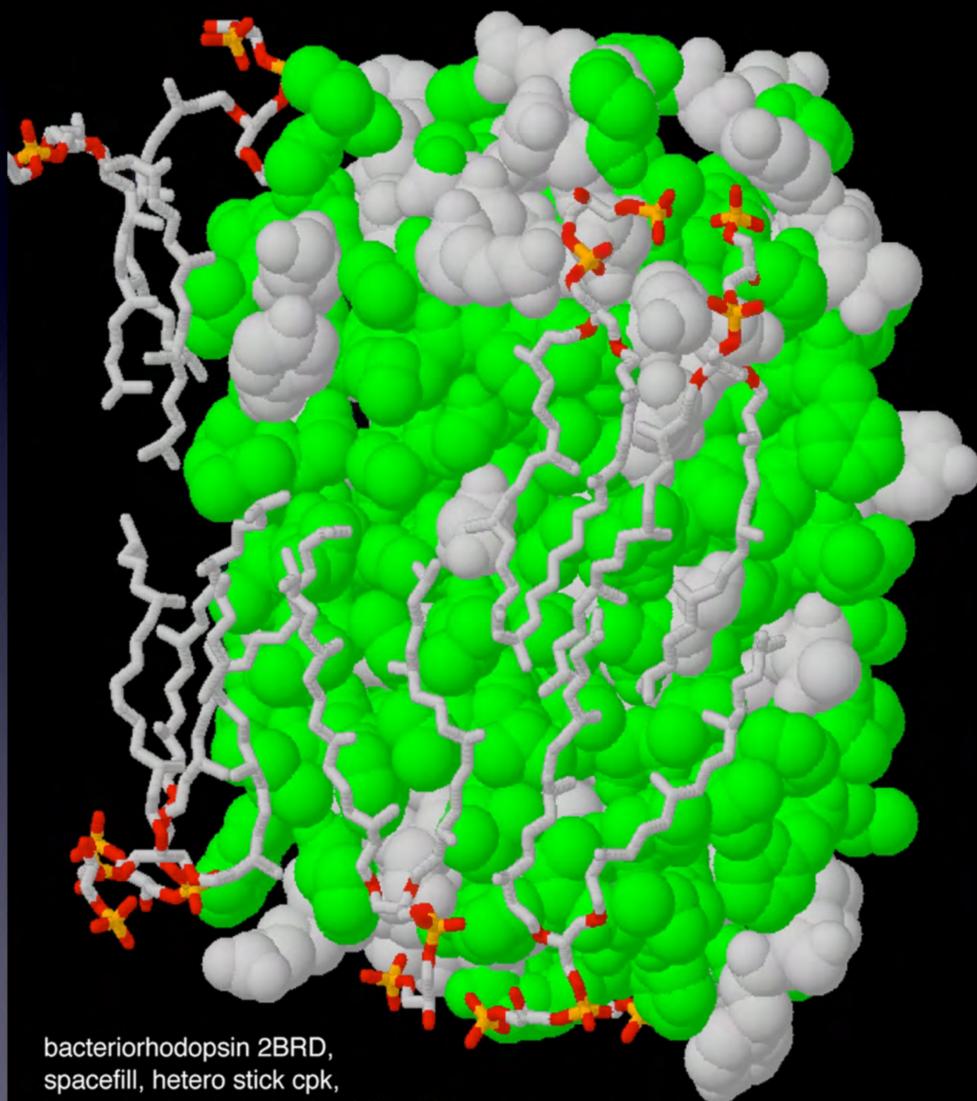


adapted from *Jackson*
– Molecular & Cellular Biophysics

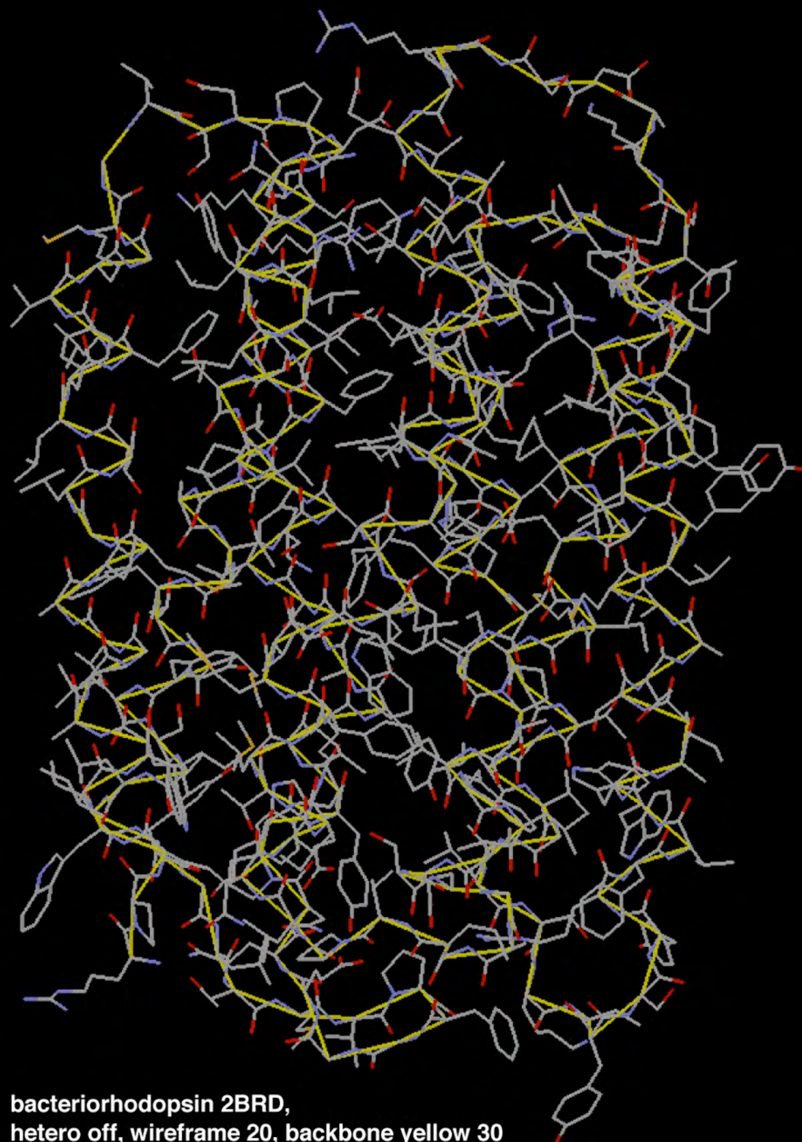
example:

bacteriorhodopsin, a membrane-bound converter for light into electrical energy

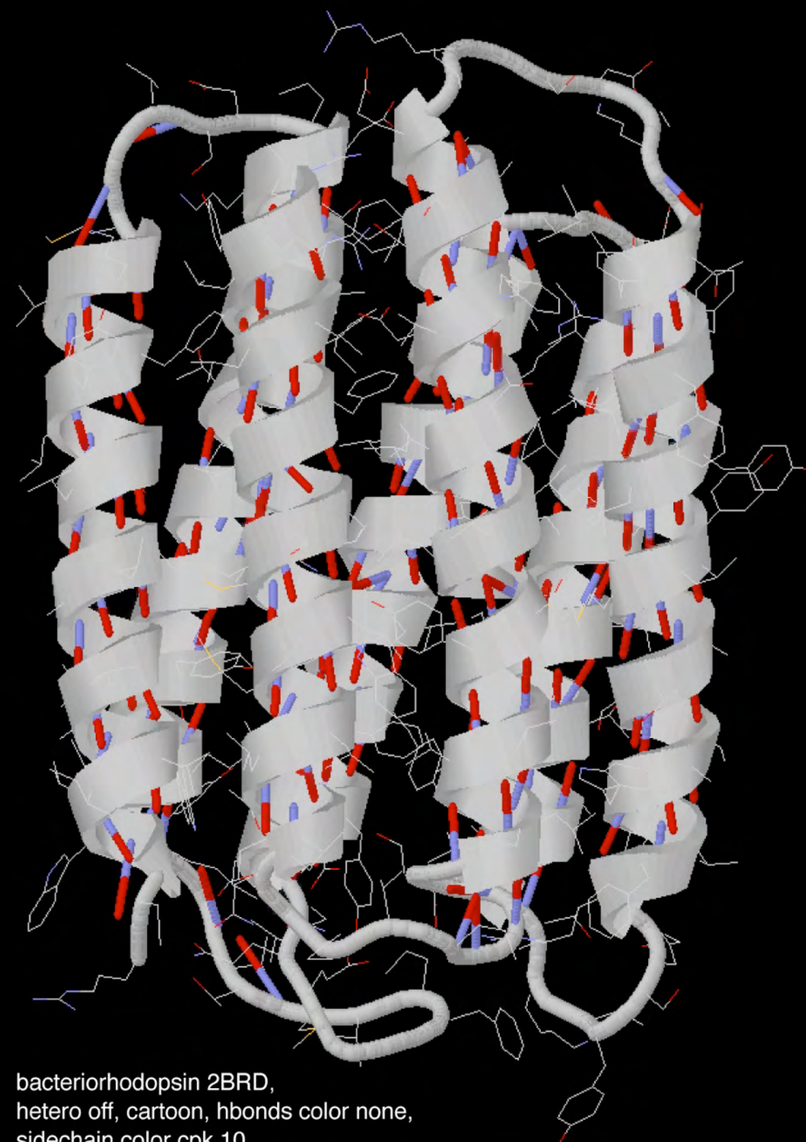




bacteriorhodopsin 2BRD,
spacefill, hetero stick cpk,
hydrophobic green, hydrophilic gray



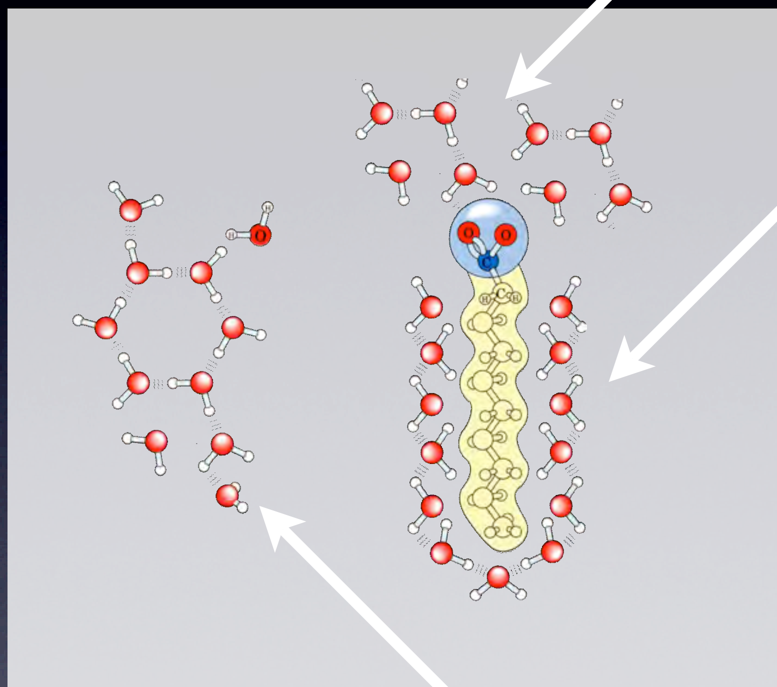
bacteriorhodopsin 2BRD,
hetero off, wireframe 20, backbone yellow 30



bacteriorhodopsin 2BRD,
hetero off, cartoon, hbonds color none,
sidechain color cpk 10

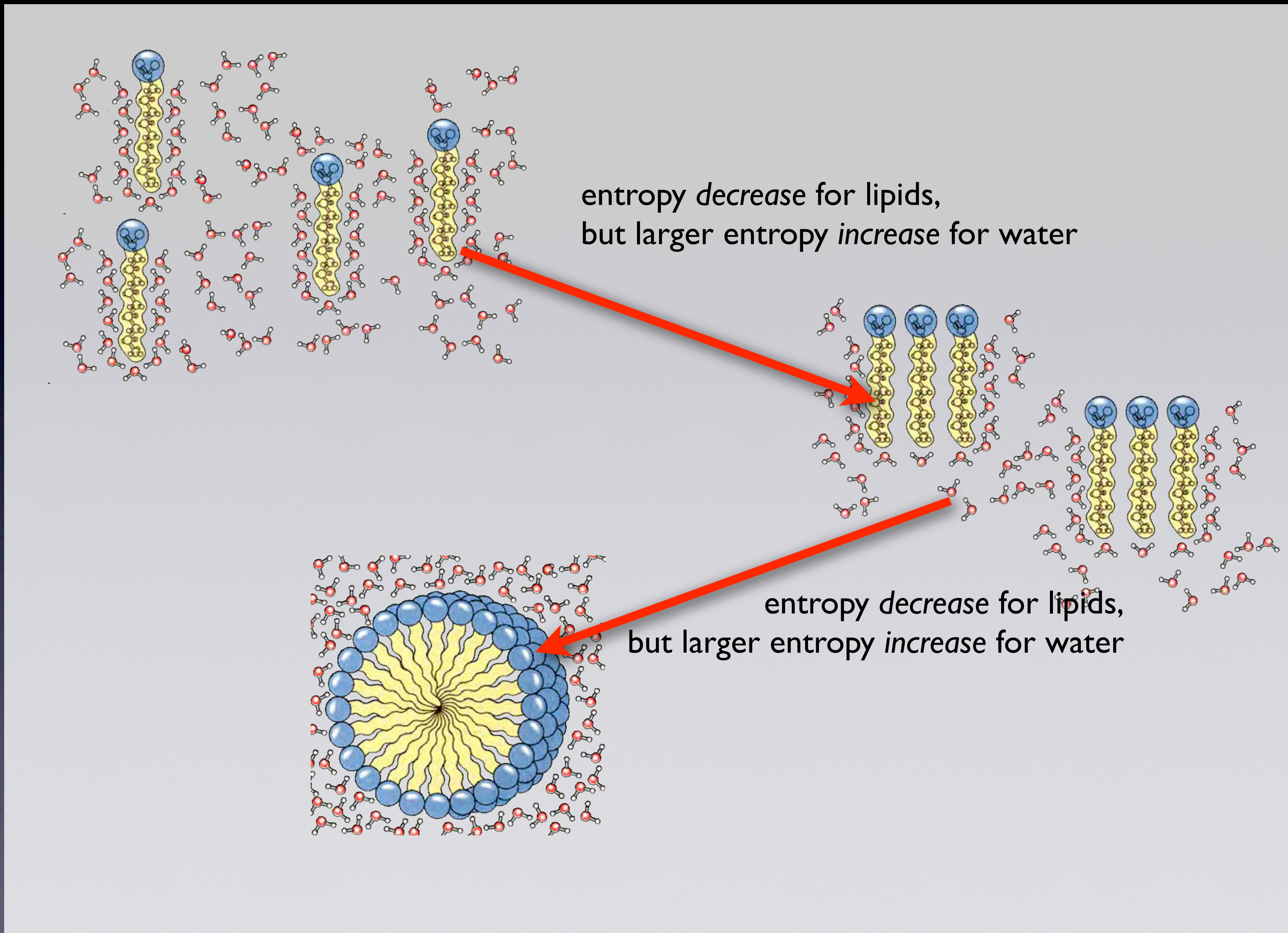
water near hydrophilic headgroup:
same structure as in “free“ water

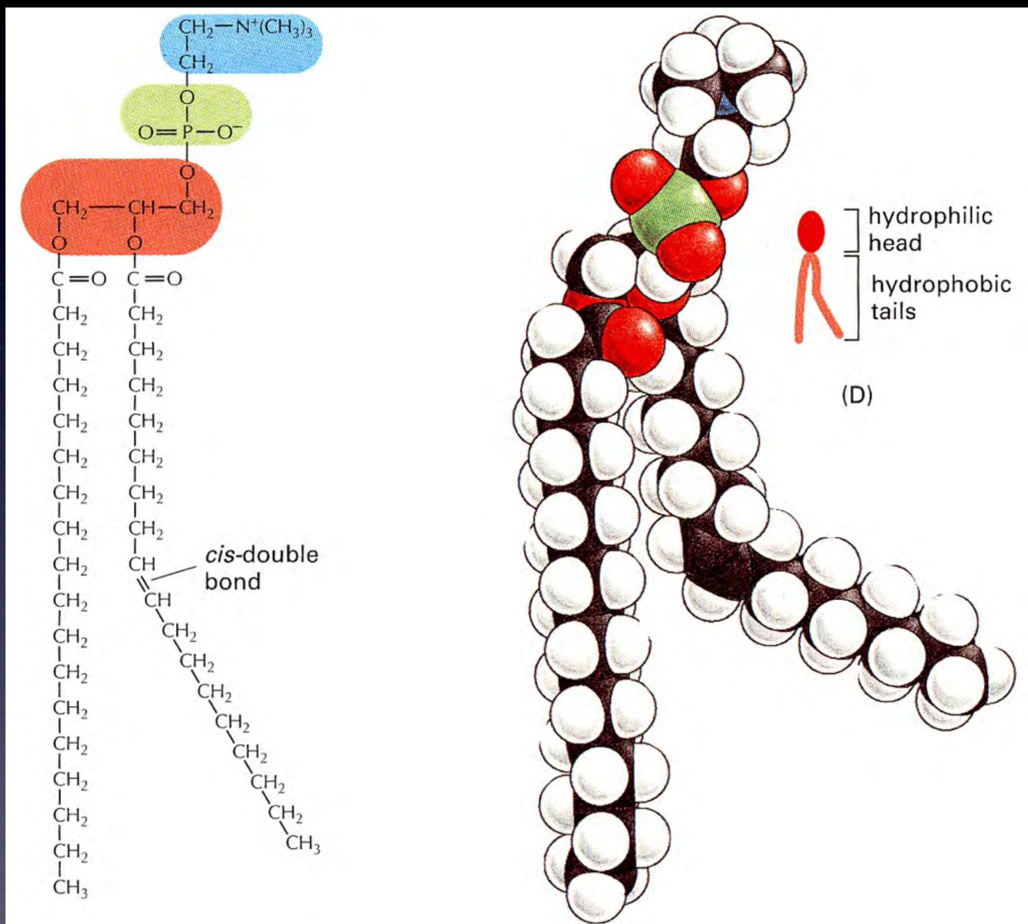
water near hydrophobic tail:
highly ordered water: *low* entropy



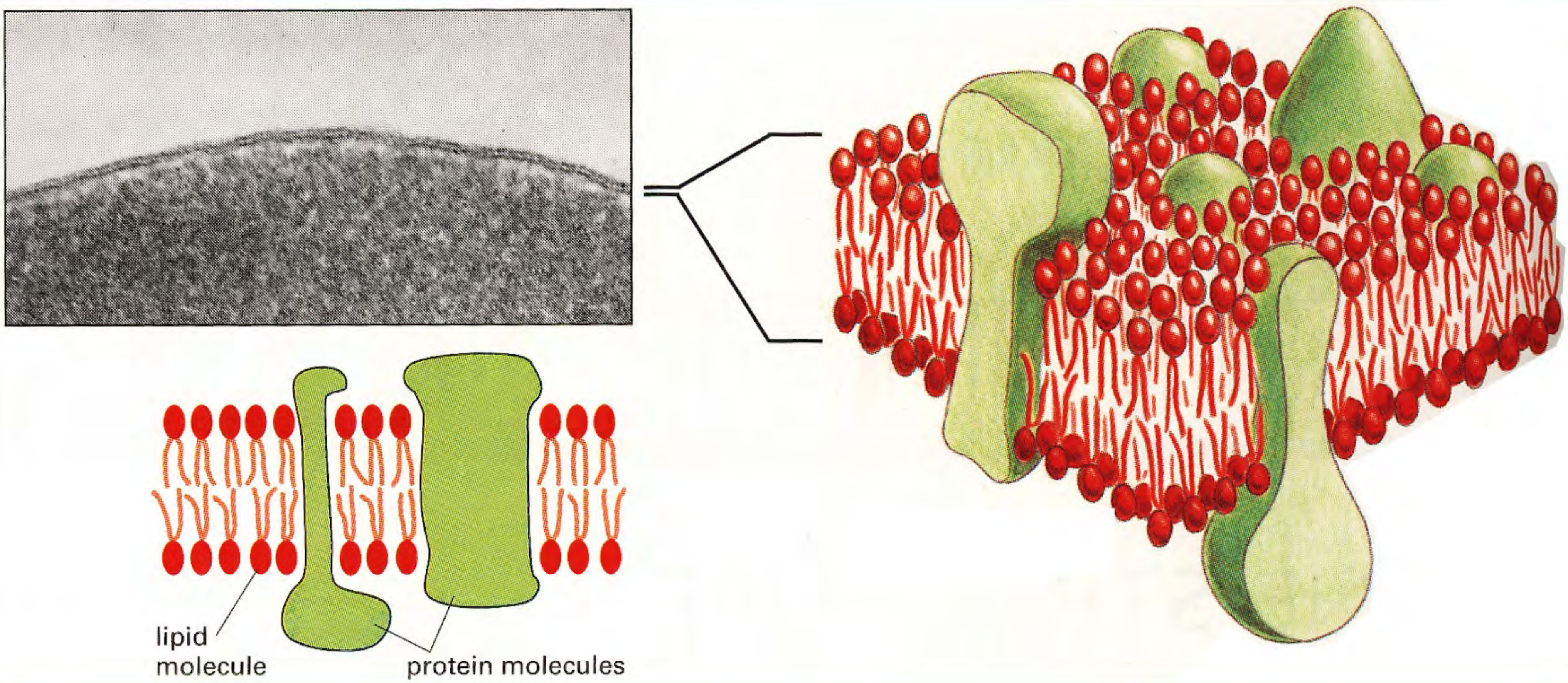
“free” water:
high disorder – tumbling motion, yet many H bonds
H bonds may form in *many* mutual orientations – entropy large

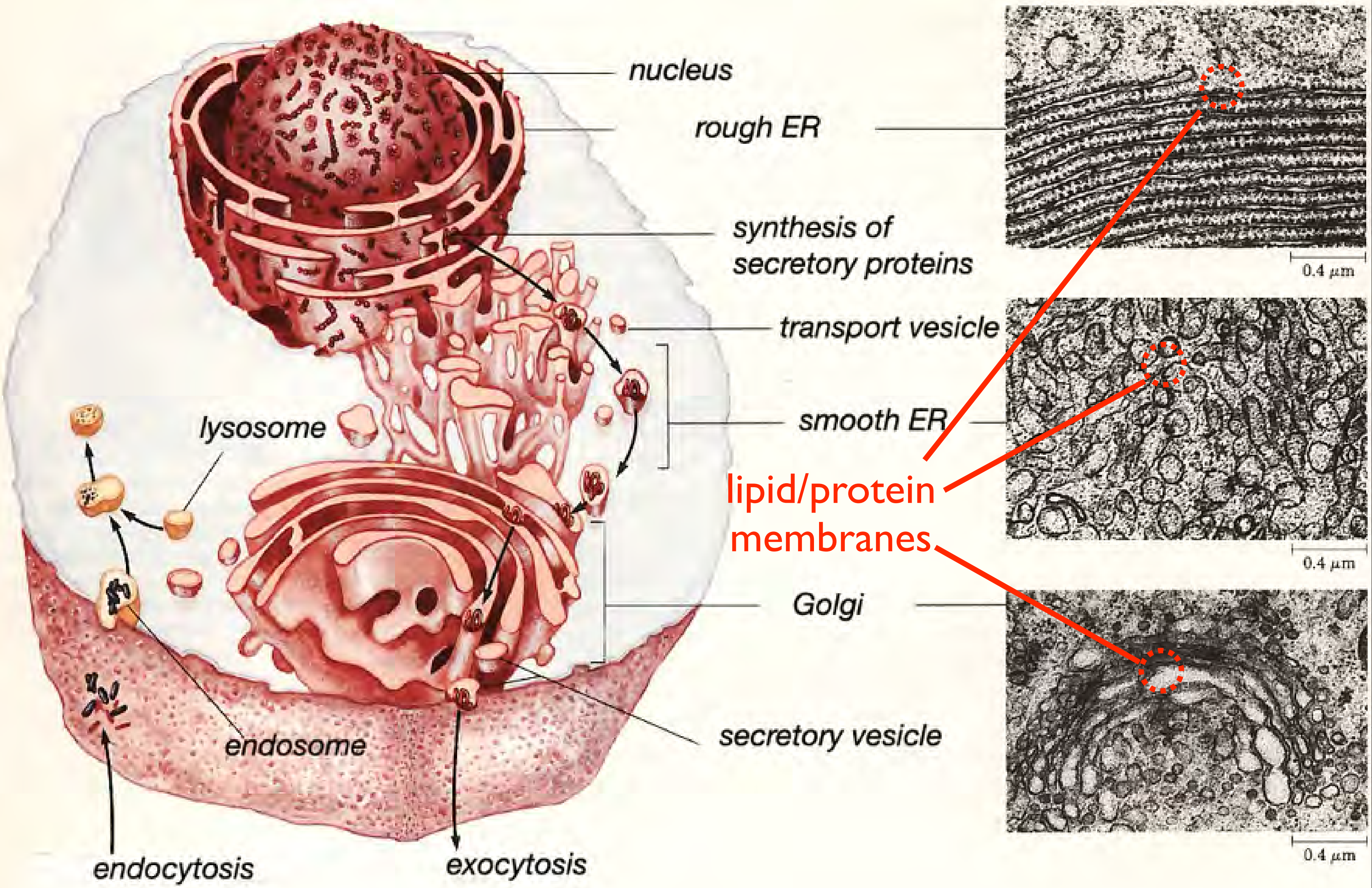
lipid aggregation in water



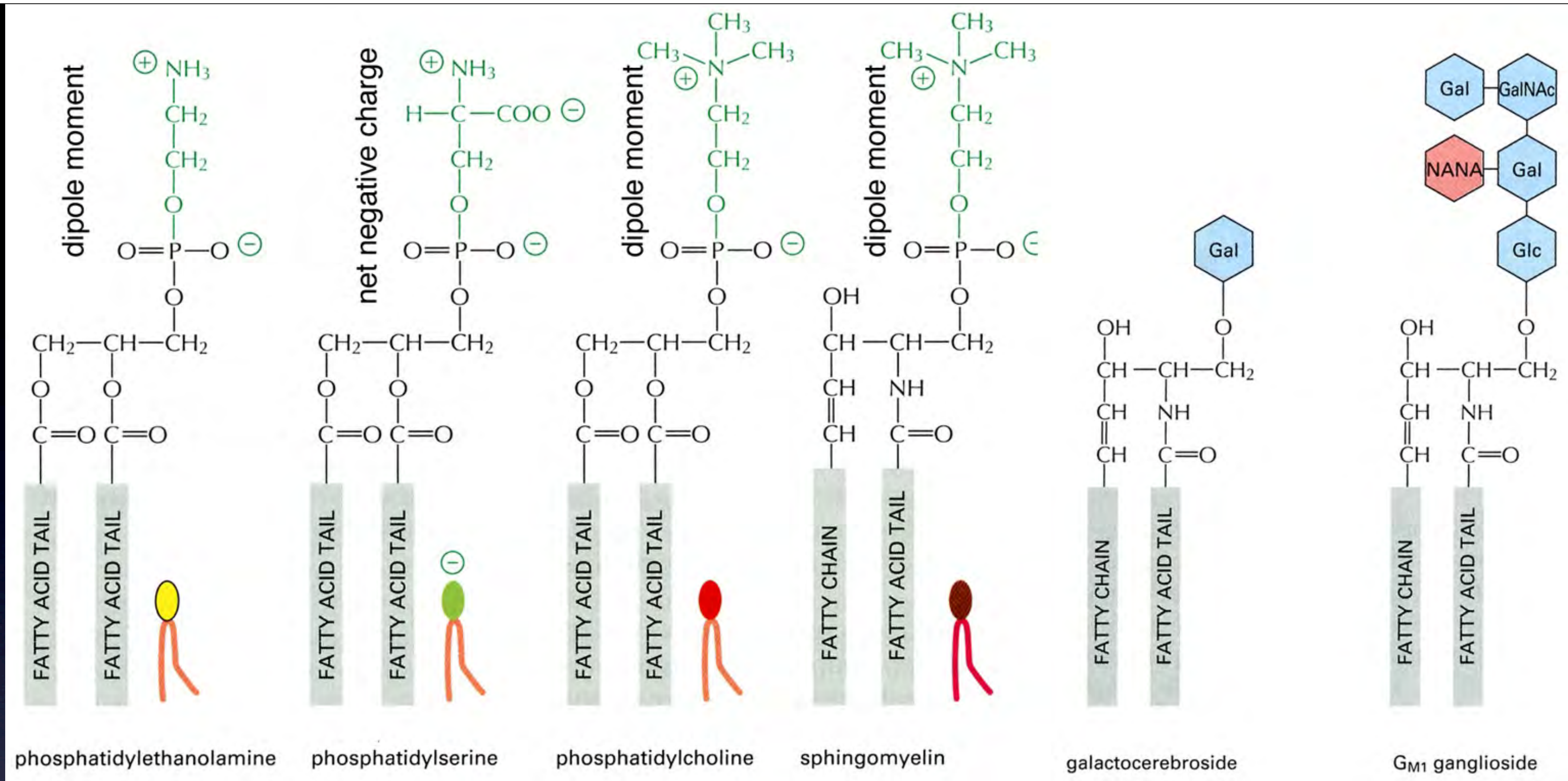


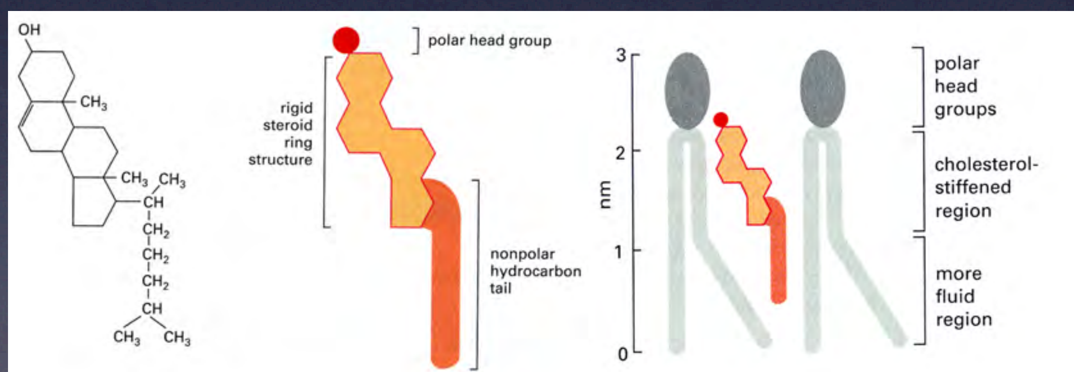
adapted from *Alberts et al.* – *Molecular Biology of the Cell*


lipid molecule
protein molecules

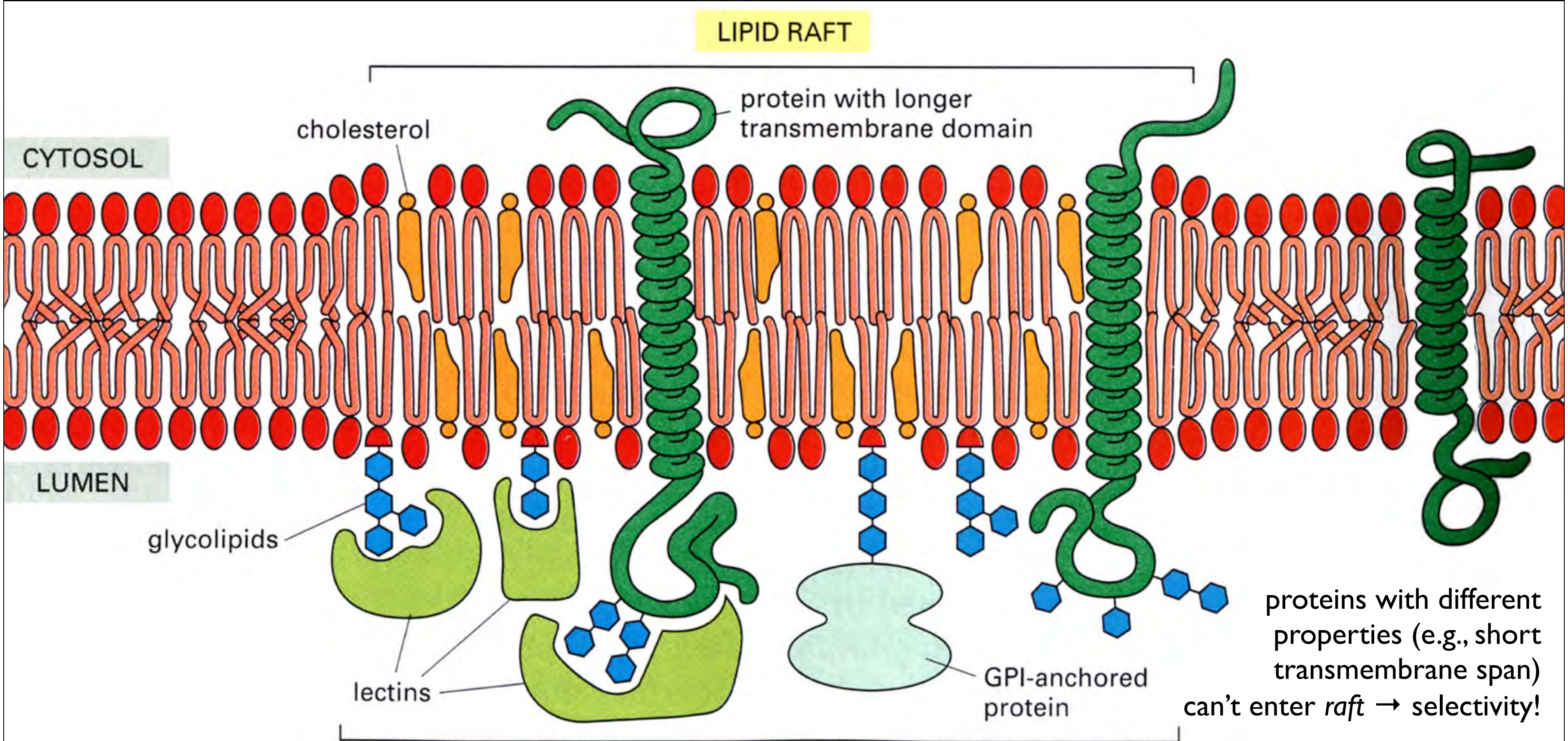


adapted from *Lehninger, Nelson & Cox – Principles of Biochemistry*



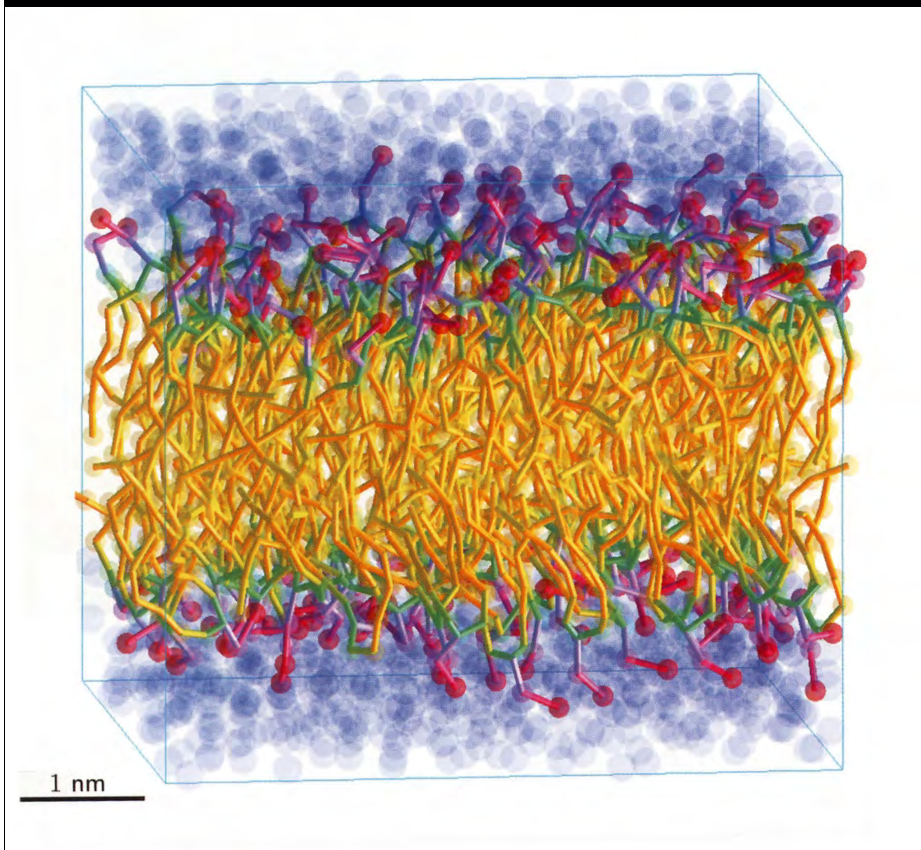


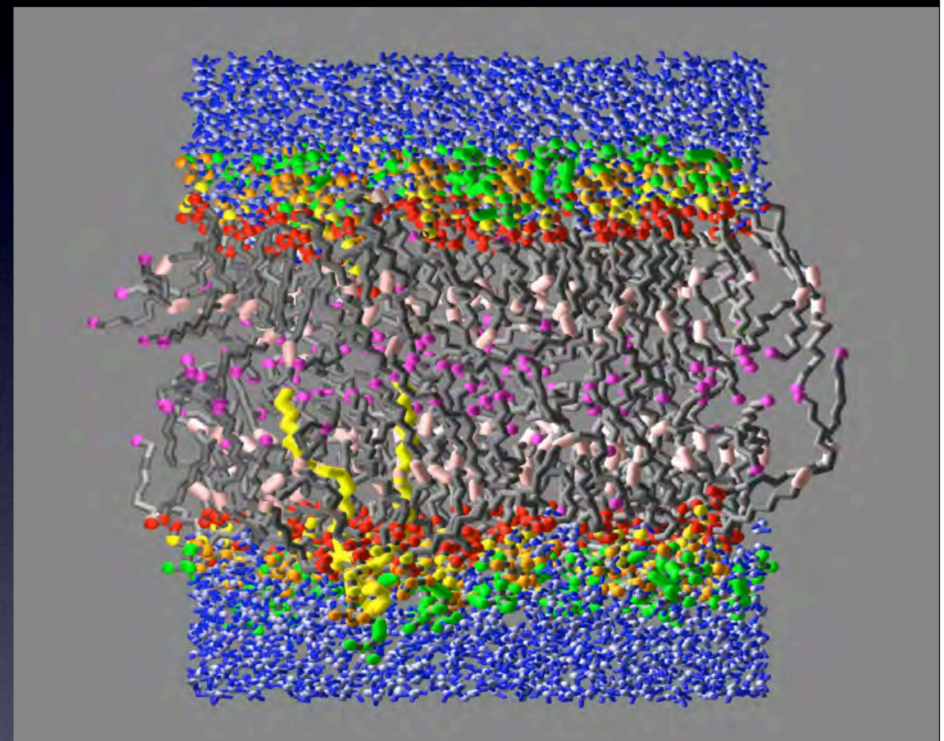
adapted from *Alberts et al.* – *Molecular Biology of the Cell*



proteins with different properties (e.g., short transmembrane span) can't enter *raft* → selectivity!

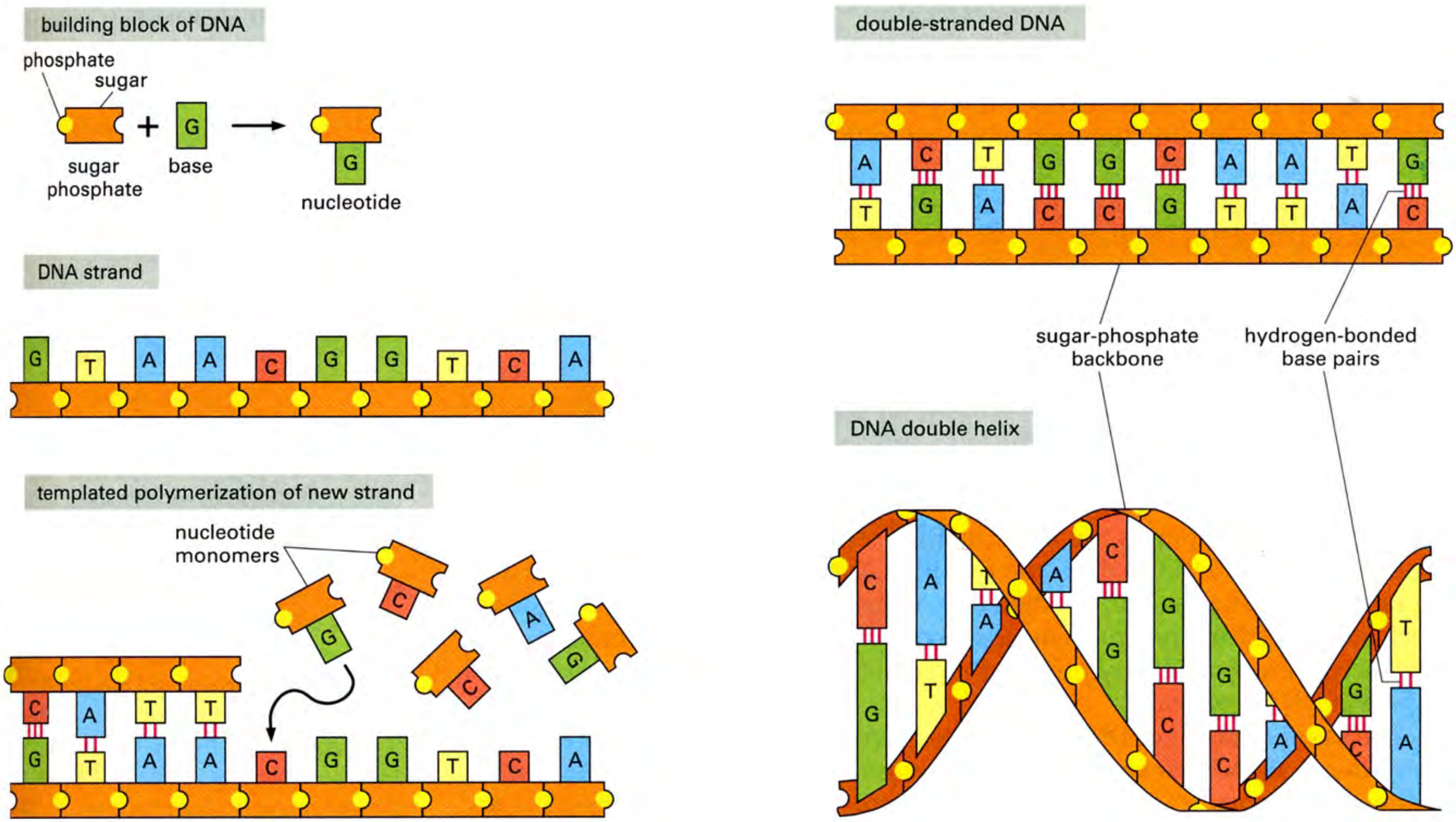
adapted from *Alberts et al.* – *Molecular Biology of the Cell*



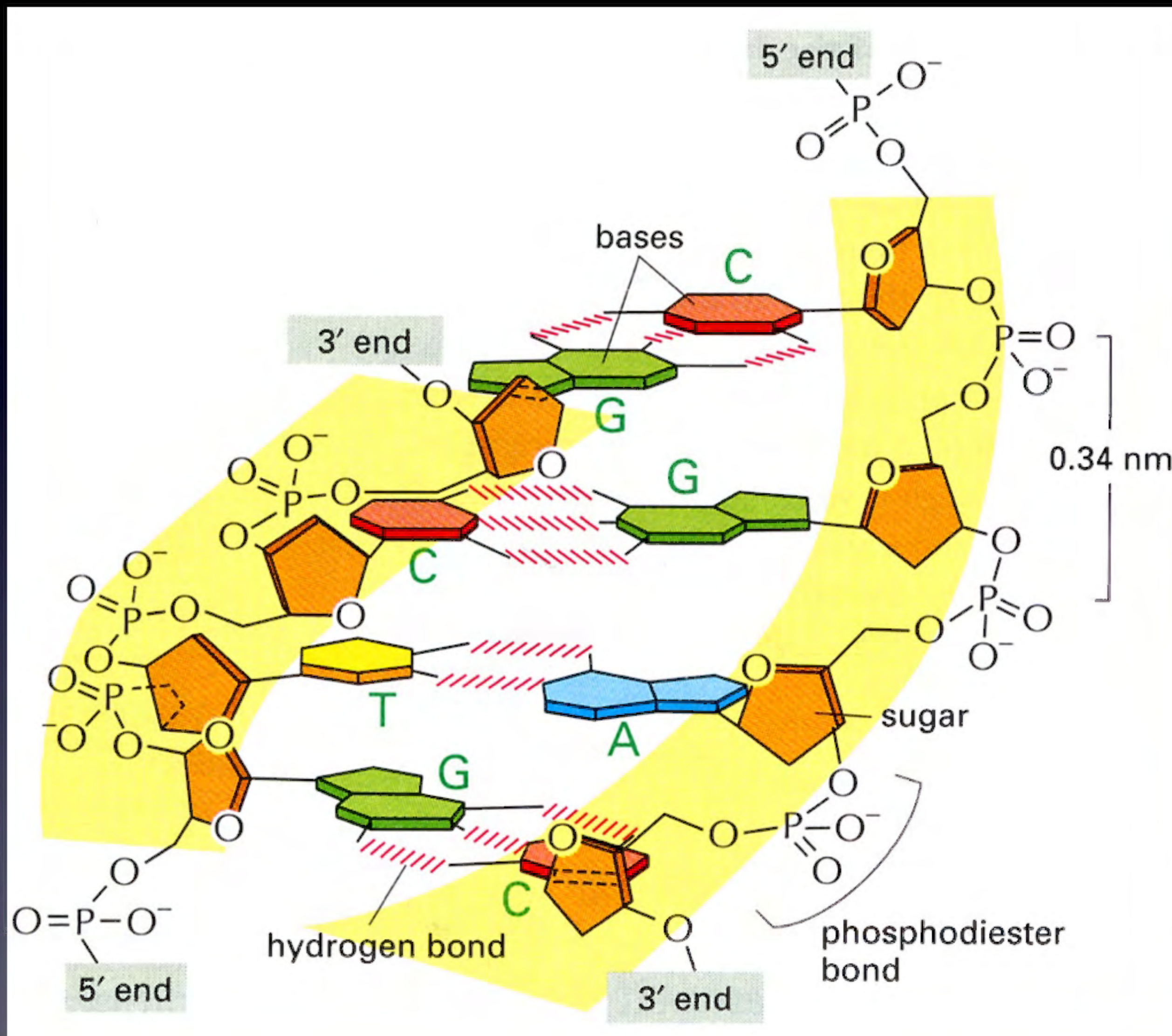


adapted from *Nelson – Biological Physics*

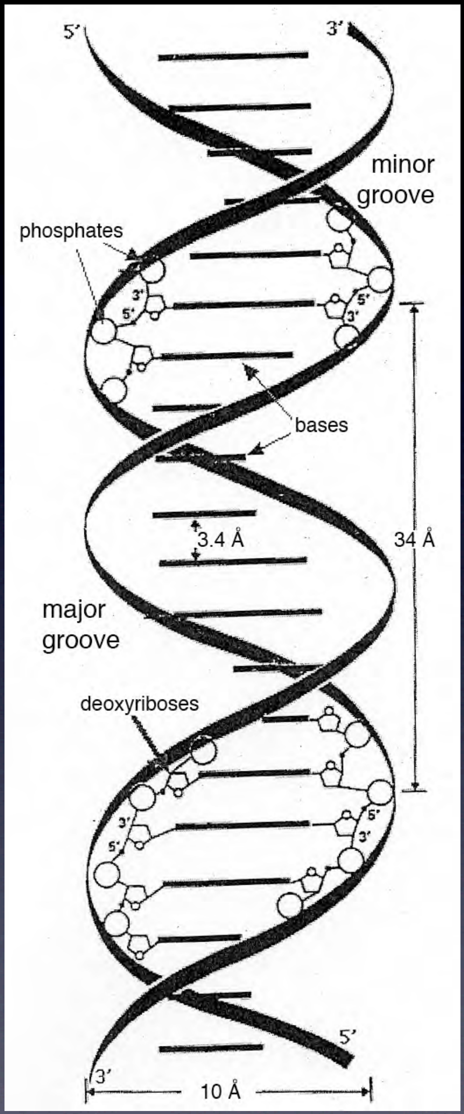
MD simulation: *D.Tobias, UC Irvine*

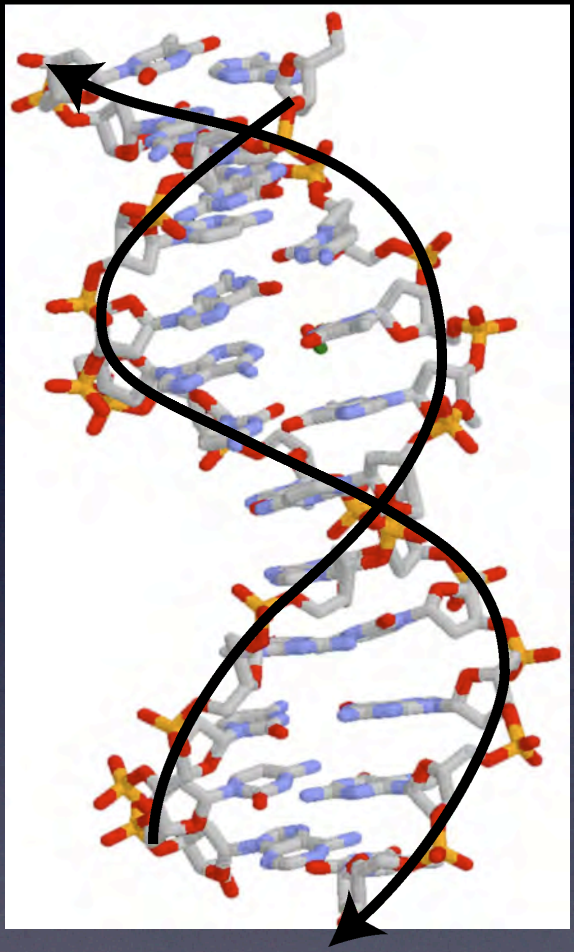


adapted from *Alberts et al.* – *Molecular Biology of the Cell*

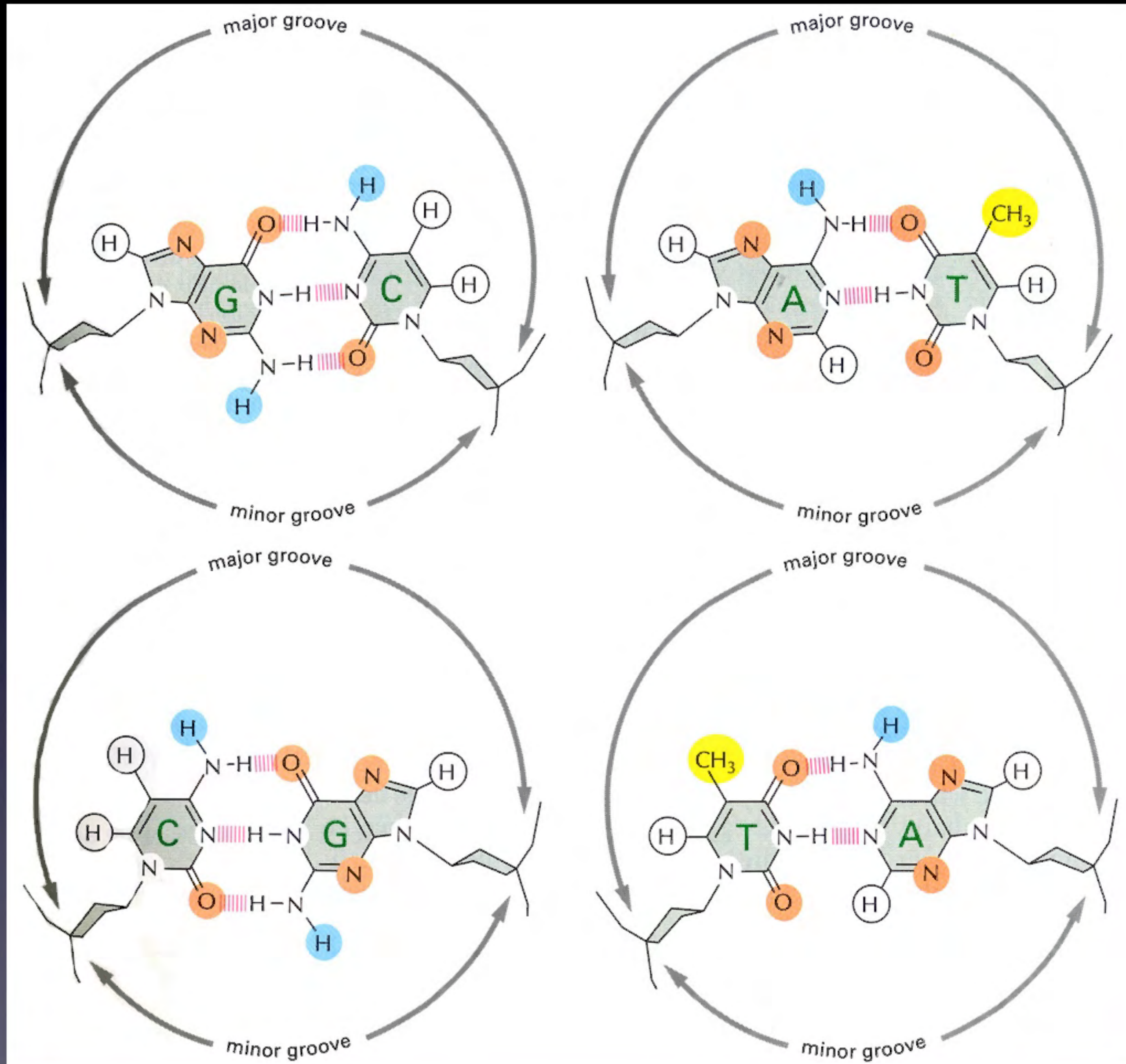


5′ end
3′ end
bases
C
G
G
C
T
A
G
C
0.34 nm
sugar
hydrogen bond
phosphodiester bond
5′ end
3′ end

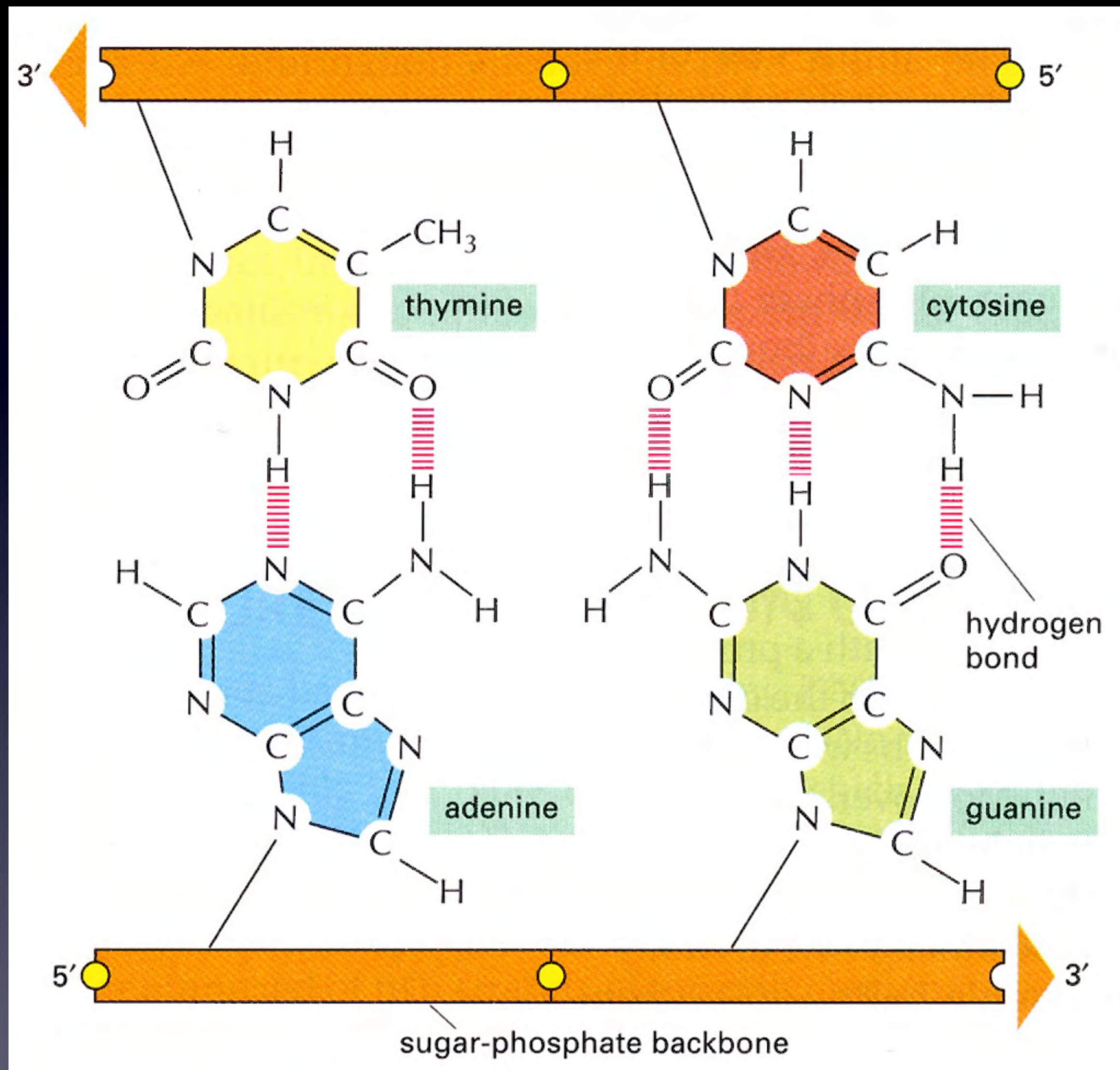


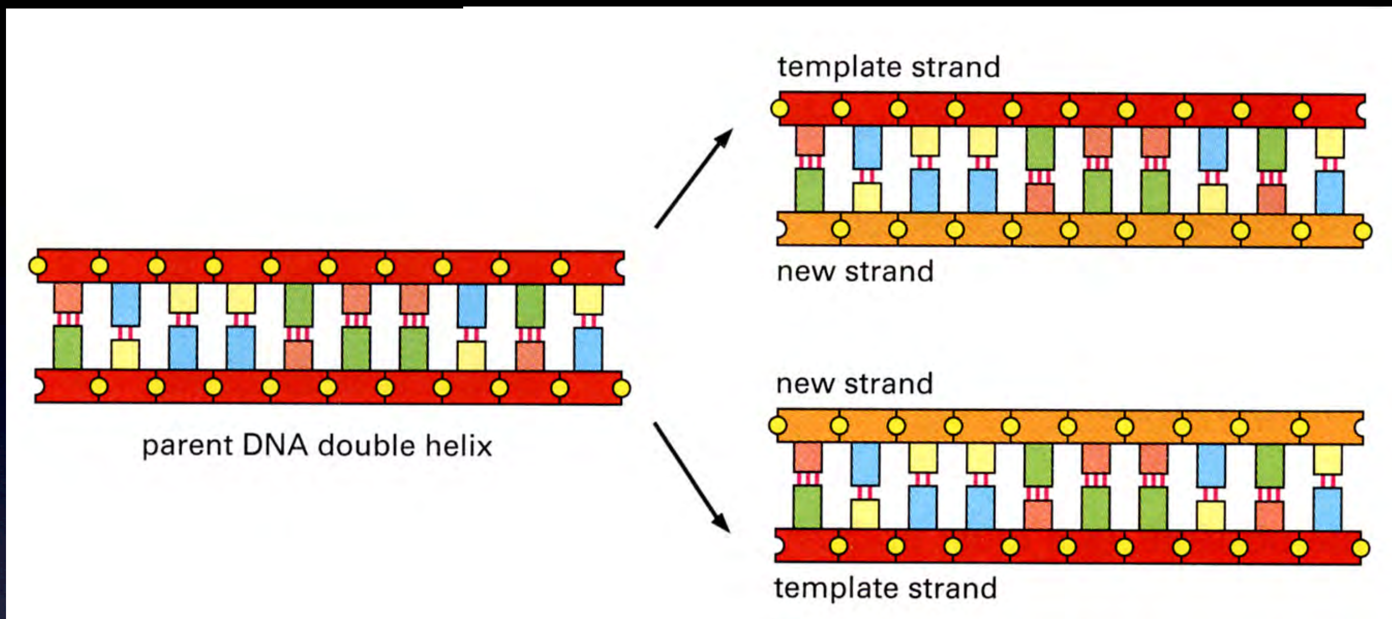


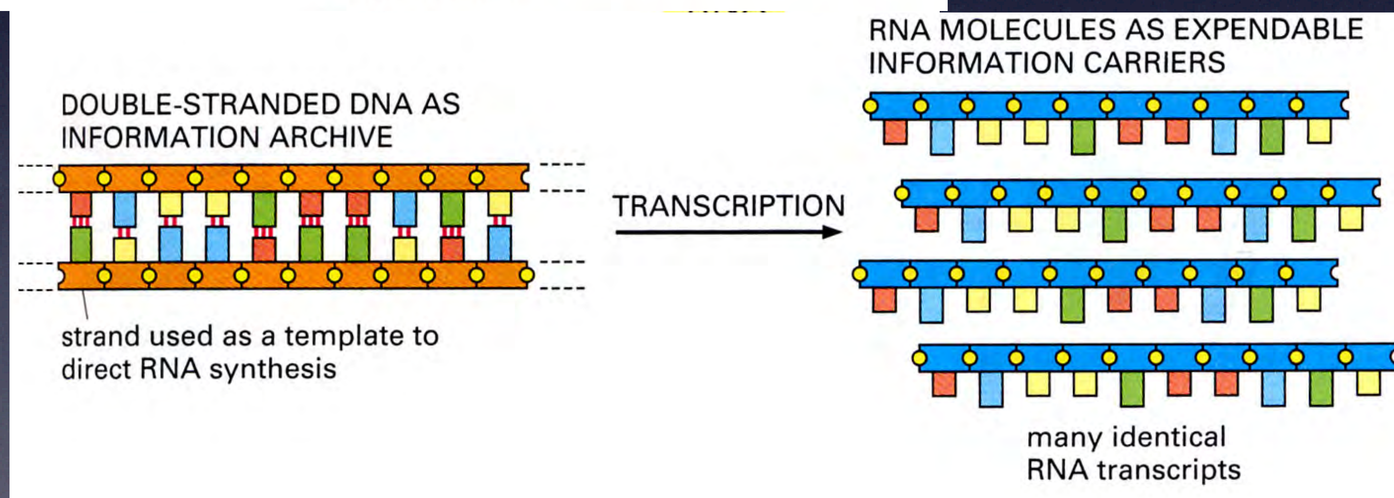
adapted from *Alberts et al.* –
Molecular Biology of the Cell



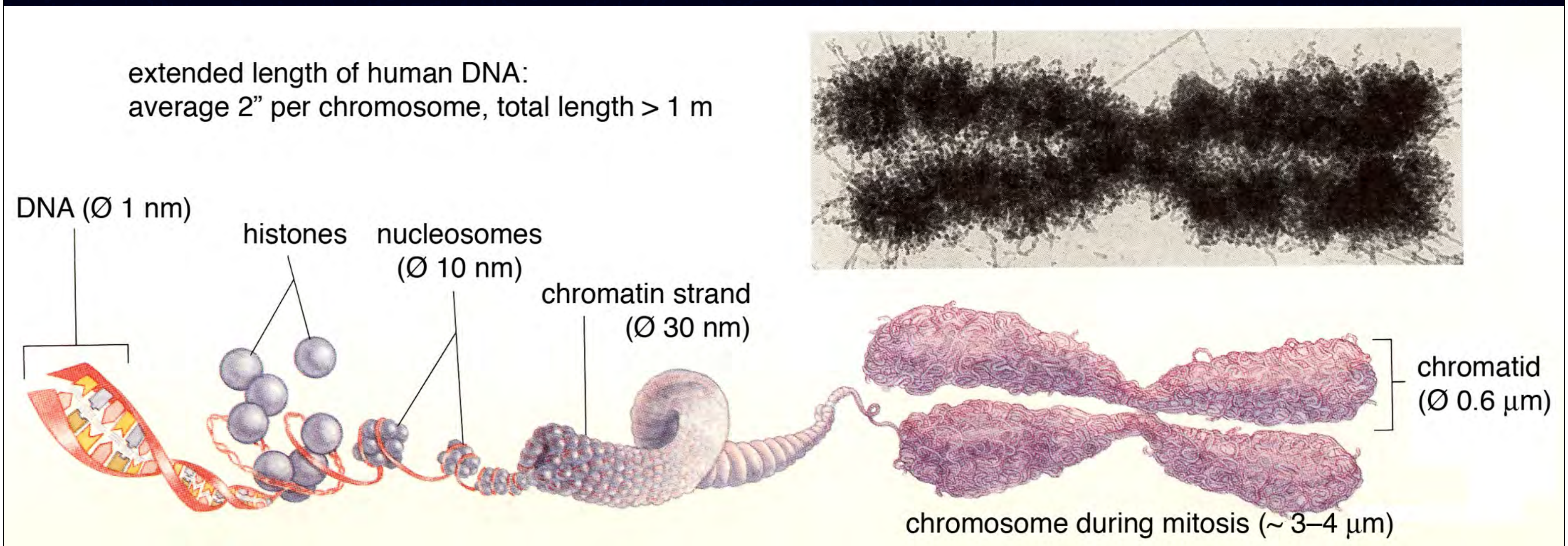
major groove
minor groove
major groove
minor groove
major groove
minor groove
major groove
minor groove
G
C
A
T
C
G
T
A


3′
5′
thymine
cytosine
adenine
guanine
hydrogen bond
5′
3′
sugar-phosphate backbone

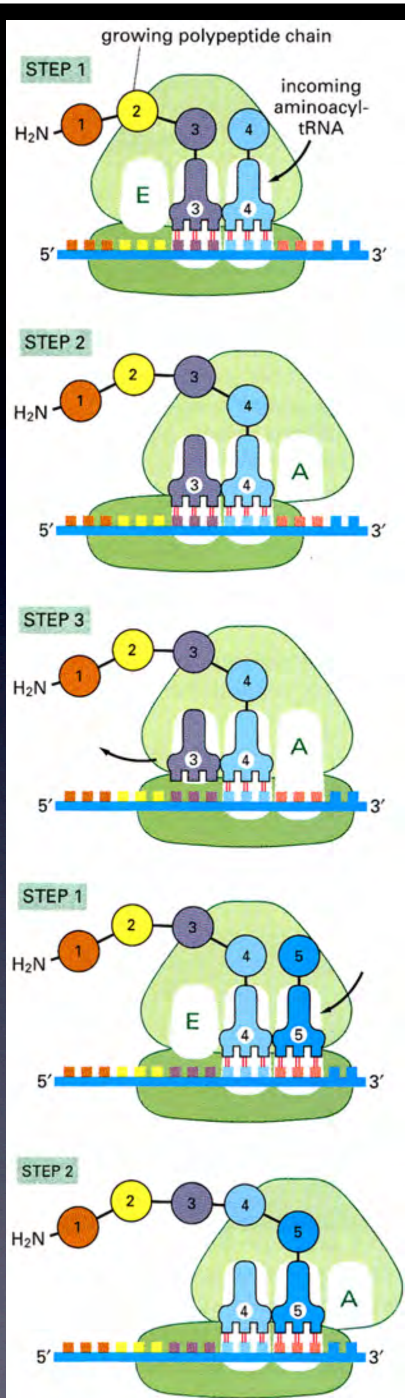




adapted from *Alberts et al.* –
Molecular Biology of the Cell



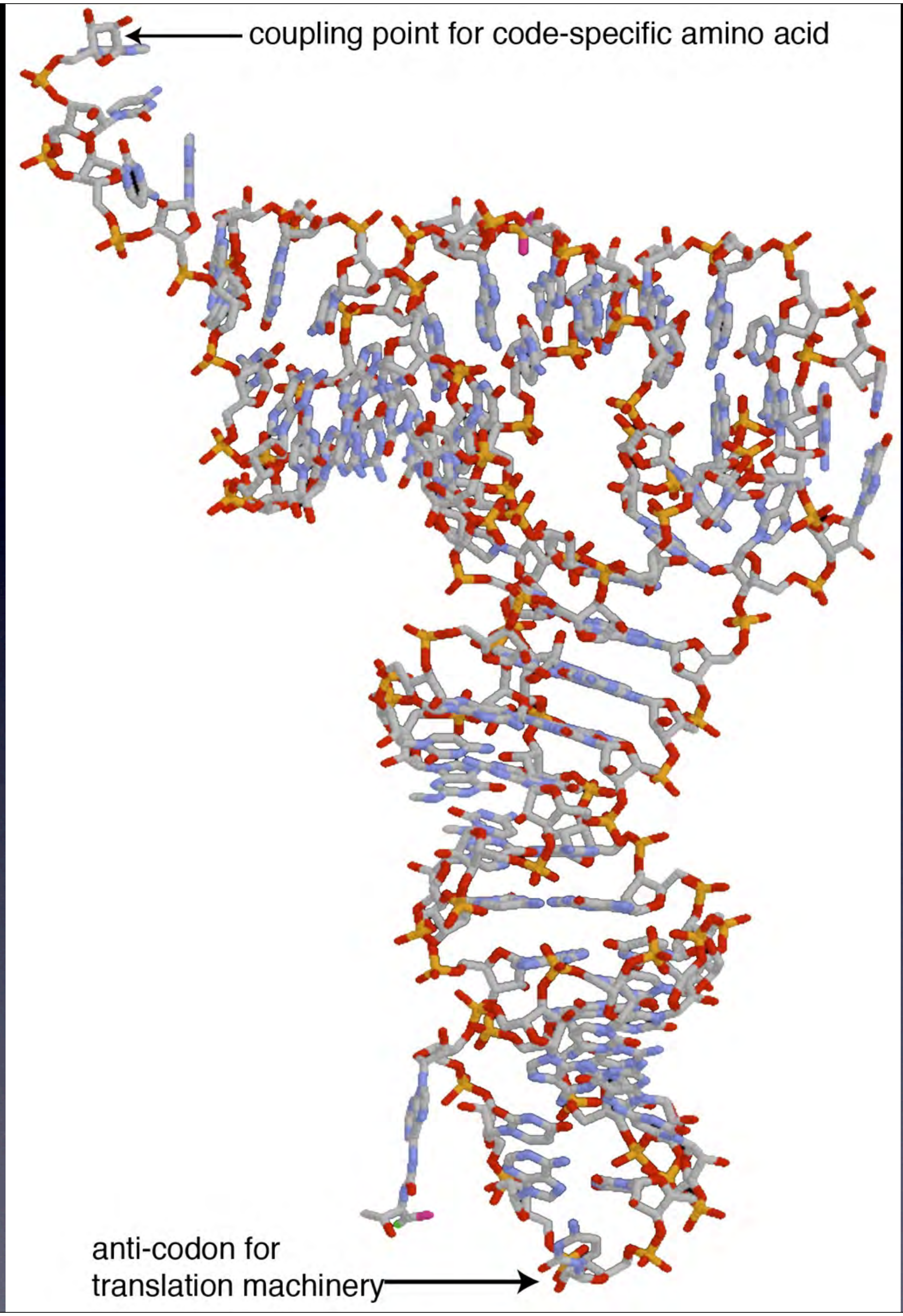
adapted from *Lehninger, Nelson & Cox*
Principles of Biochemistry



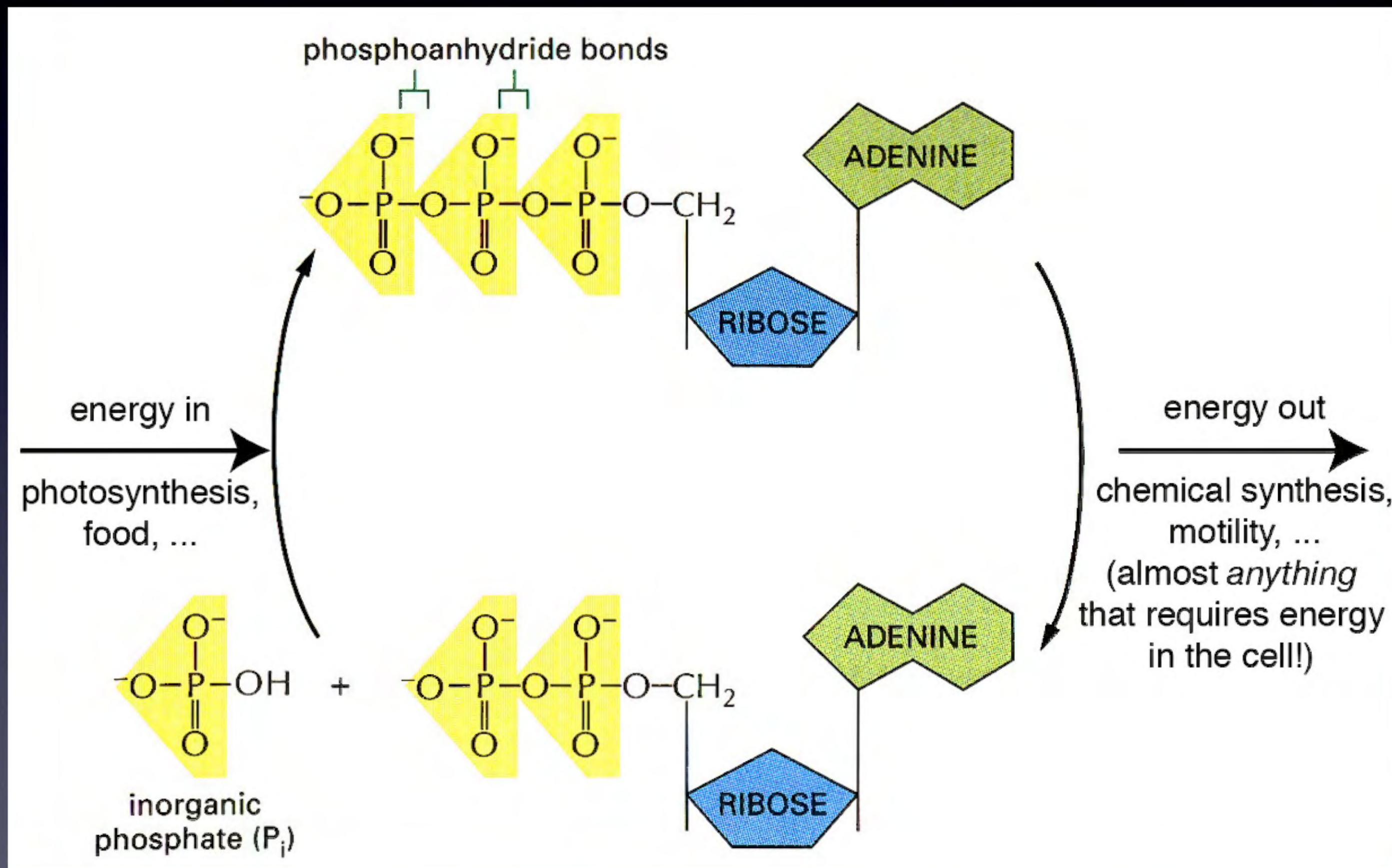
2nd letter of codon

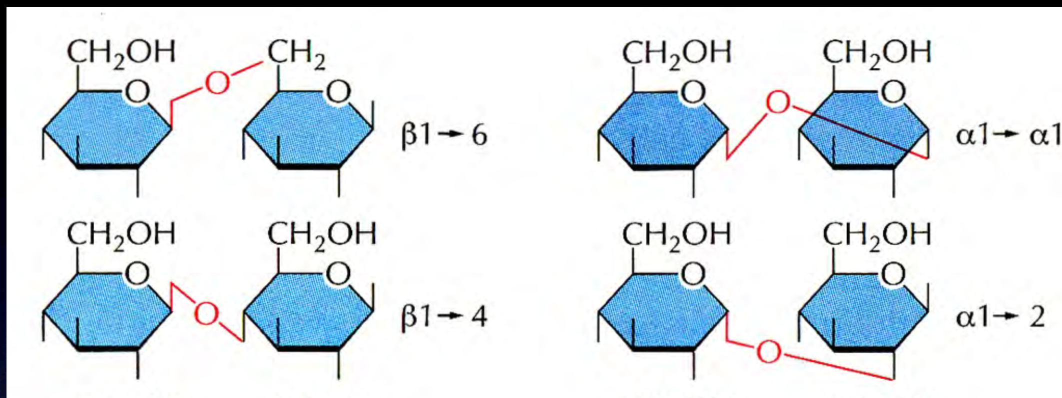
1st letter of codon	U		C		A		G	
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys
U	UUC	Phe	UCC	Ser	UAC	Tyr	UGC	Cys
U	UUA	Leu	UCA	Ser	UAA	Stop	UGA	Stop
U	UUG	Leu	UCG	Ser	UAG	Stop	UGG	Trp
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg
C	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg
C	CUA	Leu	CCA	Pro	CAA	Gln	CGA	Arg
C	CUG	Leu	CCG	Pro	CAG	Gln	CGG	Arg
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser
A	AUC	Ile	ACC	Thr	AAC	Asn	AGC	Ser
A	AUA	Ile	ACA	Thr	AAA	Lys	AGA	Arg
A	AUG	Met	ACG	Thr	AAG	Lys	AGG	Arg
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly
G	GUC	Val	GCC	Ala	GAC	Asp	GGC	Gly
G	GUA	Val	GCA	Ala	GAA	Glu	GGA	Gly
G	GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly

adapted from *Lehninger, Nelson & Cox – Principles of Biochemistry*
and from *Alberts et al. – Molecular Biology of the Cell*

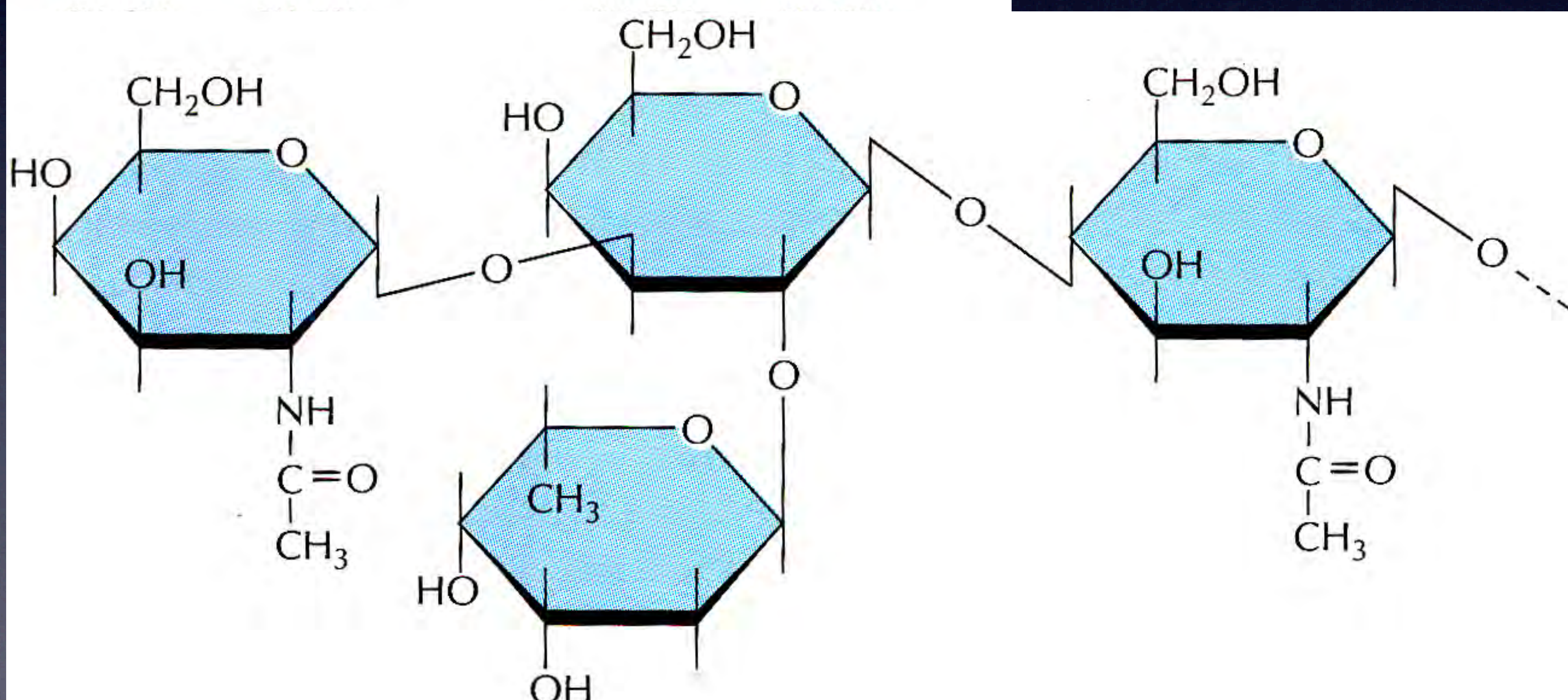

coupling point for code-specific amino acid
anti-codon for
translation machinery

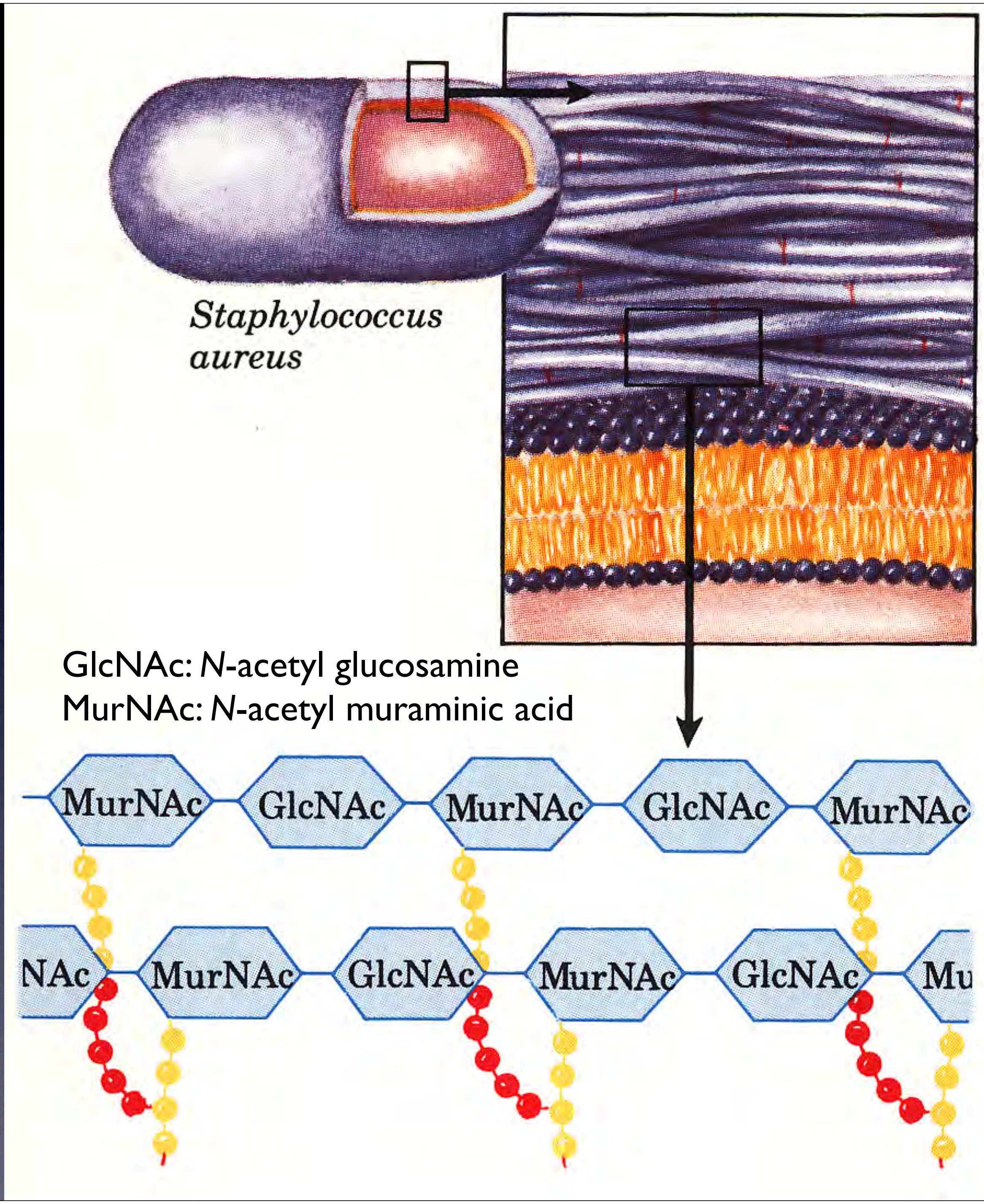
tRNA


phosphoanhydride bonds
ADENINE
RIBOSE
energy in
photosynthesis, food, ...
energy out
chemical synthesis, motility, ...
(almost *anything* that requires energy in the cell!)
ADENINE
RIBOSE
inorganic phosphate (P_i)



myriads of different structures possible!





adapted from
Lehninger, Nelson & Cox
Principles of Biochemistry