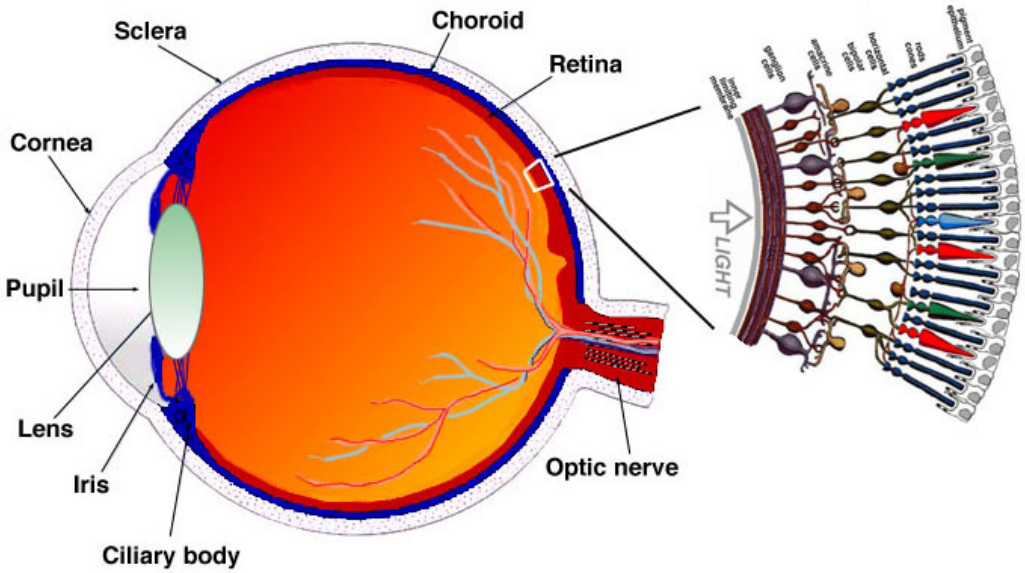
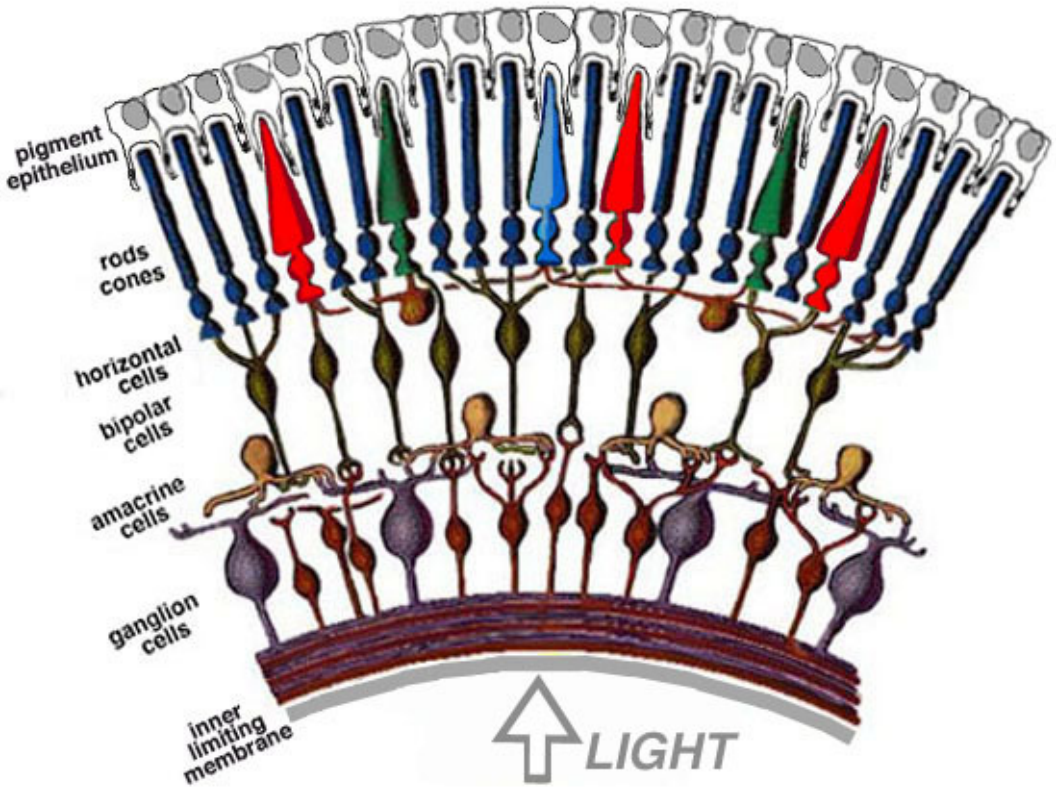
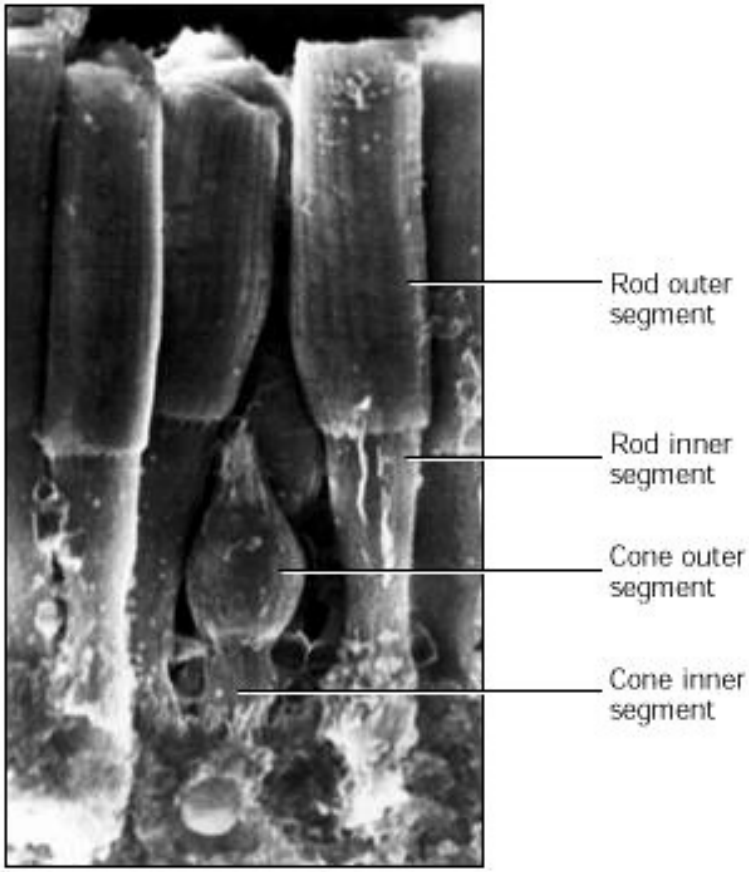
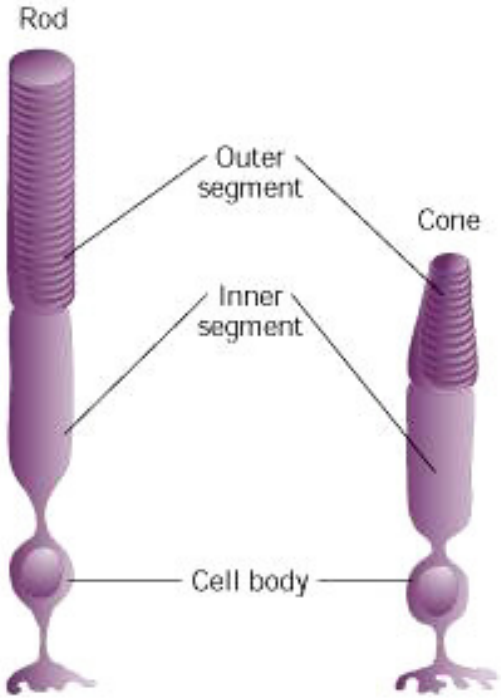

Sclera
Choroid
Retina
Cornea
Pupil
Lens
Iris
Ciliary body
Optic nerve
LIGHT

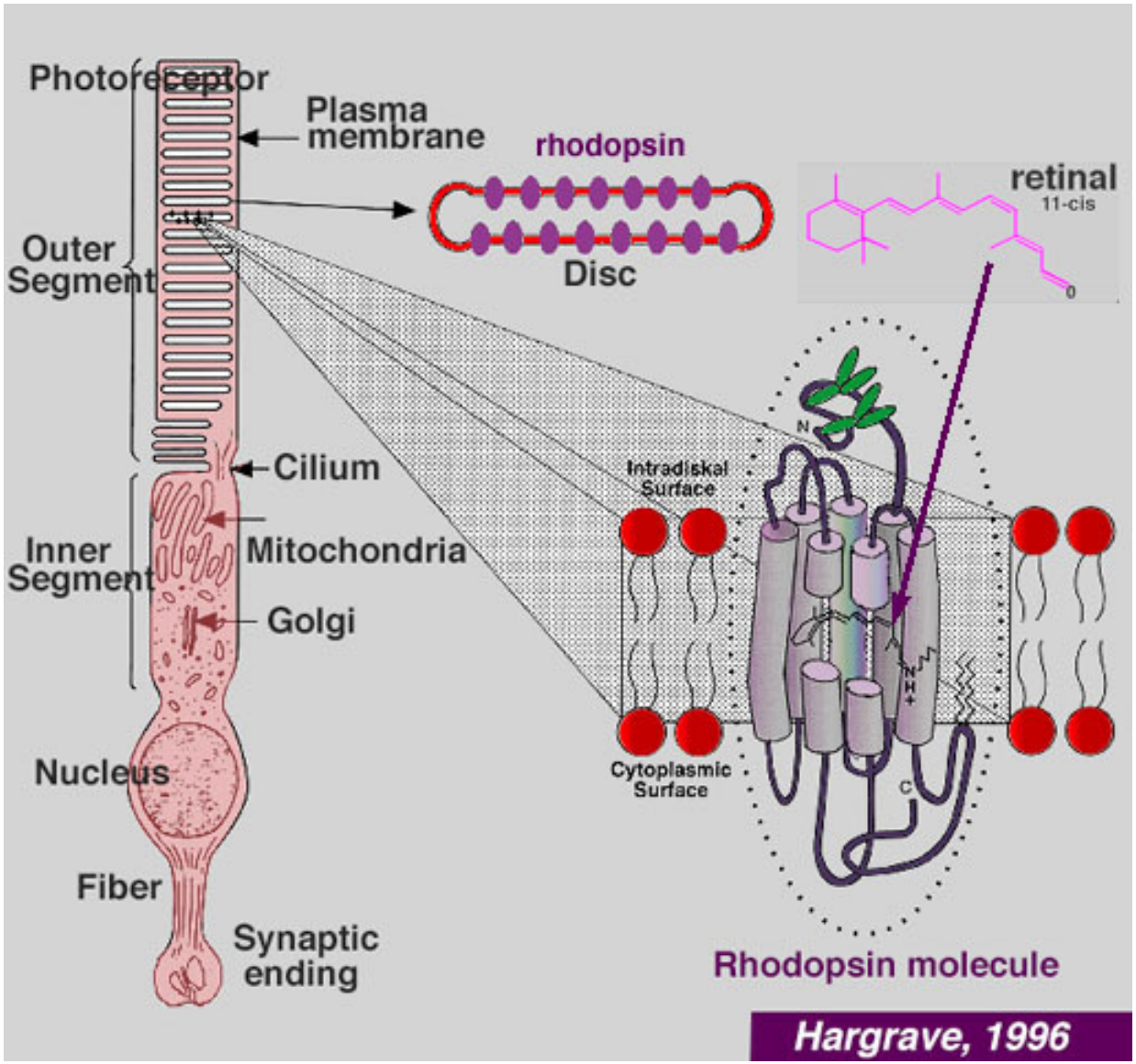

pigment epithelium
rods
cones
horizontal cells
bipolar cells
amacrine cells
ganglion cells
inner limiting membrane
LIGHT

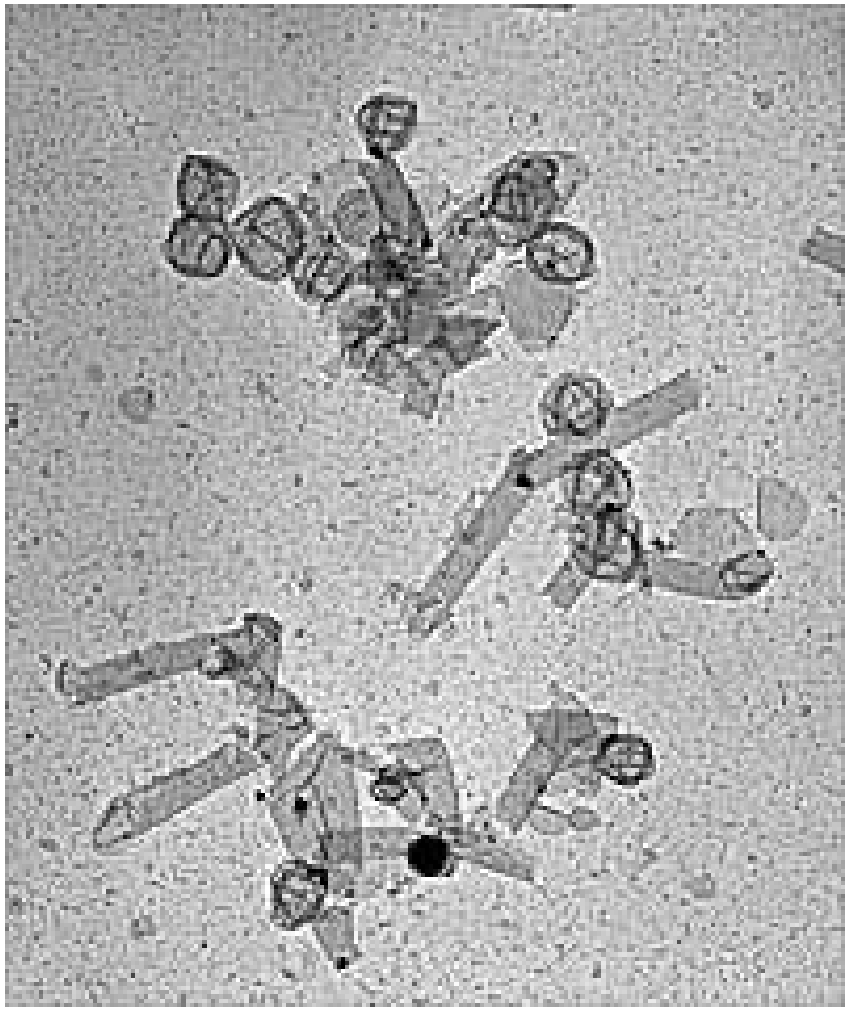
A

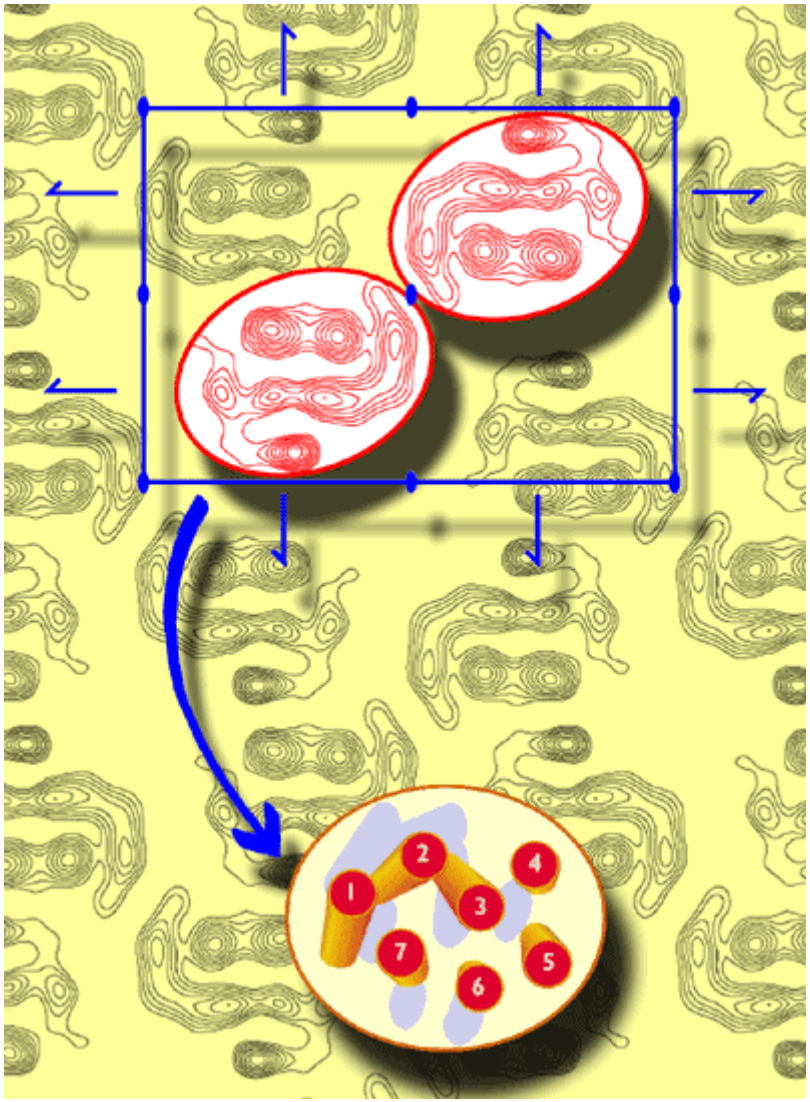

Rod outer segment
Rod inner segment
Cone outer segment
Cone inner segment

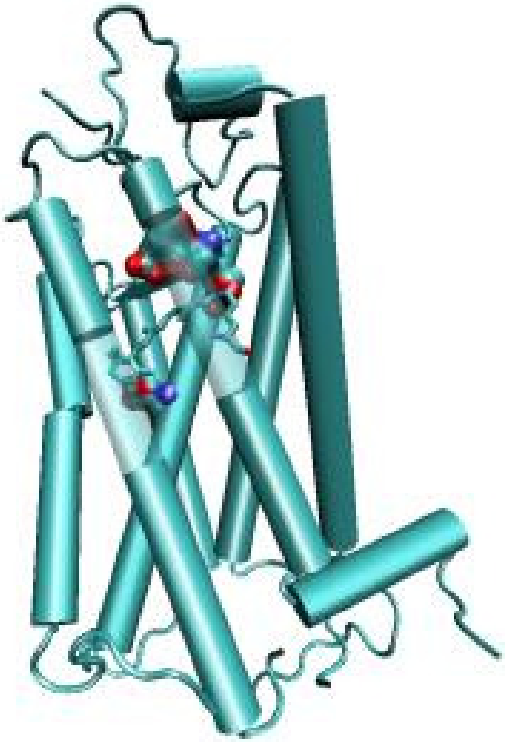
B

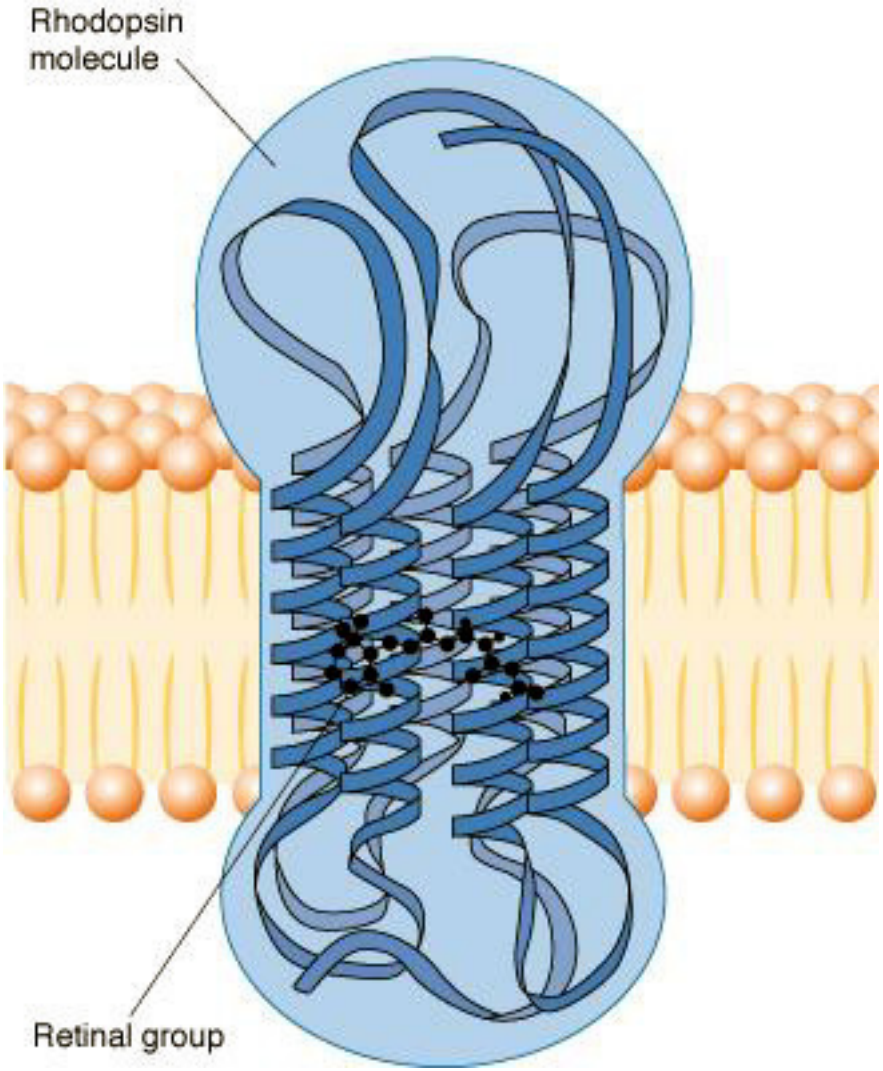

Rod
Outer segment
Cone
Inner segment
Cell body

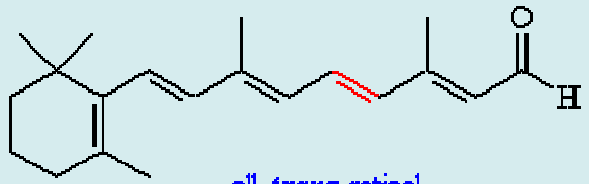

Photoreceptor
Plasma membrane
rhodopsin
retinal
11-cis
Disc
Outer Segment
Cilium
Inner Segment
Mitochondria
Golgi
Nucleus
Fiber
Synaptic ending
Intradiskal Surface
Cytoplasmic Surface
N
C
NH+
Rhodopsin molecule
Hargrave, 1996



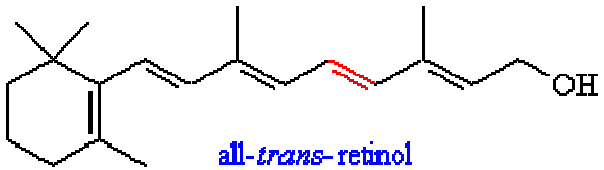

1
2
3
4
5
6
7



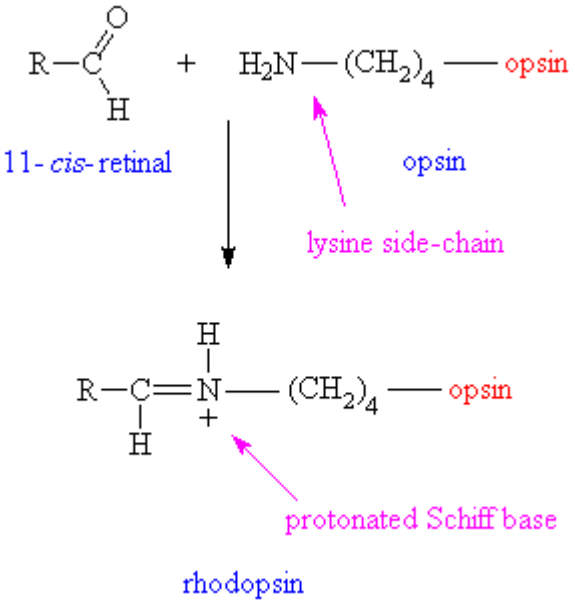

Rhodopsin
molecule
Retinal group



all-*trans*-retinal

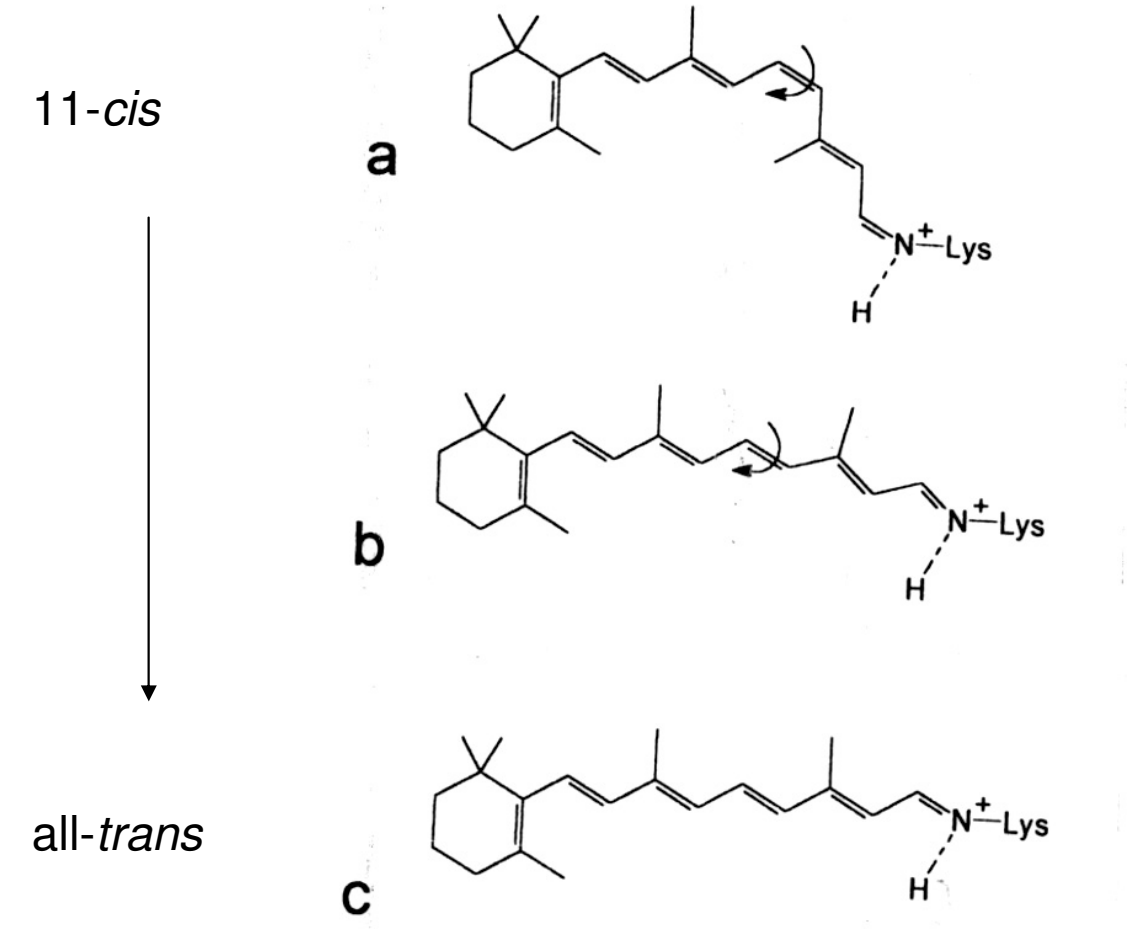


all-*trans*-retinol
(Vitamin A)

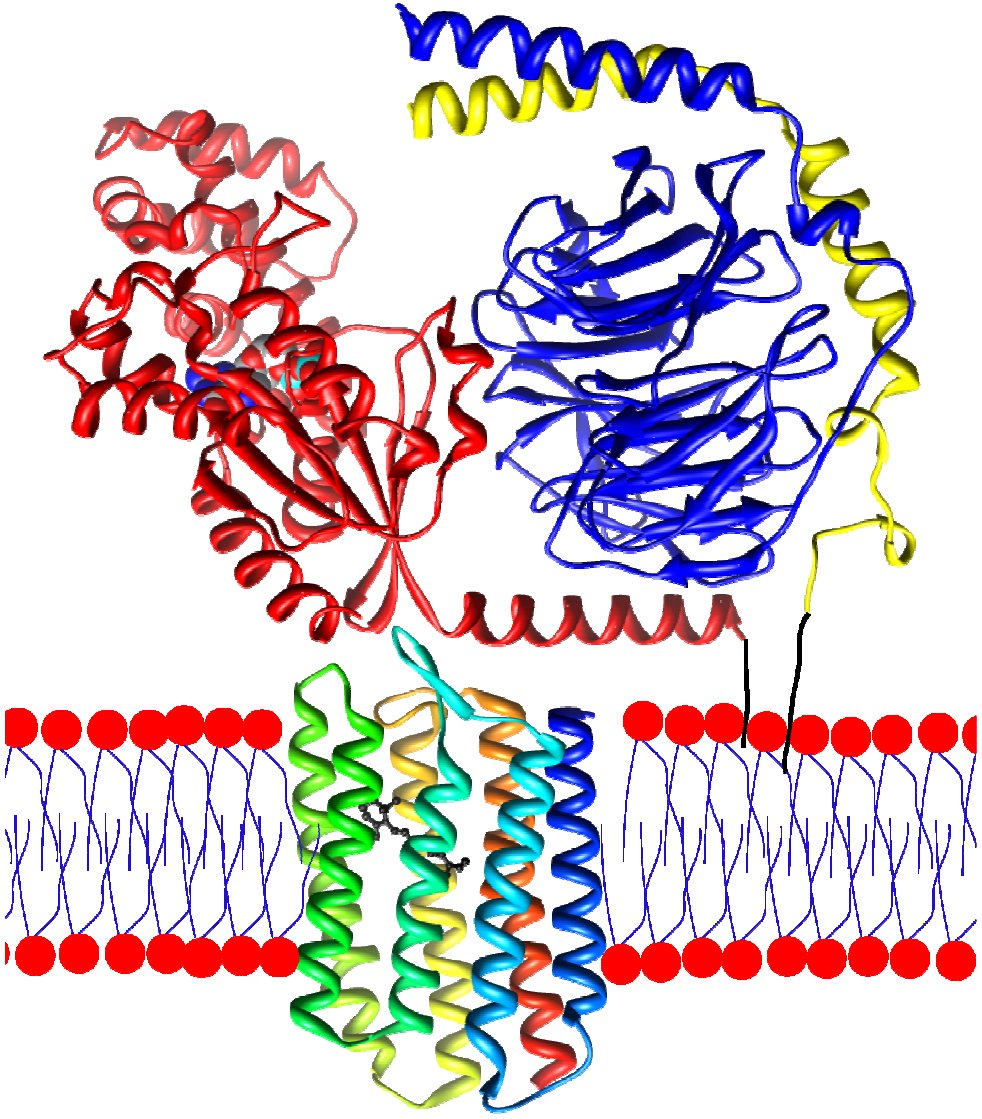


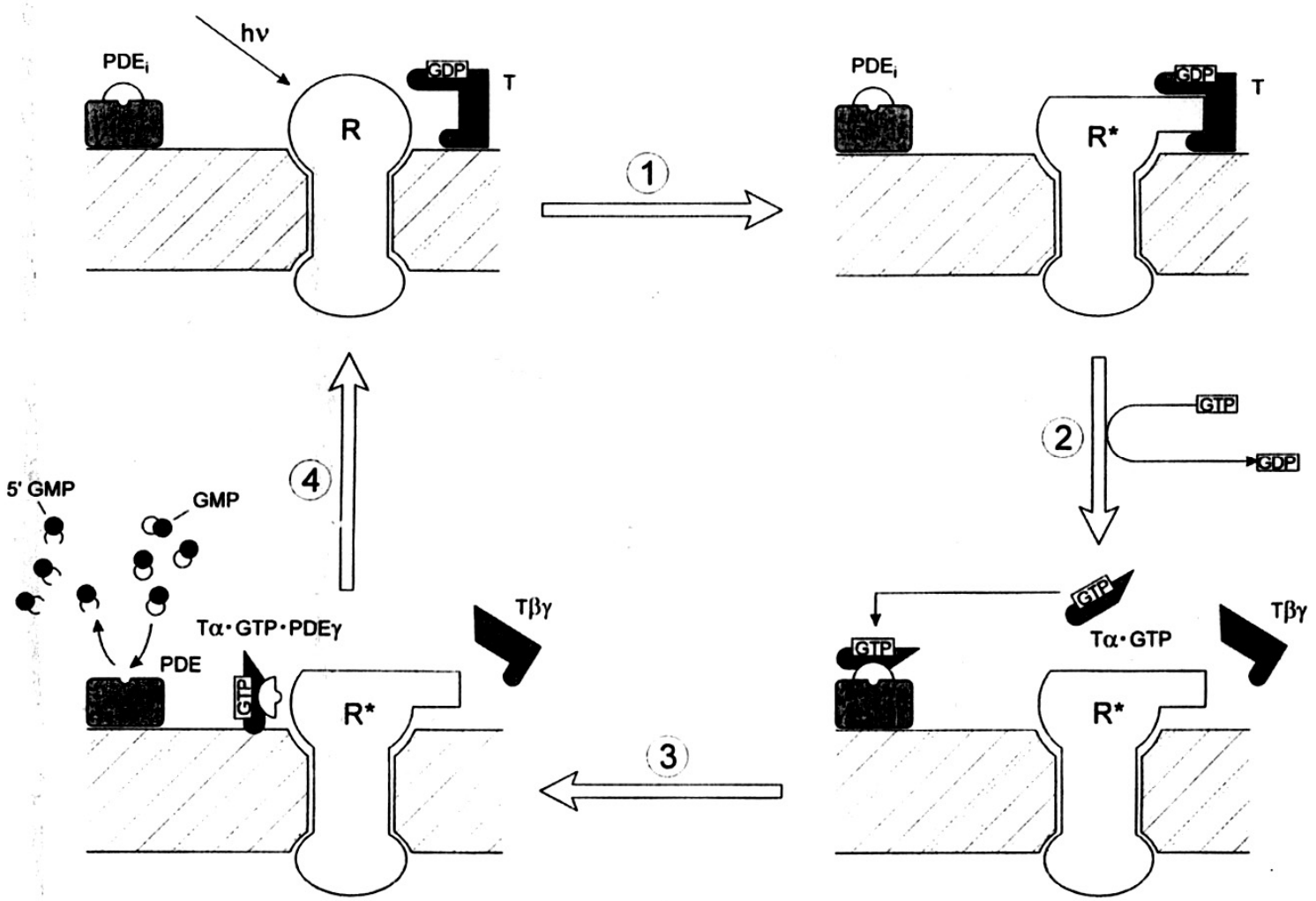
Retinal photoisomerization

11-*cis*



all-*trans*

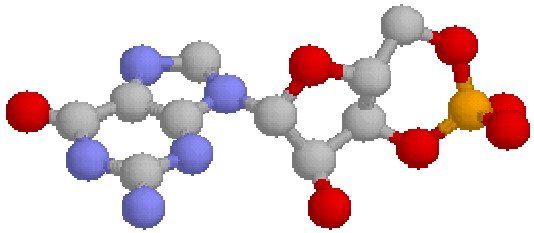


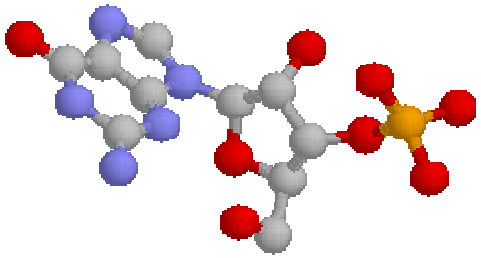


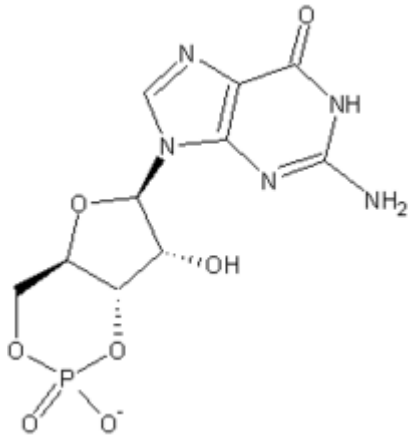
R = Rhodopsin T = Transducin PDE = Phosphodiesterase

5'-GMP = guanosine monophosphate GMP = cyclic guanosine monophosphate

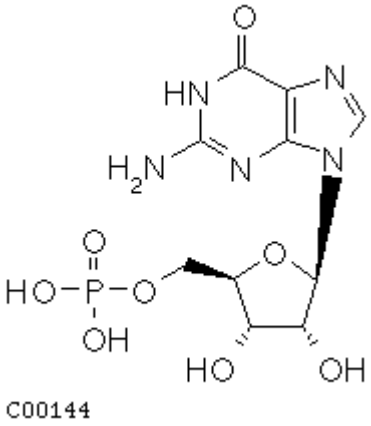
GTP/GDP = guanosine tri/diphosphate



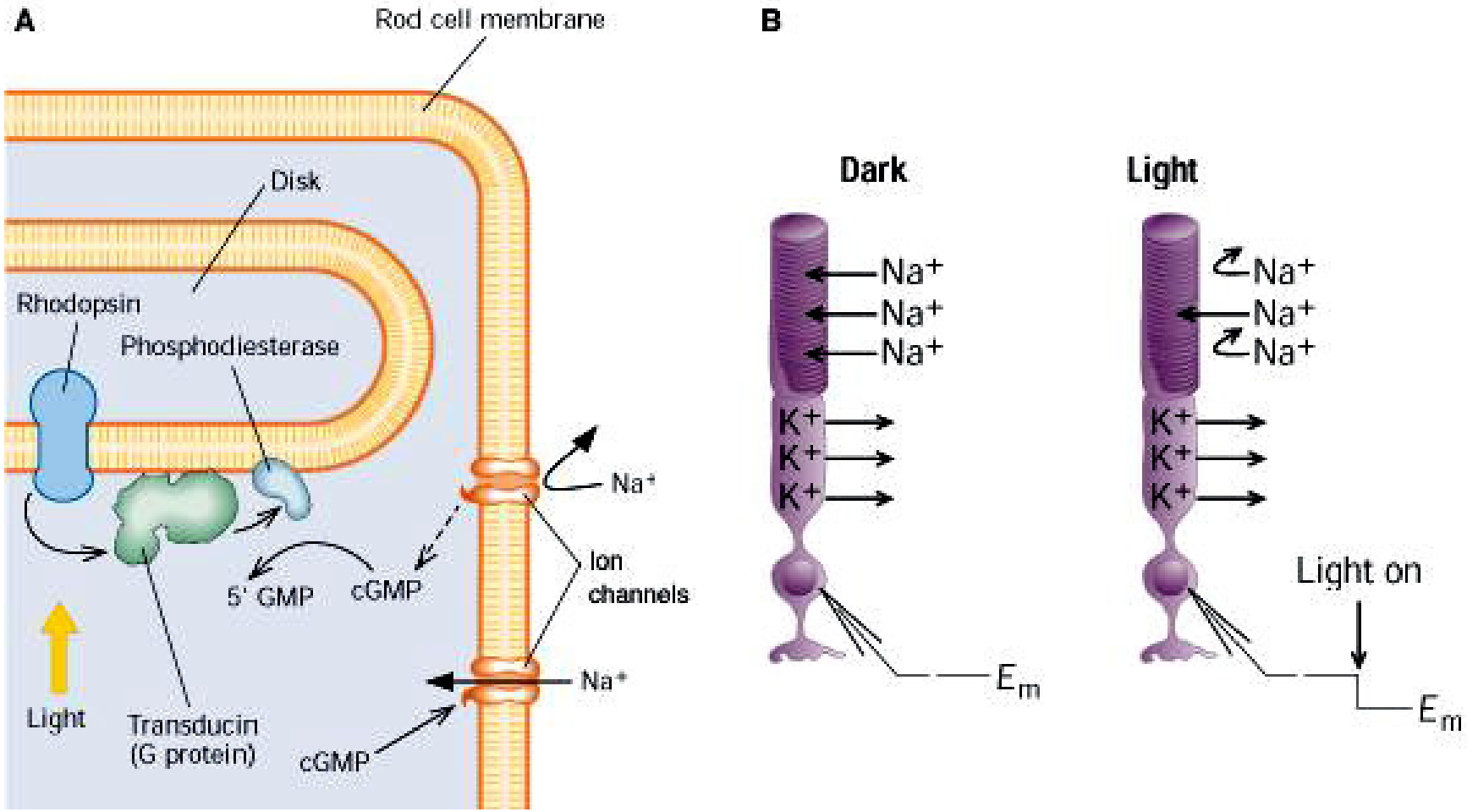




3’,5’-GMP
cycl



5’-GMP


A
Rod cell membrane
Disk
Rhodopsin
Phosphodiesterase
Na+
5' GMP
cGMP
Ion channels
Light
Transducin (G protein)
cGMP
Na+
B
Dark
Na+
Na+
Na+
K+
K+
K+
Em
Light
Na+
Na+
Na+
K+
K+
K+
Light on
Em

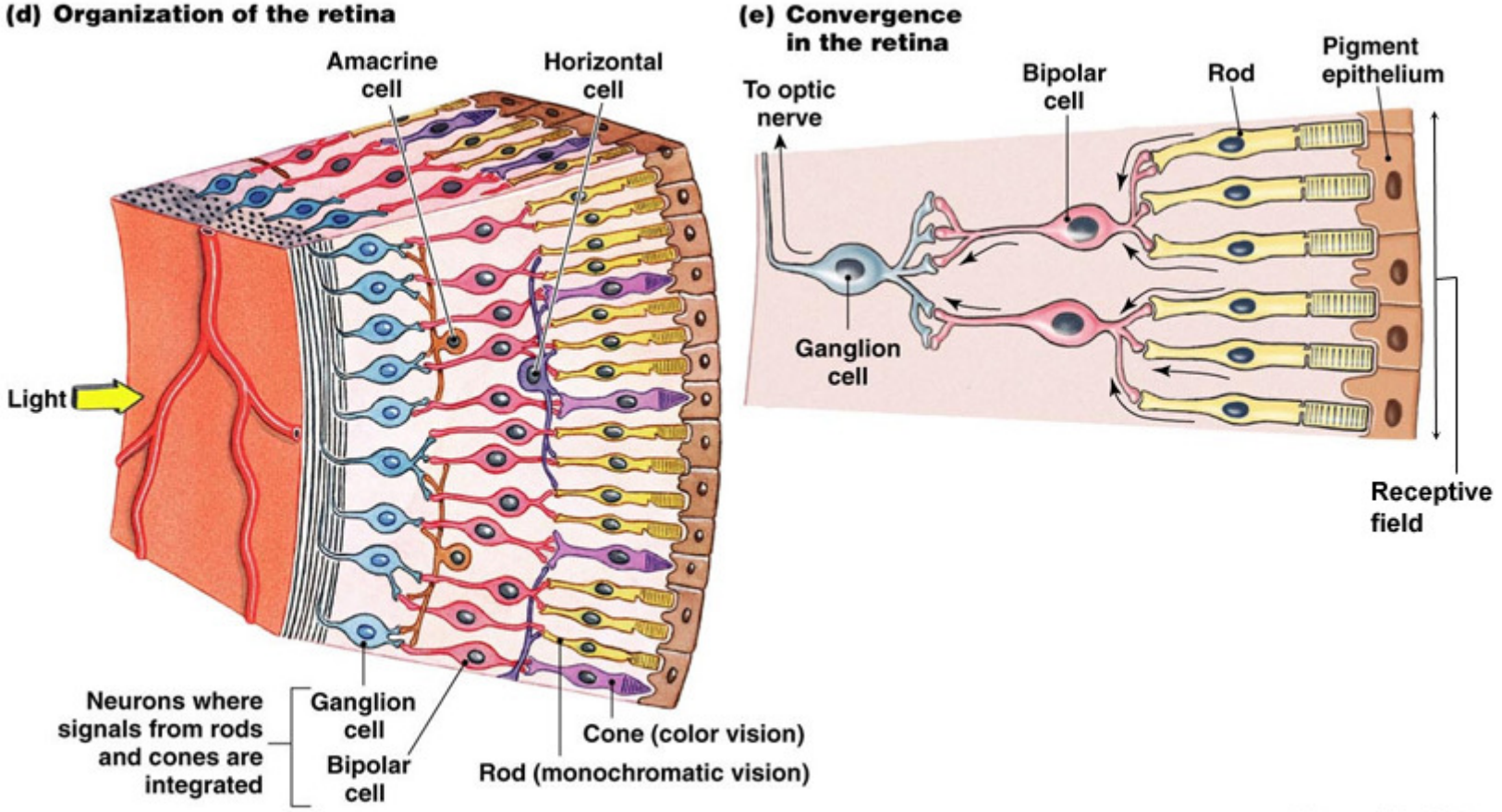
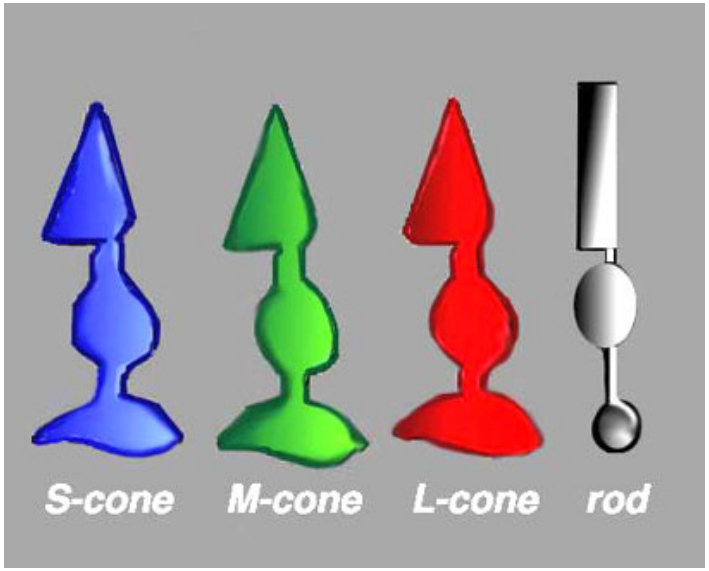
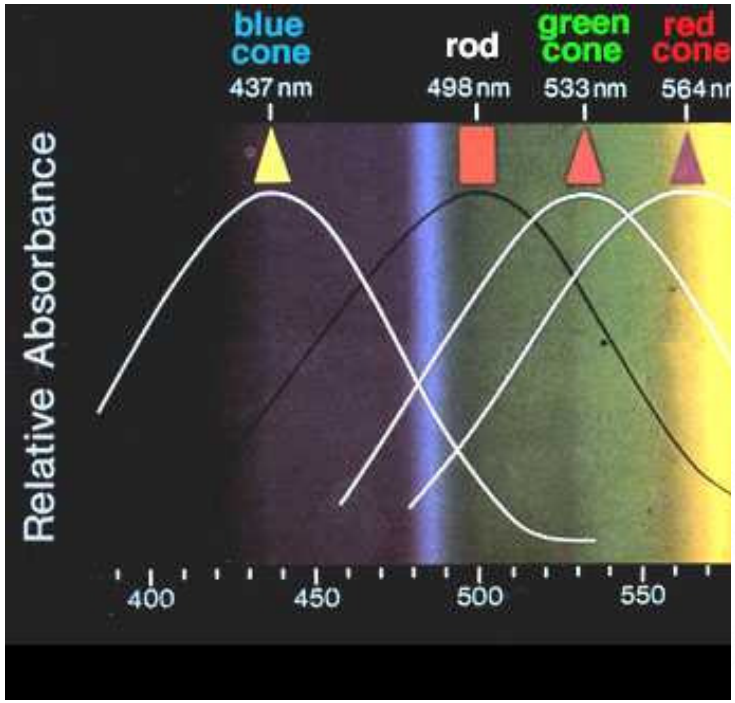
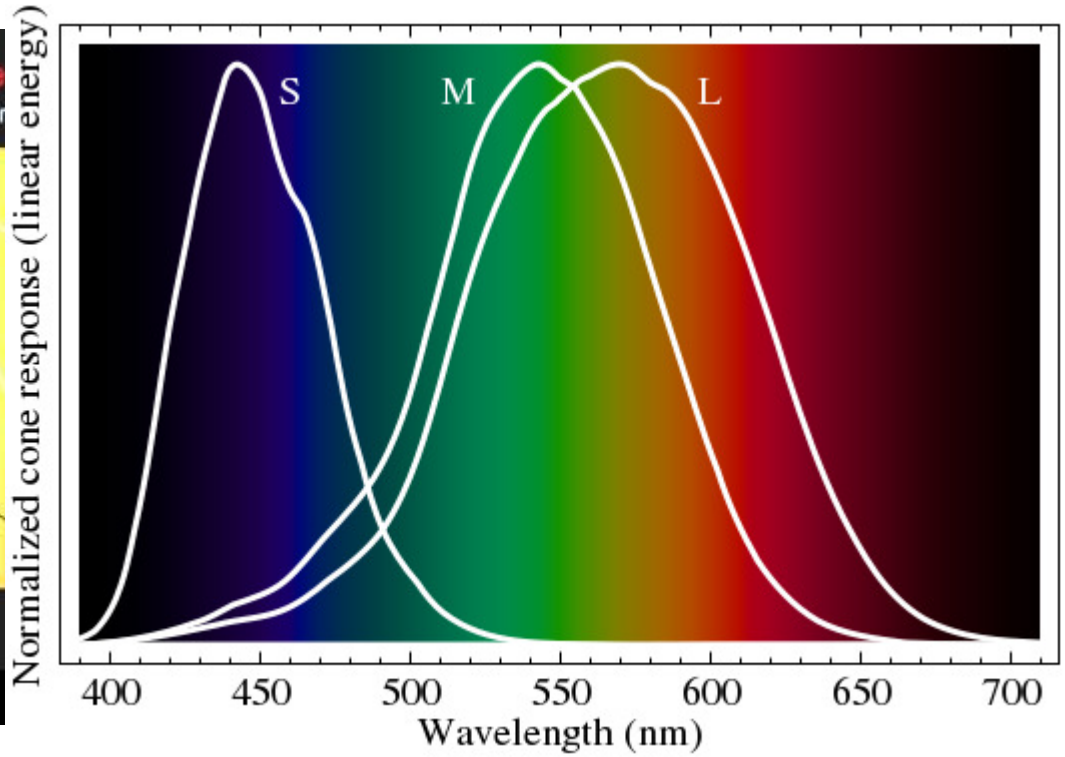
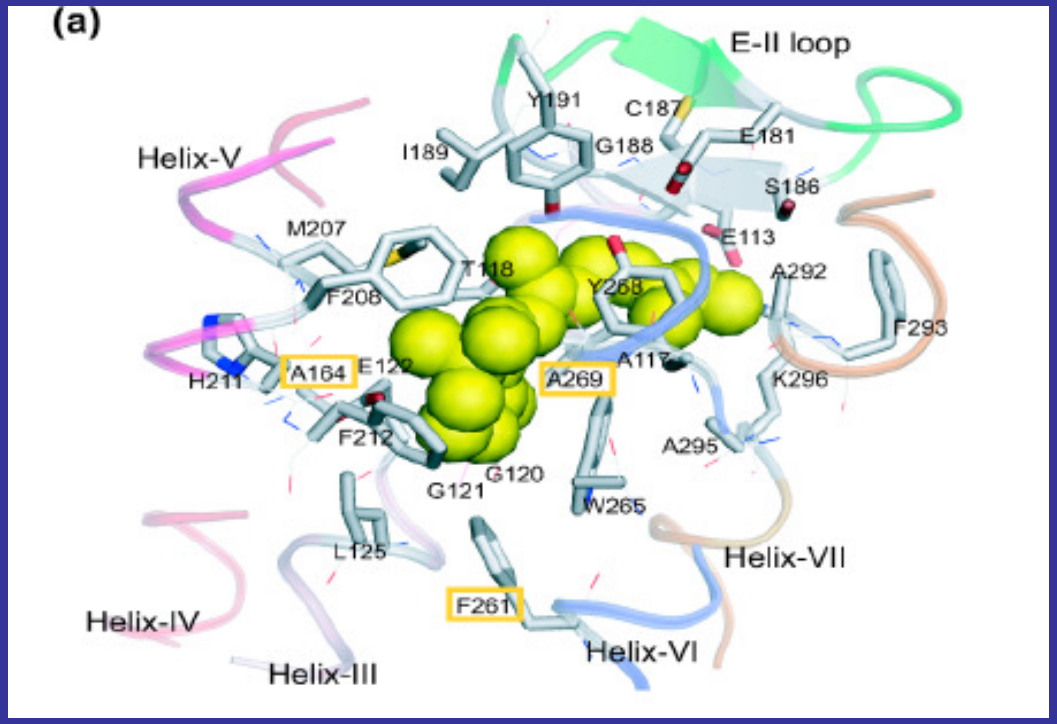


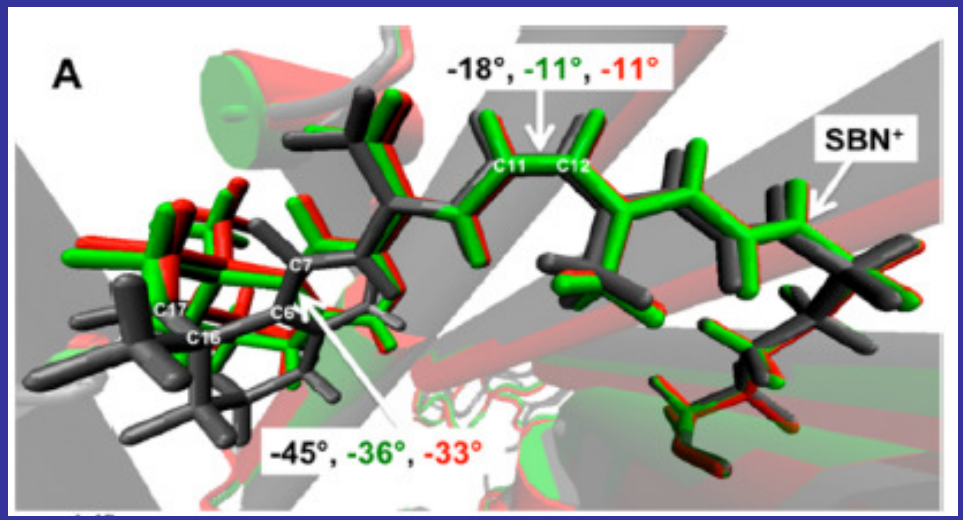
Fig. 10-35


S-cone
M-cone
L-cone
rod

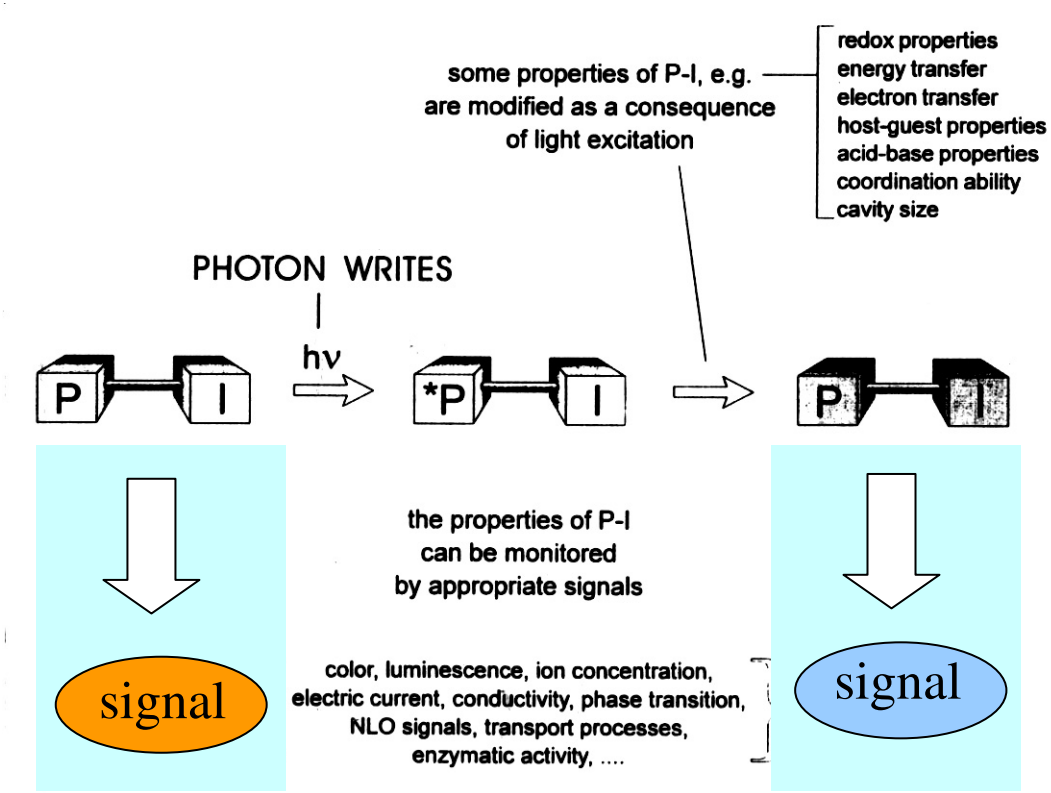

blue cone
437 nm
rod
498 nm
green cone
533 nm
red cone
564 nm
Relative Absorbance
400
450
500
550


S
M
L
Normalized cone response (linear energy)
400
450
500
550
600
650
700
Wavelength (nm)


(a)
E-II loop
Y191
C187
E181
I189
G188
Helix-V
S186
M207
E113
T118
A292
Y268
F208
F293
A164
E122
A269
A117
K296
H211
F212
A295
G120
G121
W265
L125
Helix-VII
F261
Helix-IV
Helix-VI
Helix-III


A
-18°, -11°, -11°
SBN+
C11
C12
C7
C17
C6
C16
-45°, -36°, -33°

“PHOTON WRITES” DEVICES



Information Storage
Optical Memories
Optical Switches

DATA STORAGE DENSITY

- book 5×10^{-2} cm^2 /char 20 char/cm^2

- CD 1×10^{-7} cm^2 /char 1×10^{7} char/cm^2

- "molecular memory" (10 Å)

2D 10^{-14} cm^2 10^{14} char/cm^2

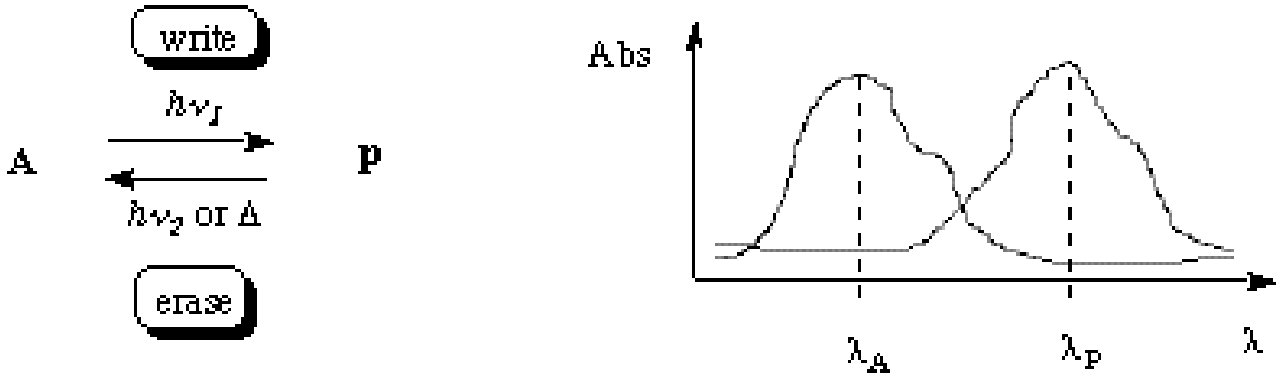
3D 10^{-21} cm^2 10^{21} char/cm^3

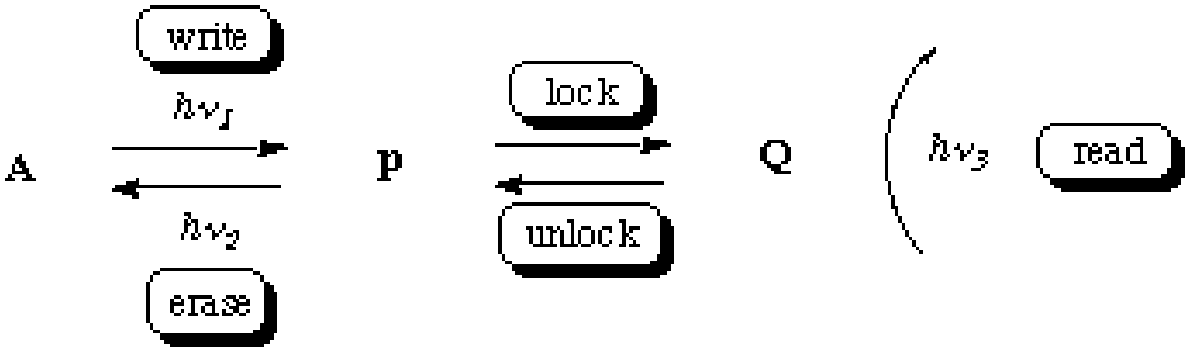
- if light is used to "write", $\Delta x \approx \lambda$

e. g., for $\lambda = 500$ nm 2D 2×10^{9} cm^2 3D 10^{13} cm^3

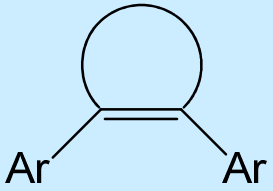
Information Storage (Write/Read/Erase)

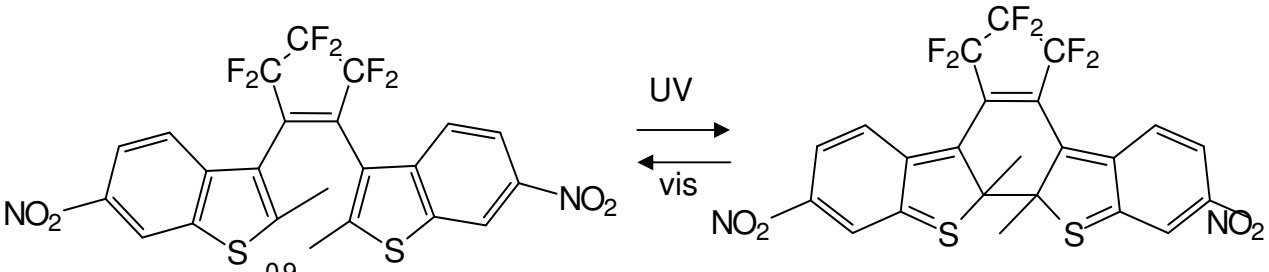
with Photochromic Systems

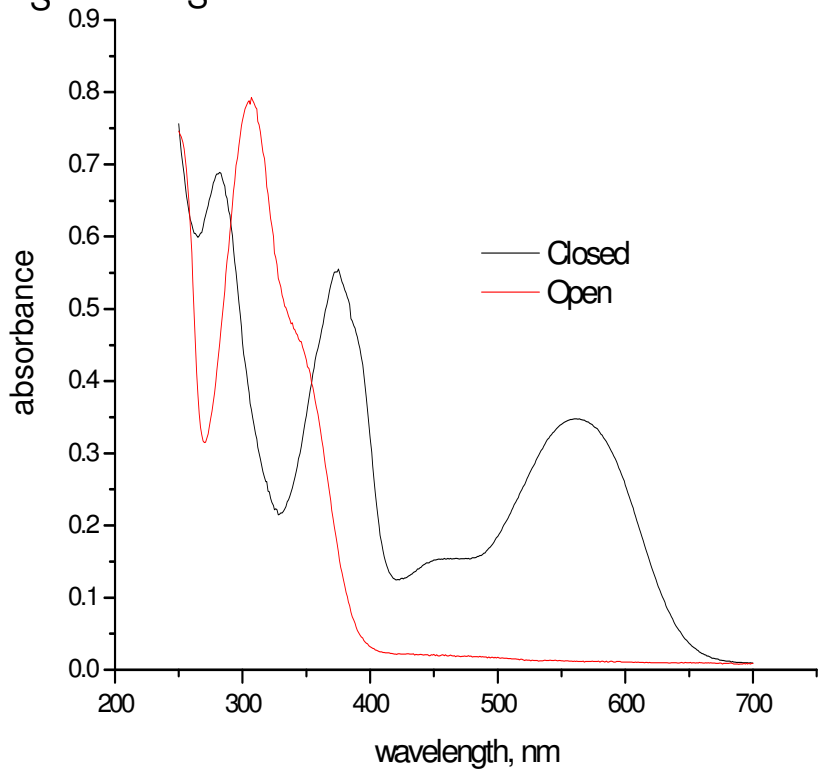




Photochromic Diarylethenes

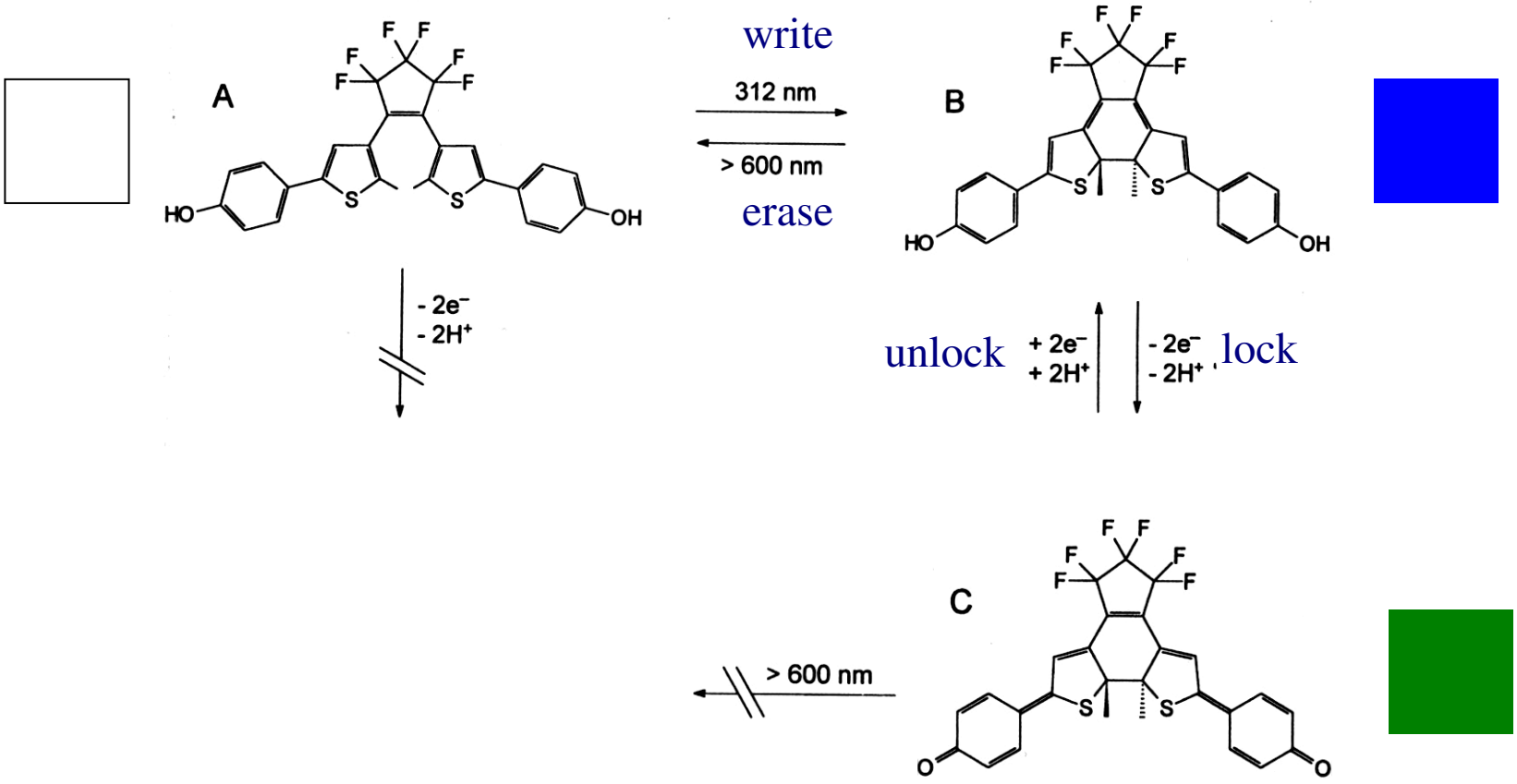






Drawback: destructive readout

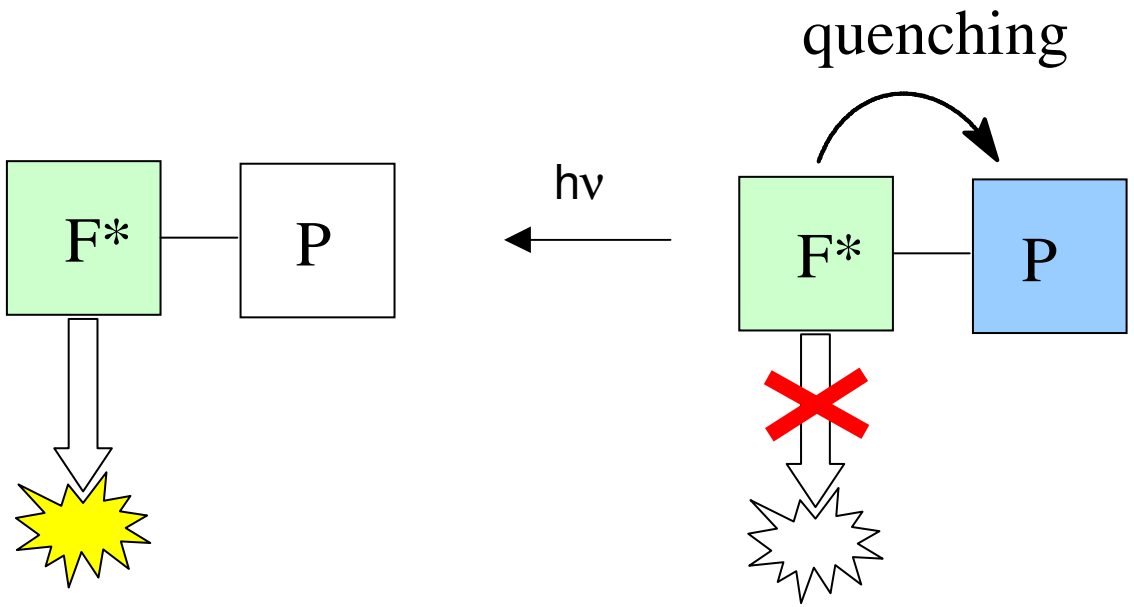
A lock/unlock write-read-erase molecular system



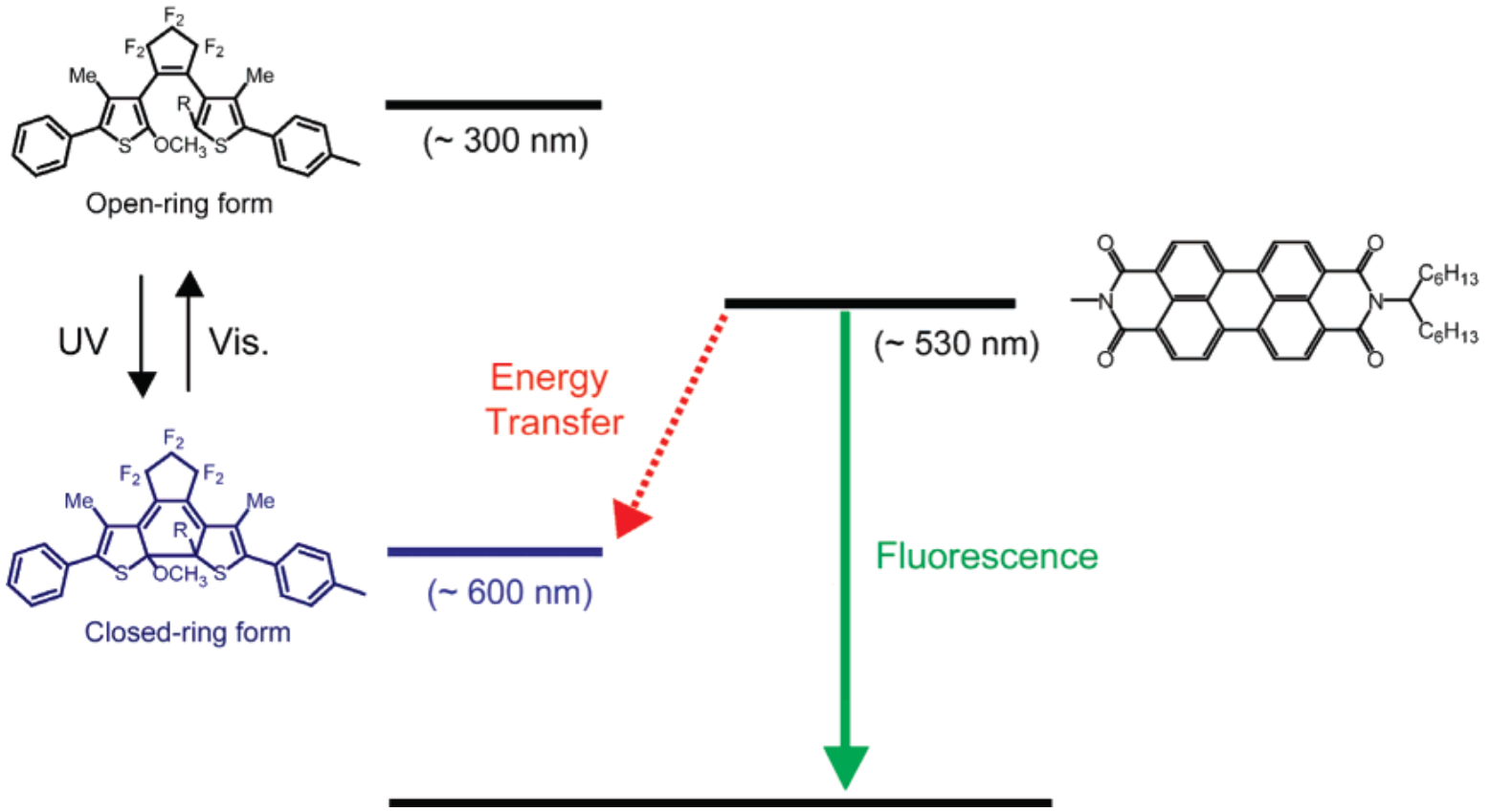
Fluorescence Readout Memory: Fluorophore + Photochromic unit

F = Fluorophore

P = Photochromic unite

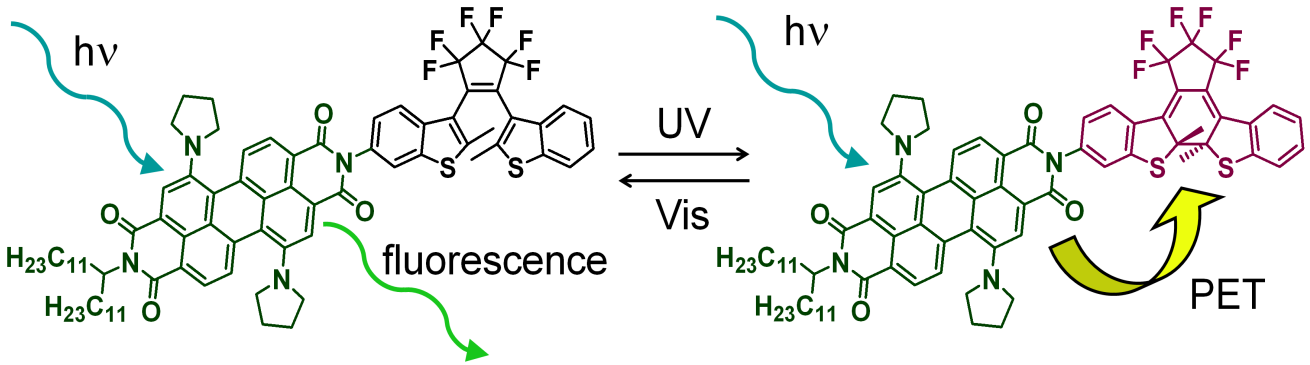


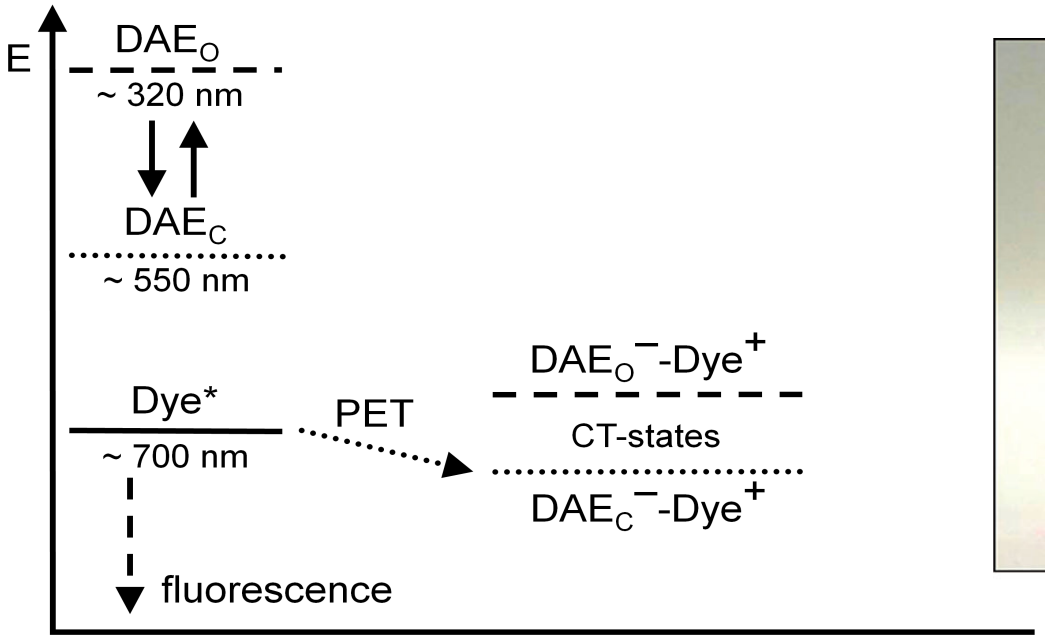
Fluorescence Readout Memory:
Dyad with Fluorophore + Photochromic unit

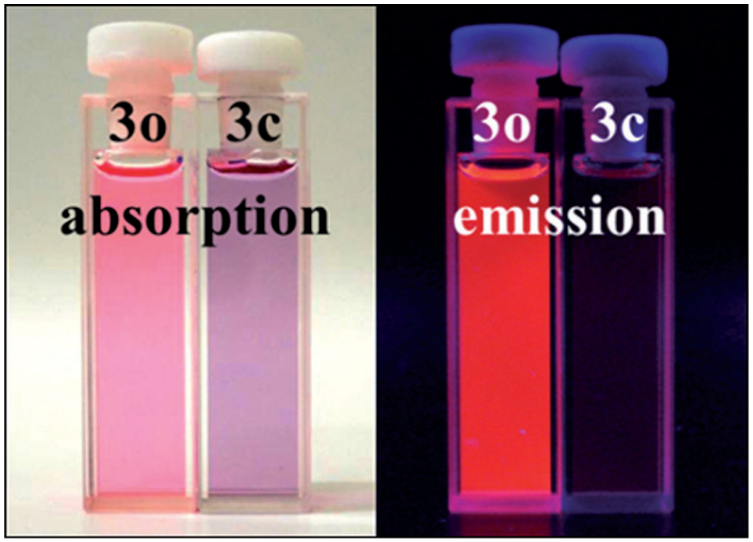


Selective quenching by closed form. Quenching mechanism: energy transfer
Drawback: destructive readout

Fluorescence Readout Memory: Dyad with Fluorophore + Photochromic unit

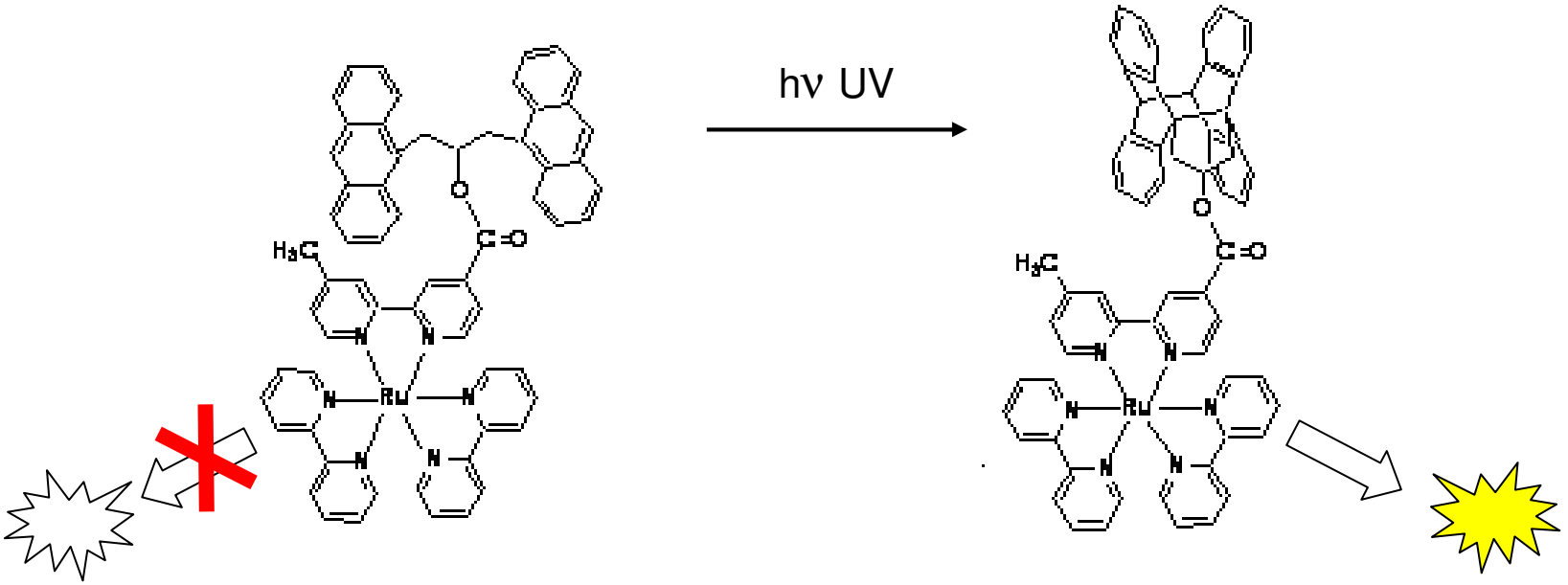


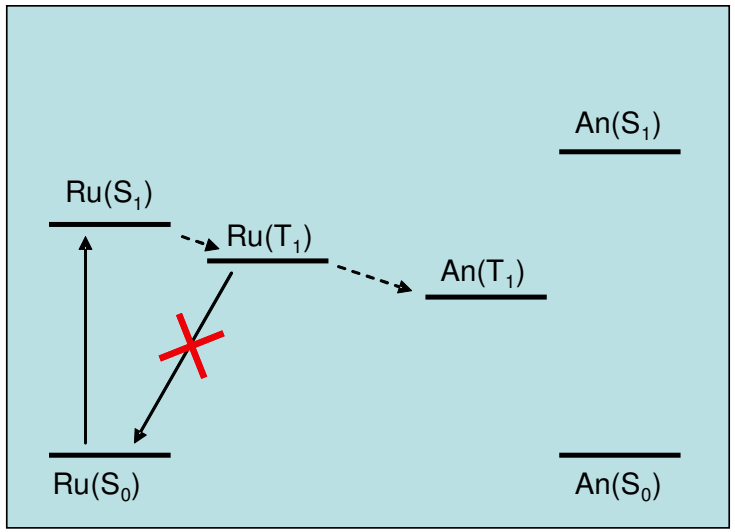


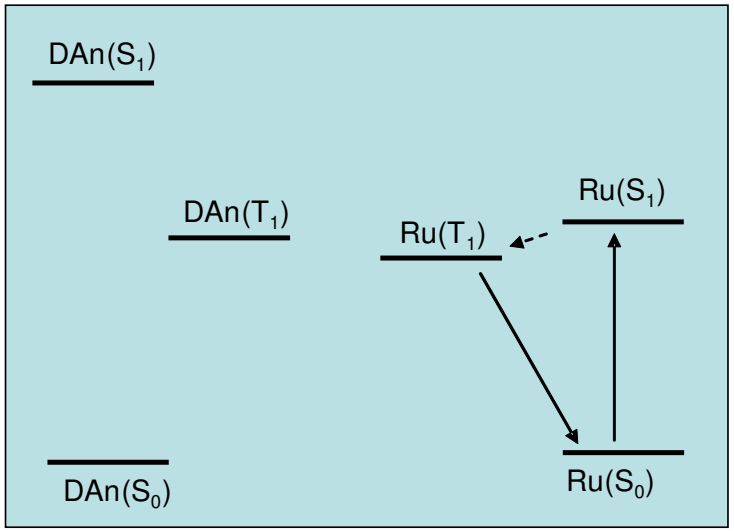


Selective quenching by closed form. Quenching mechanism: **electron** transfer
Advantage: non-destructive readout

Non-destructive Readout Fluorescence Memory: Triplet Quenching by Photochromic Unit

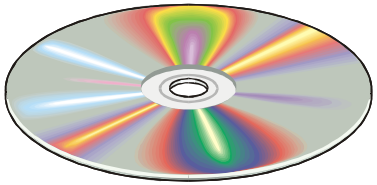


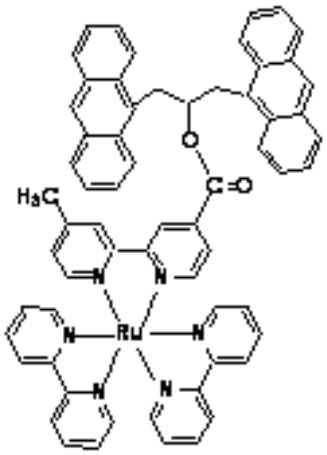


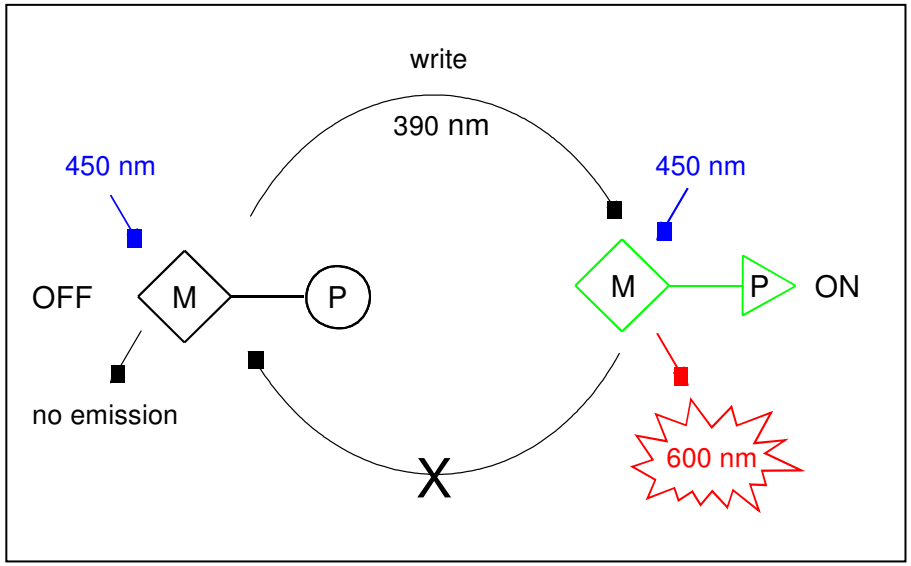


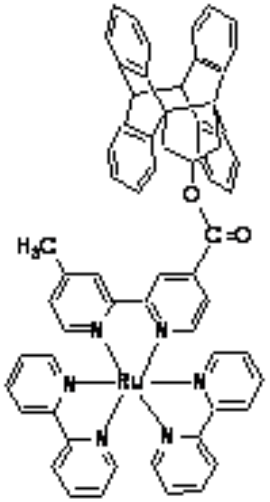
Functional Materials

Luminescent Optical Memories

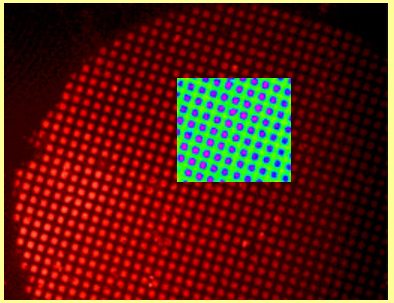






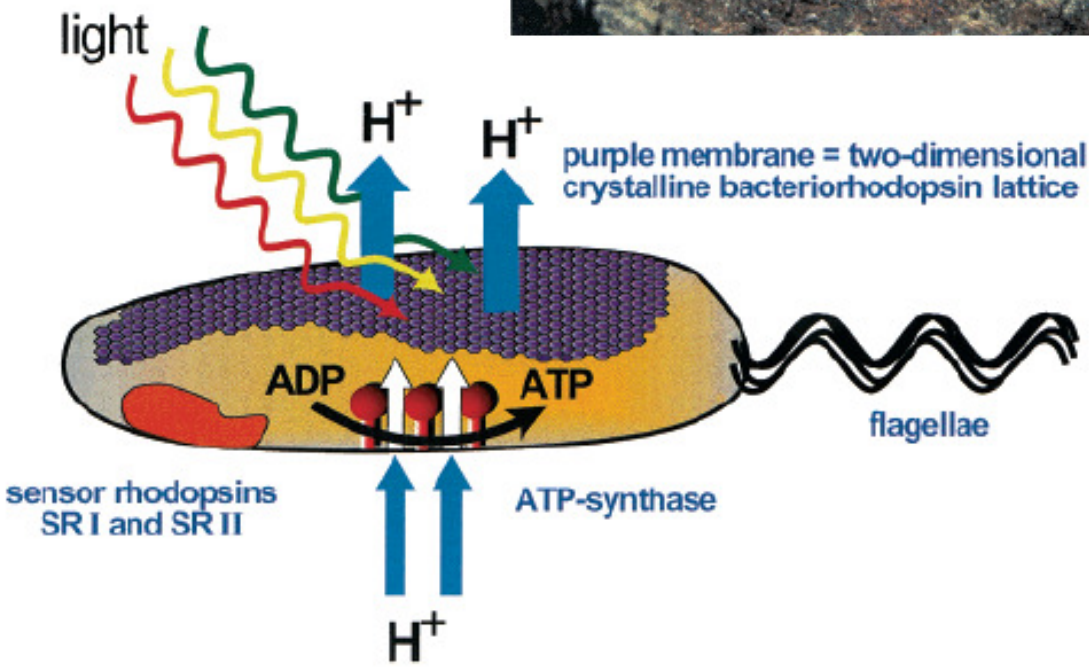


Fluorescent microscope image written with a frequency doubled Ti:Sapphire laser through a TEM grid (10 μm resolution)

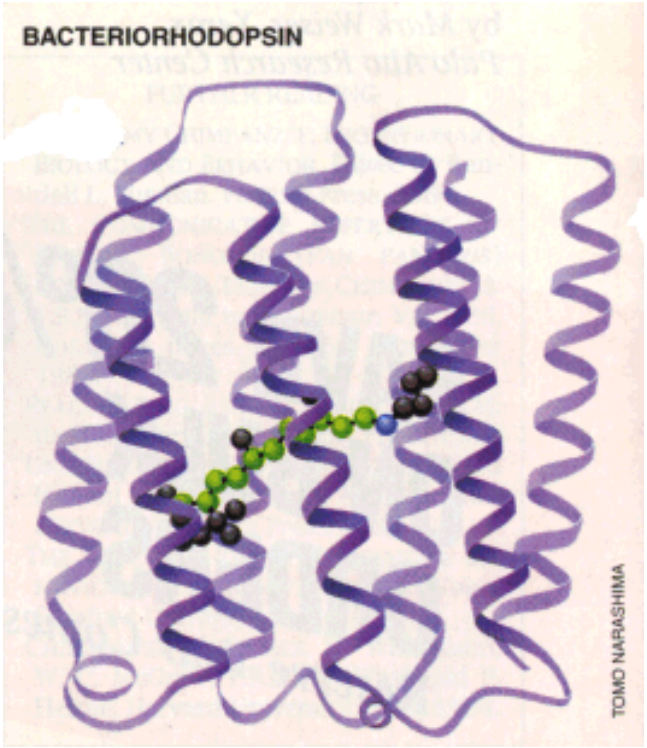


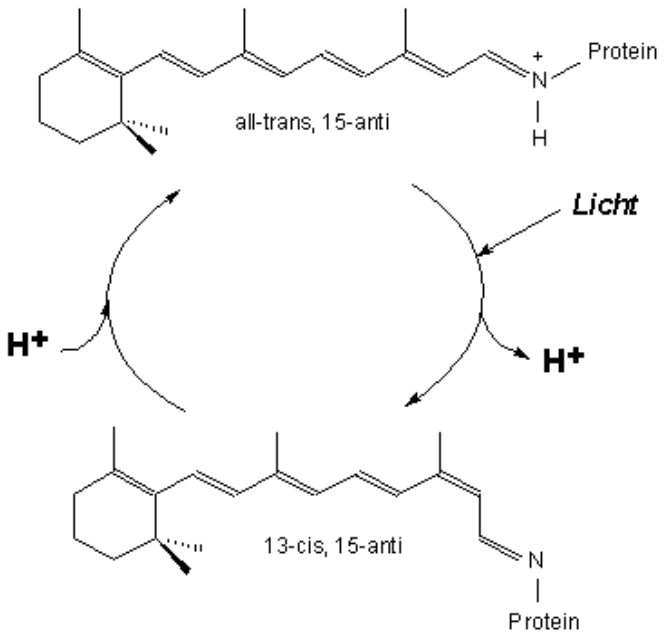
Bacteriorhodopsin from

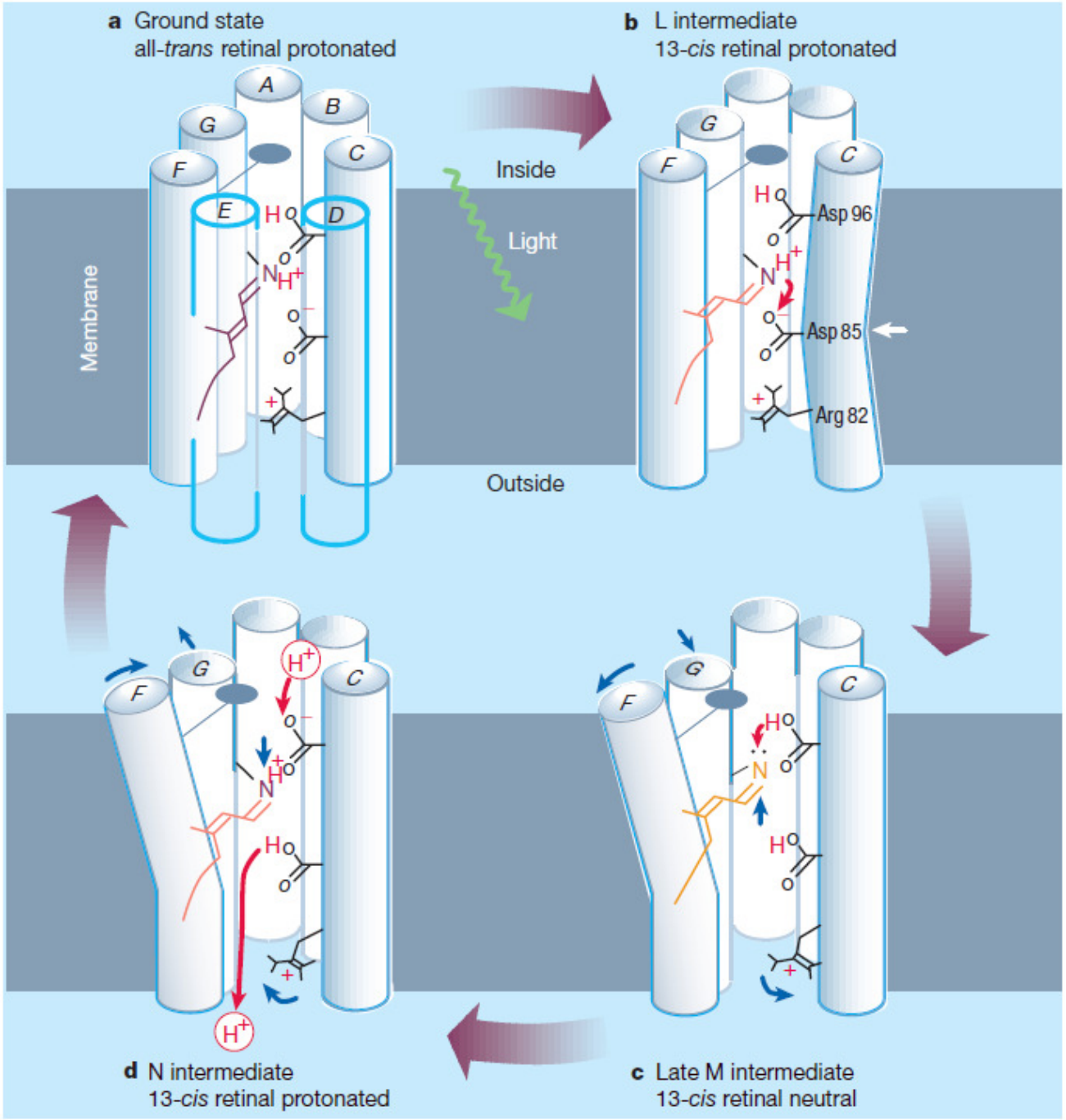
Halobacterium Halobium



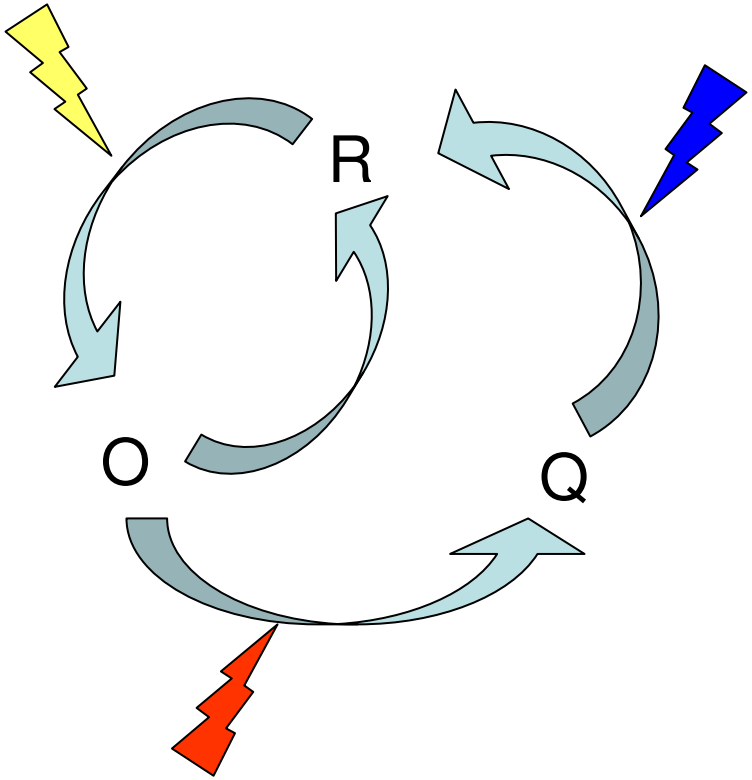
Bacteriorhodopsin
A natural photochromic system

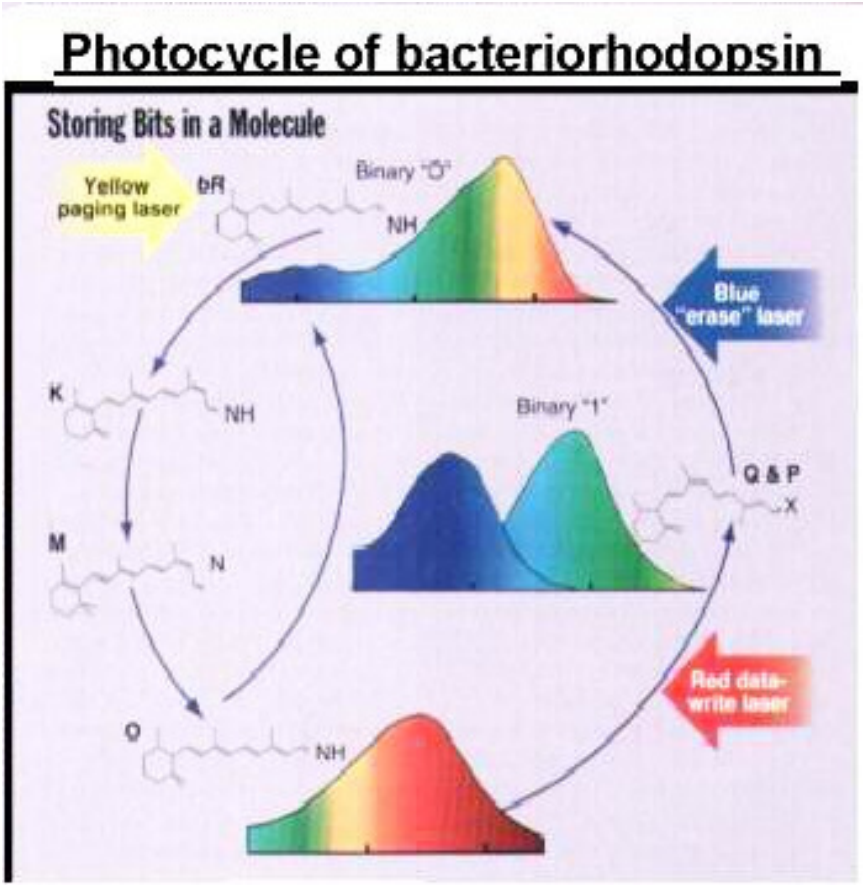




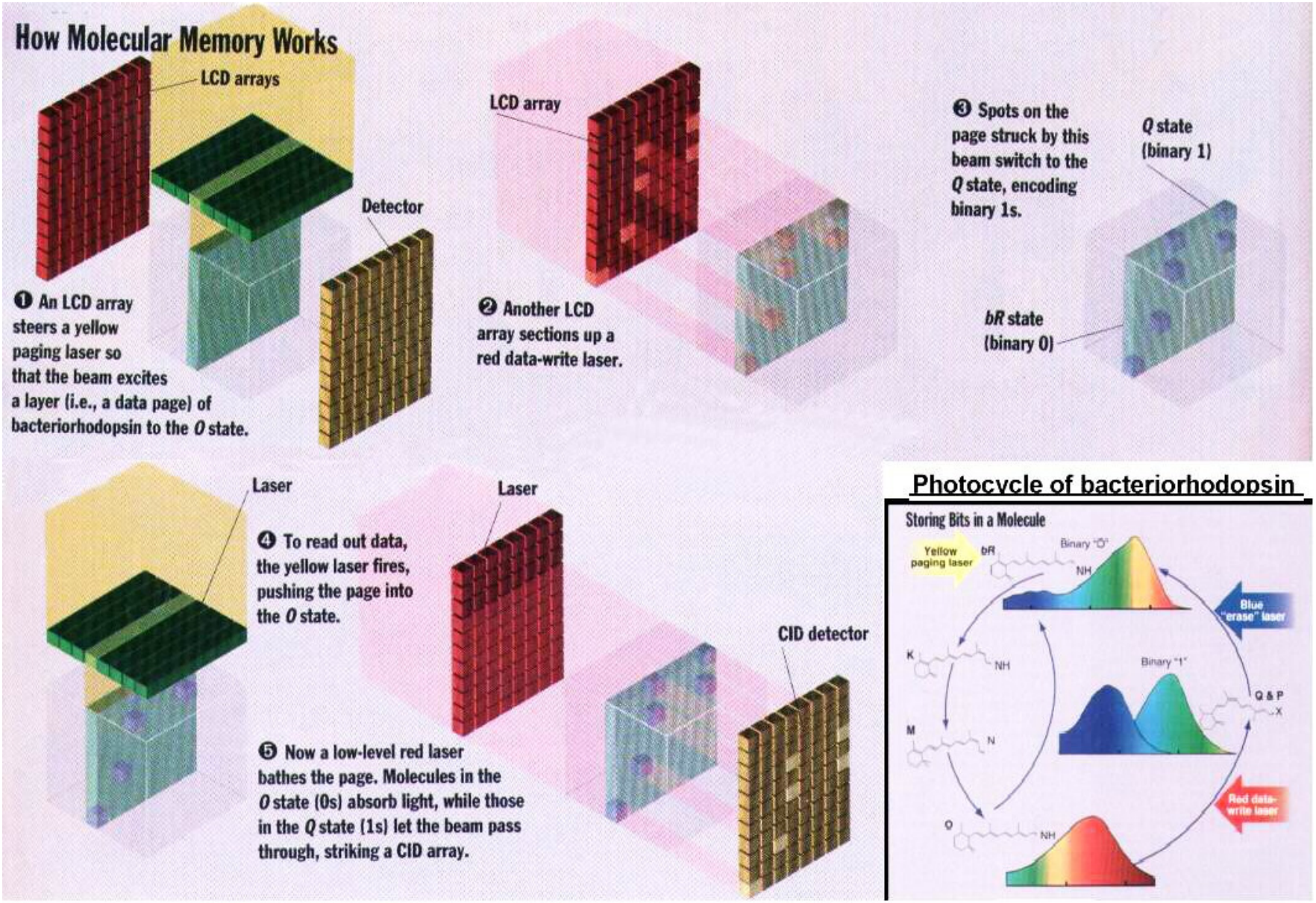

a Ground state
all-trans retinal protonated
b L intermediate
13-cis retinal protonated
Inside
Light
Outside
Membrane
A
B
C
D
E
F
G
Asp 96
Asp 85
Arg 82
d N intermediate
13-cis retinal protonated
c Late M intermediate
13-cis retinal neutral

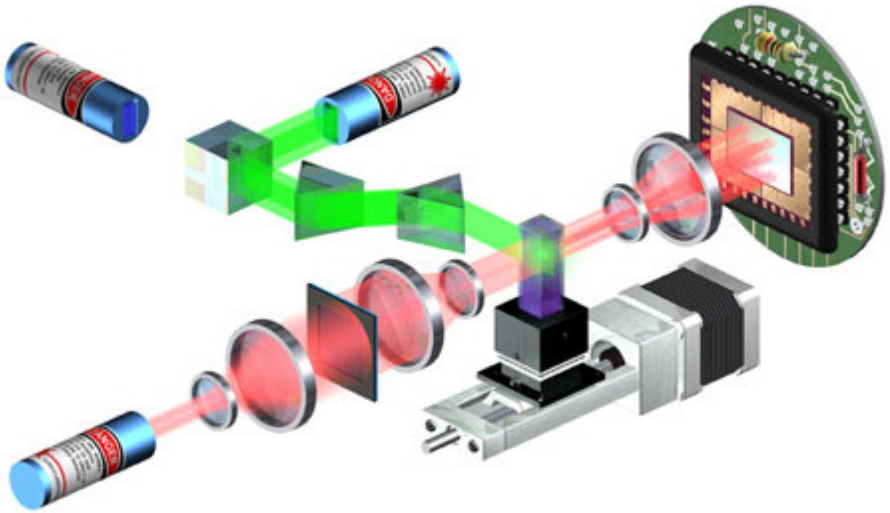
Bacteriorhodopsin:
a natural photochromic system

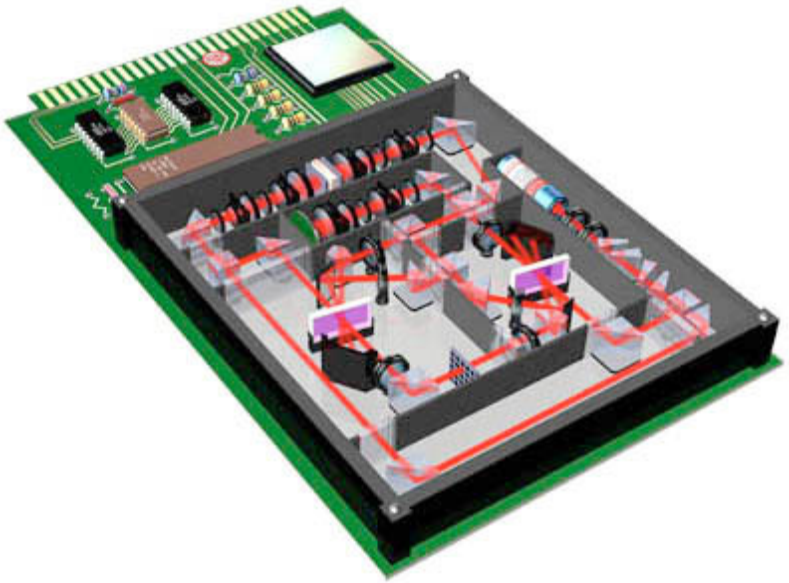




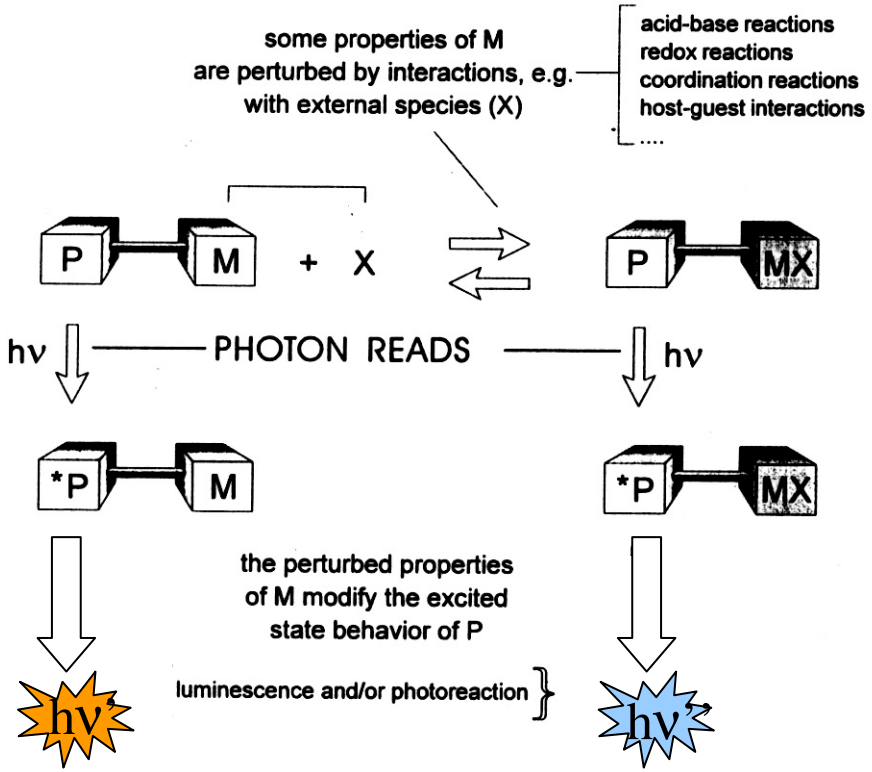
3D Optical Memory based on BacterioRhodopsin







"PHOTON READS" DEVICES



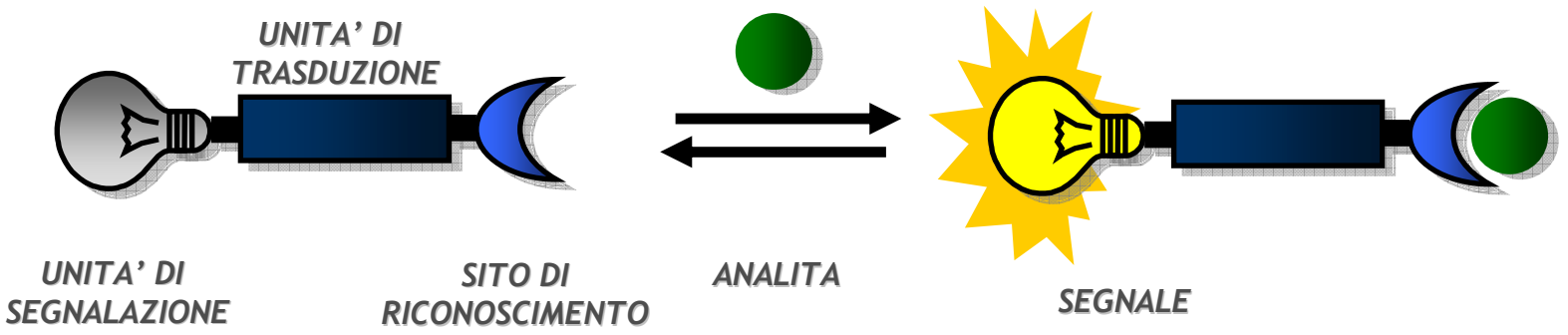
Sensors
Luminescent Probes

Chemosensor (molecular sensor)

Chemical sensors (Chemosensors)

"A chemosensor is molecule of abiotic origin that signals the presence of matter or energy"

(A. W. Czarnick)



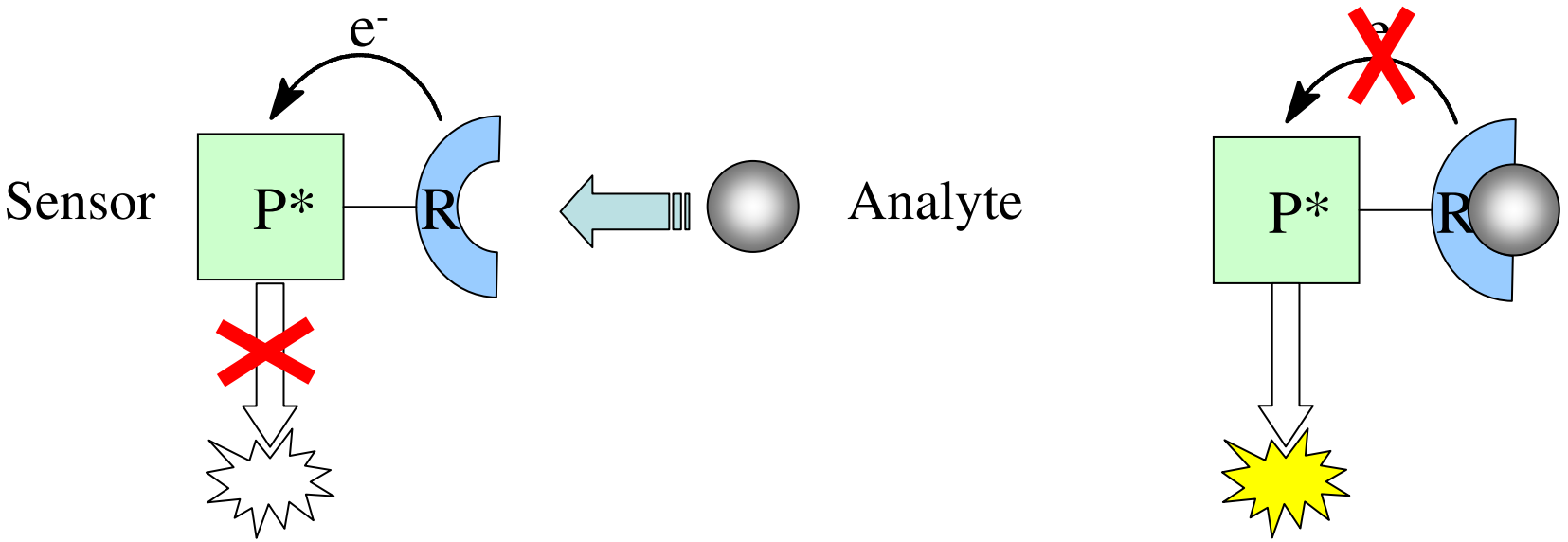
Fluorescent chemosensor

It is a chemosensor that generate a fluorescence signal

Why fluorescence?

- ✓ Sensitivity (even single molecule detection is possible)
- ✓ High spatial and temporal resolution
- ✓ Low cost and easily performed instrumentations

Fluorescent Sensor based on ET quenching



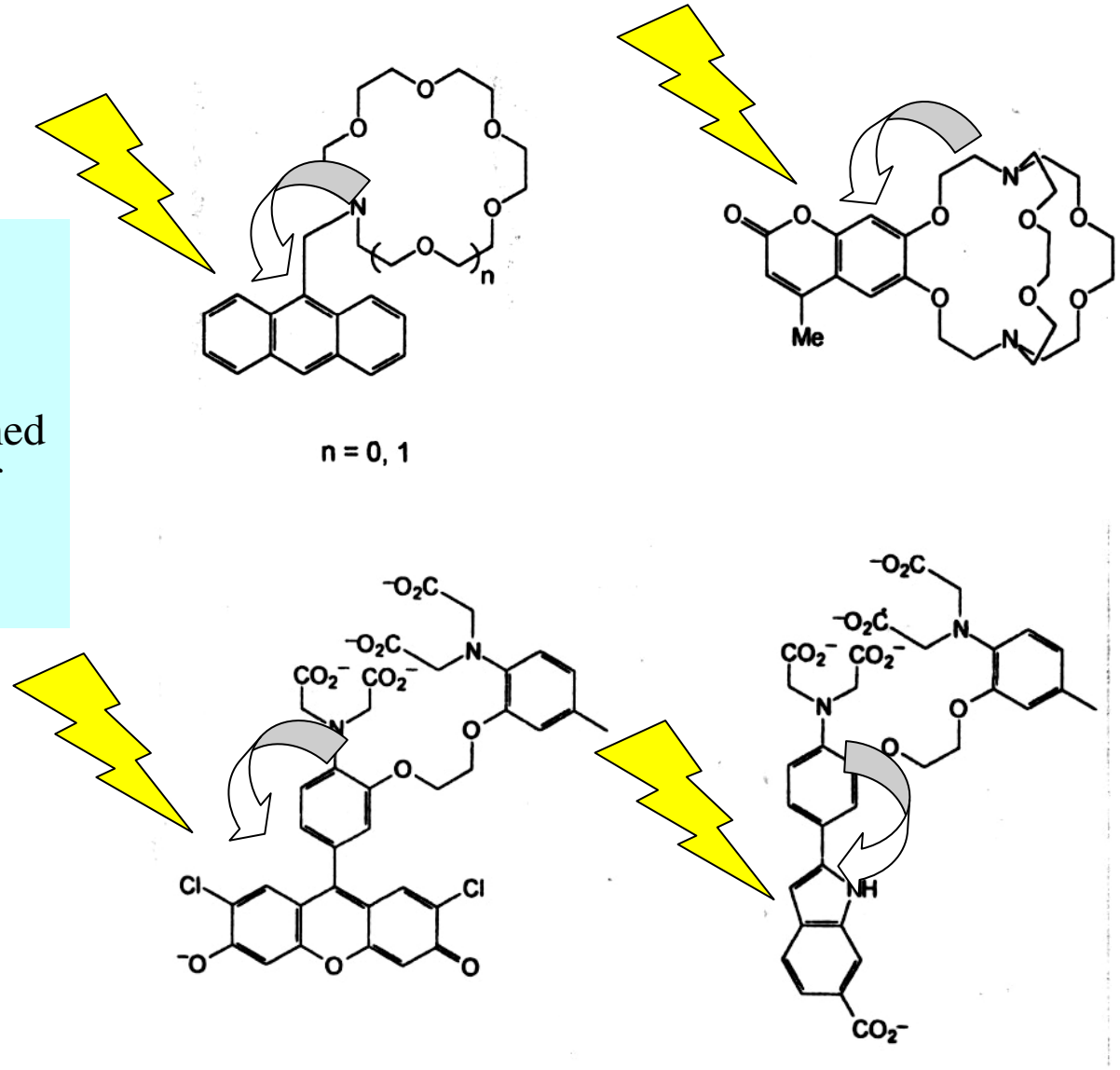
Fluorophore quenched by free receptor

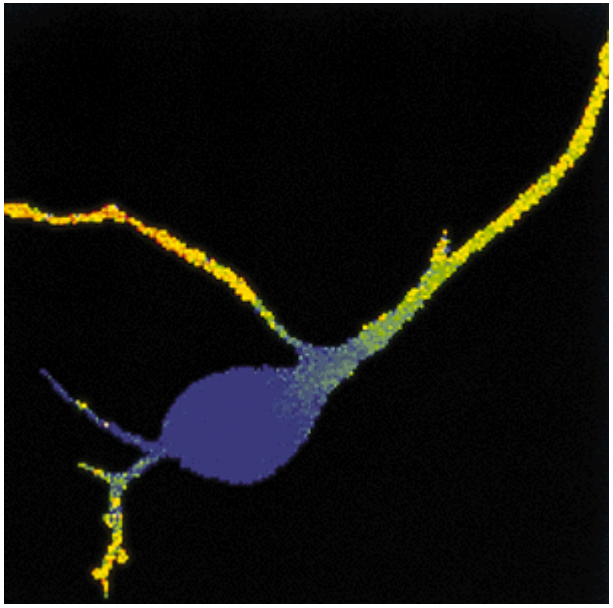
No quenching by receptor-analyte. Fluorescence switched on

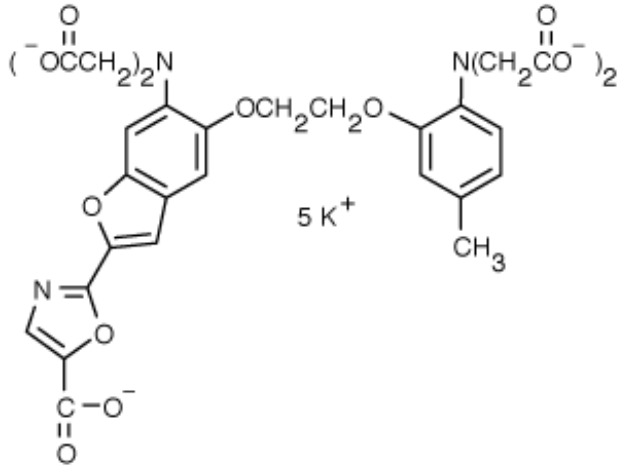
Fluorophore-Receptor Supermolecules

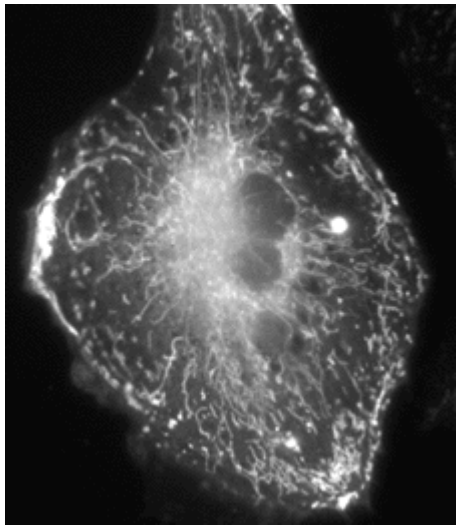
OFF state:

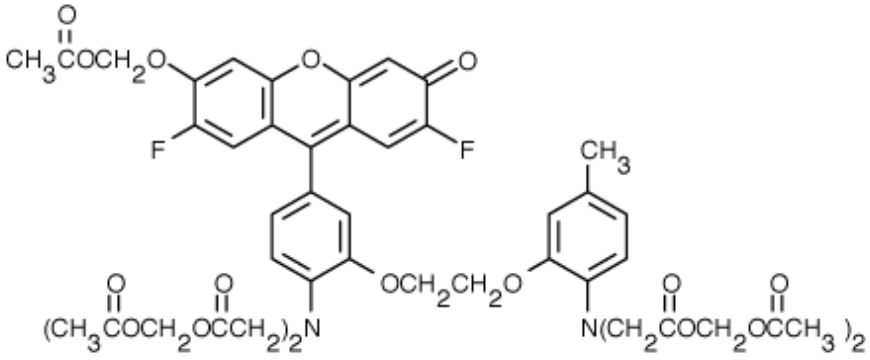
S_1 state of fluorophore quenched by ET from amino group of receptor





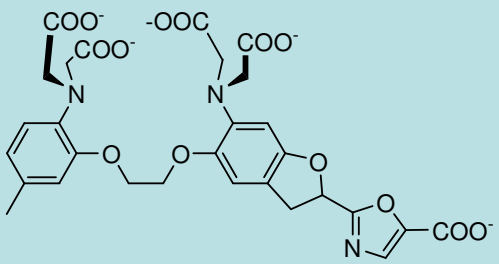

O
(⁻OCCH2)2N
N(CH2CO⁻)2
O
OCH2CH2O
O
5 K+
CH3
N
O
C−O⁻
O



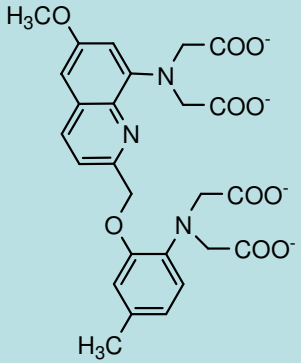

O
CH3COCH2O
O
O
F
F
CH3
OCH2CH2O
O
O
O
(CH3COCH2OCCH2)2N
N(CH2COCH2OCCH3)2

Intrinsic chemosensors 1

Ca^{2+}

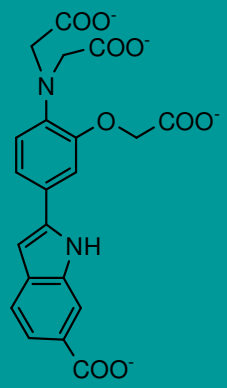


FURA-2
(Tsien 1980)



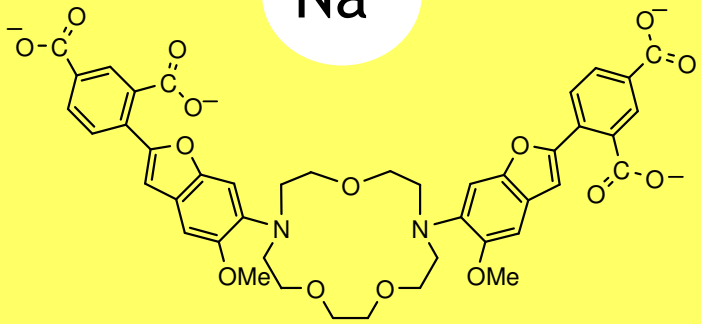
Quin-2
(Tsien 1985)

Mg^{2+}



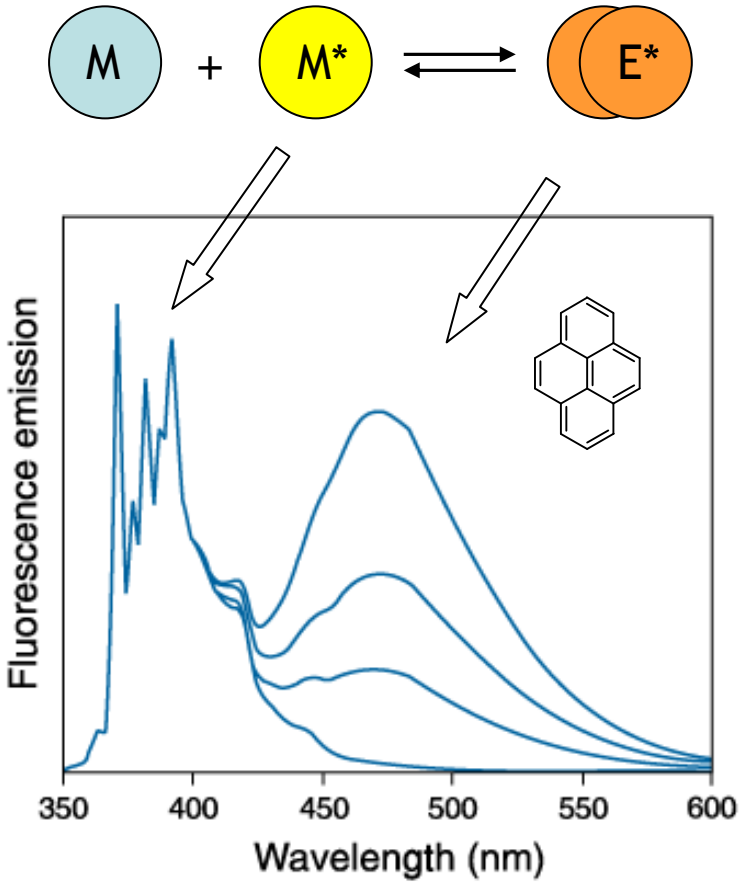
Mag-Indo-1
(London 1989)

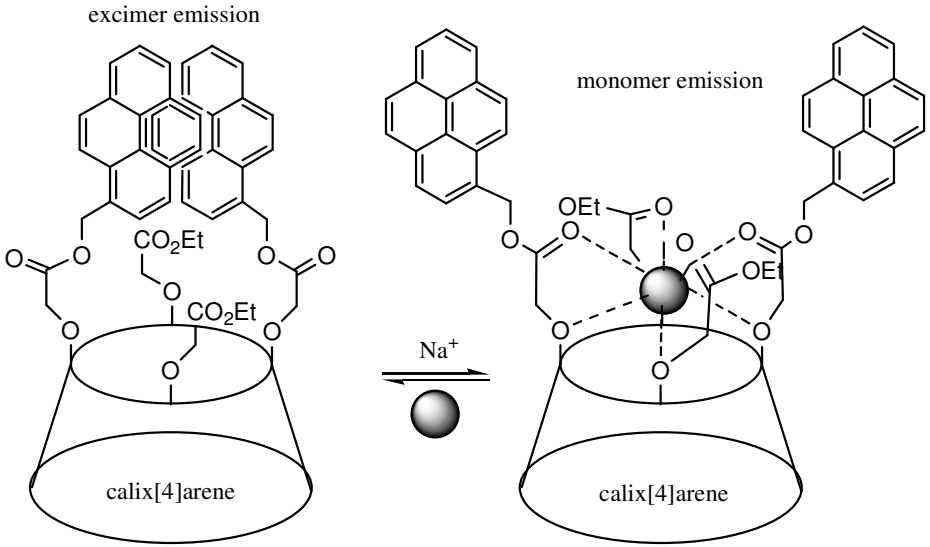
Na^{+}



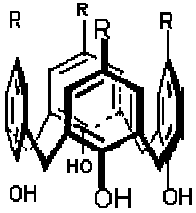
(Tsien 1989)

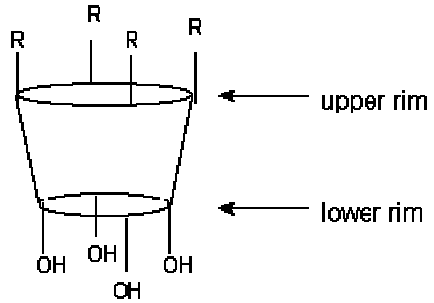
Excimers formation



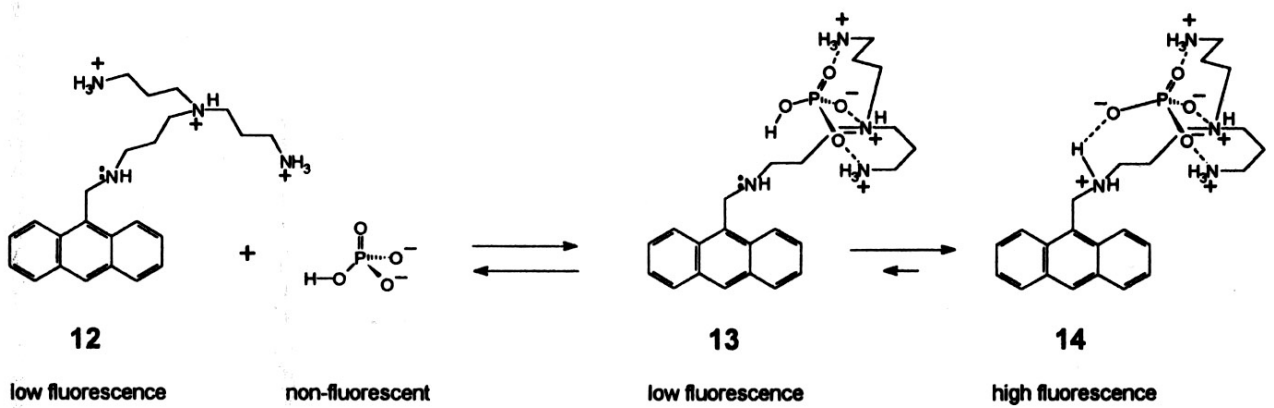


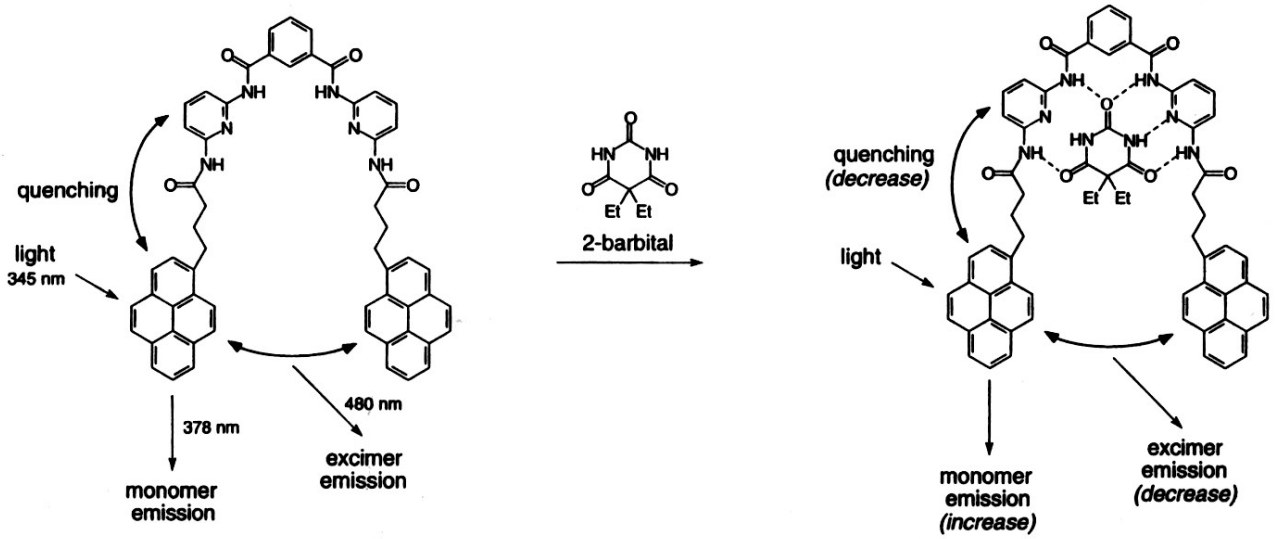
Jin et al. *J. Chem. Soc., Chem. Commun.*, **1992**, 499.



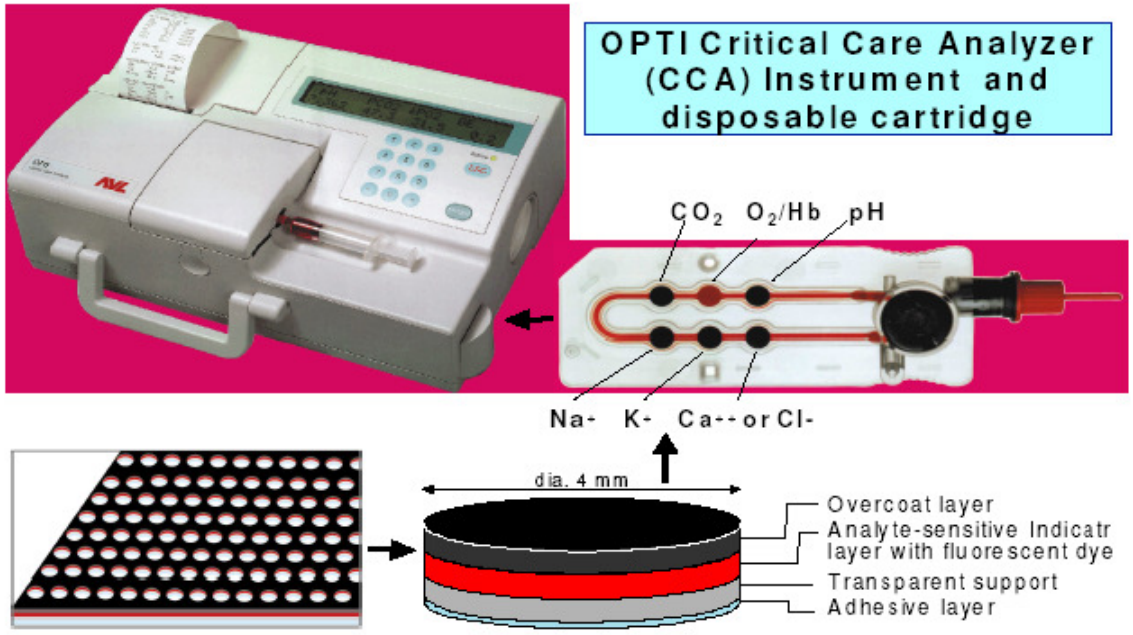


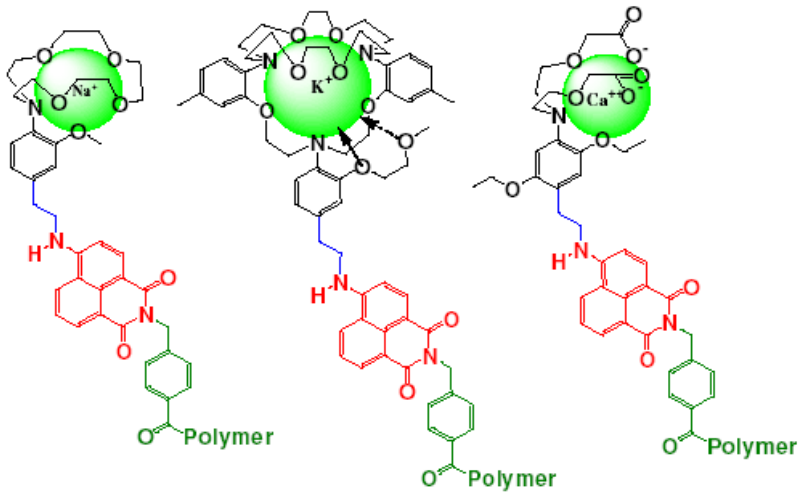
Molecular Recognition/Sensing





Intrinsic chemosensors 2



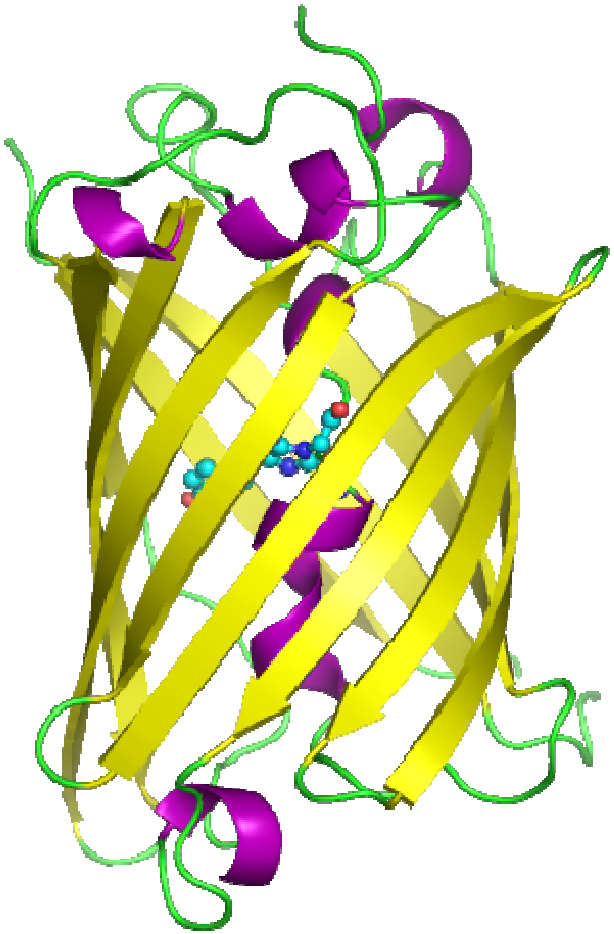


J.K. Tusa, H. He

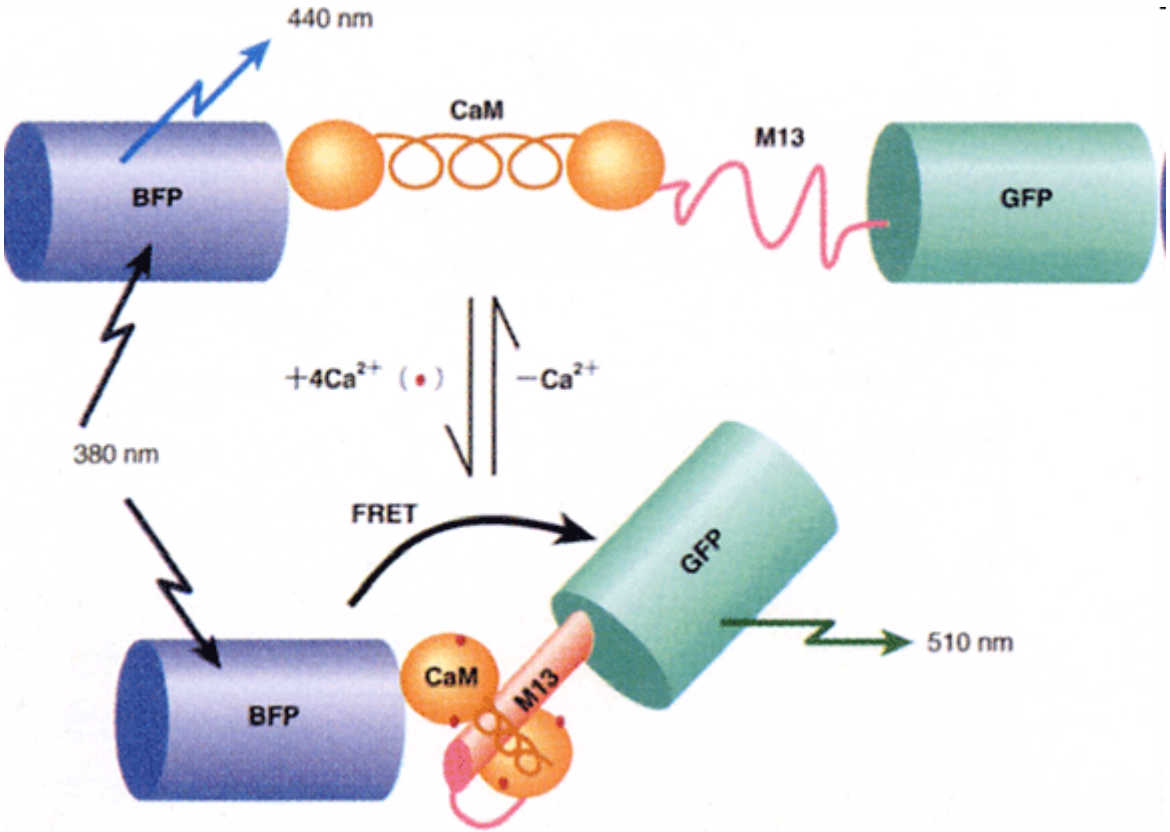
Special Fluorophores:

Greeen Fluorescent Protein

chromophore:
4-(p-hydroxybenzylidene)imidazolidin-5-one (HBI)

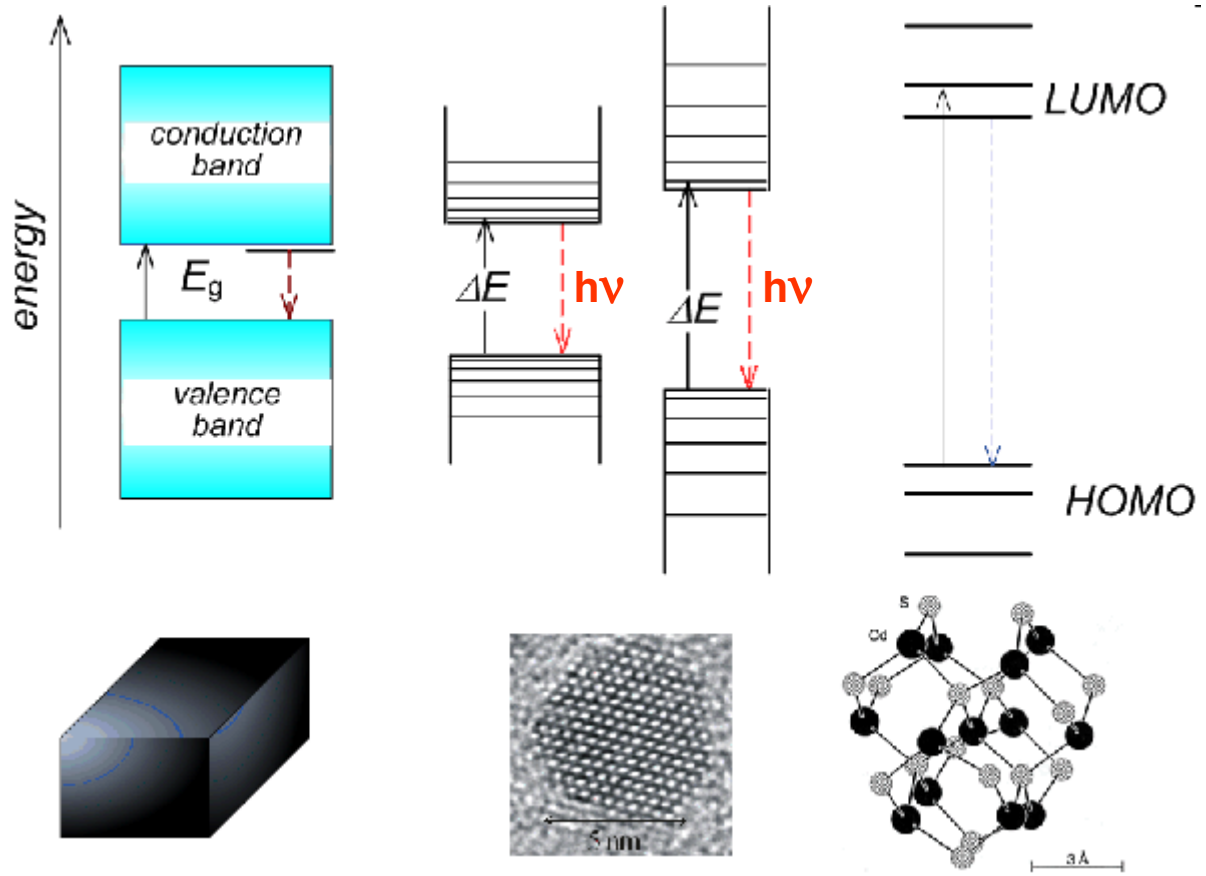


Martin Chalfie, Osamu Shimomura,Roger Y. Tsien
2008 Nobel Prize in Chemistry


440 nm
CaM
M13
BFP
GFP
+4Ca2+
−Ca2+
380 nm
FRET
GFP
510 nm
CaM
M13
BFP

Special Fluorophores: Semiconductor Quantum Dots

Quantum Size Effects

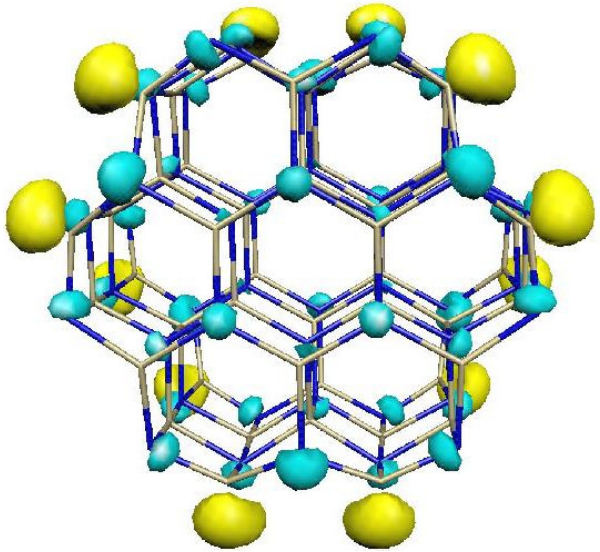


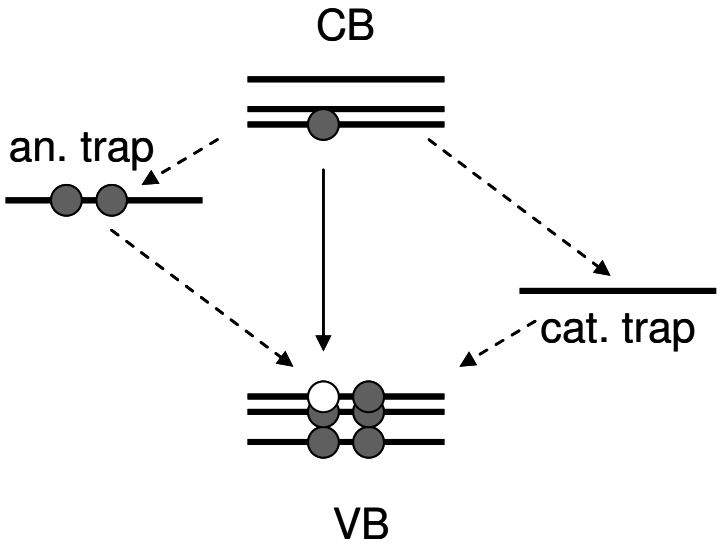
$$E_n = \frac{\hbar^2 \pi^2}{2mL^2} n^2.$$

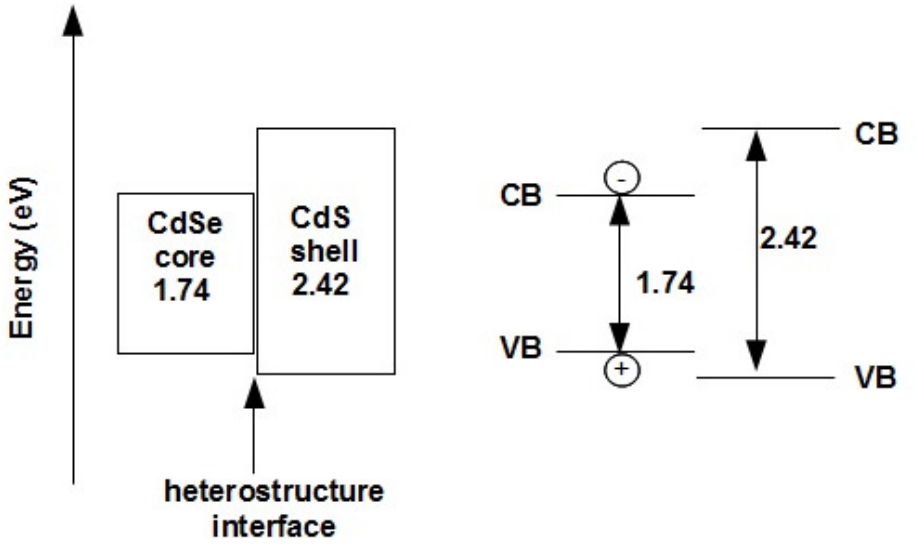
The atoms on the surface of a crystal facet are incompletely bonded within the crystal attice and leave “dangling orbitals” pointed outward from the crystal.

If these surface energy states are within the semiconductor band gap, they can trap charge carriers at the surface, thereby increasing the probability of nonradiative recombination

To minimize intraband gap surface states and reduce surface atomic reconstruction, the surface must be “passivated” with (i) organic ligands or (ii) insulating inorganic shell

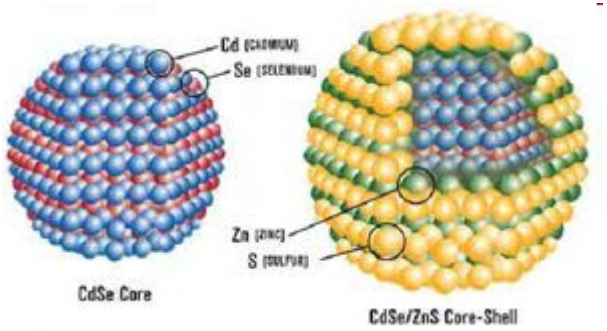


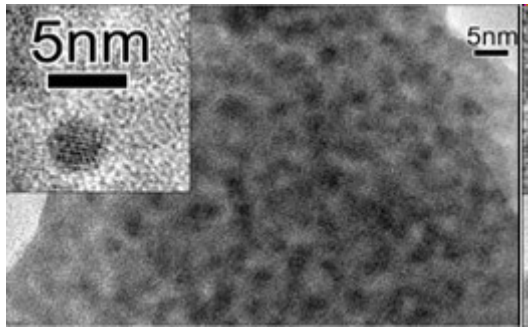


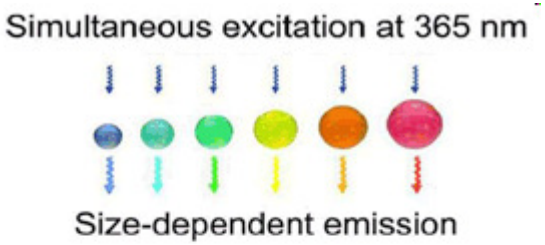


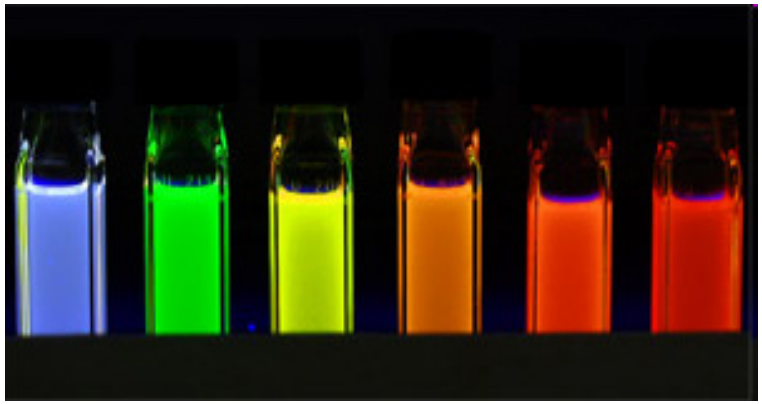
Special Fluorophores:

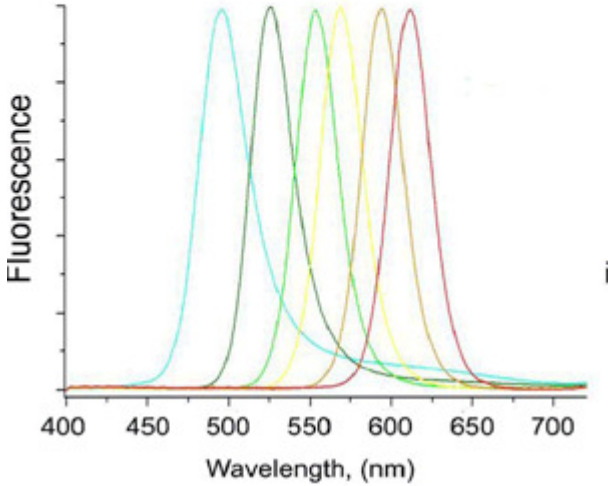
Semiconductor Quantum Dots



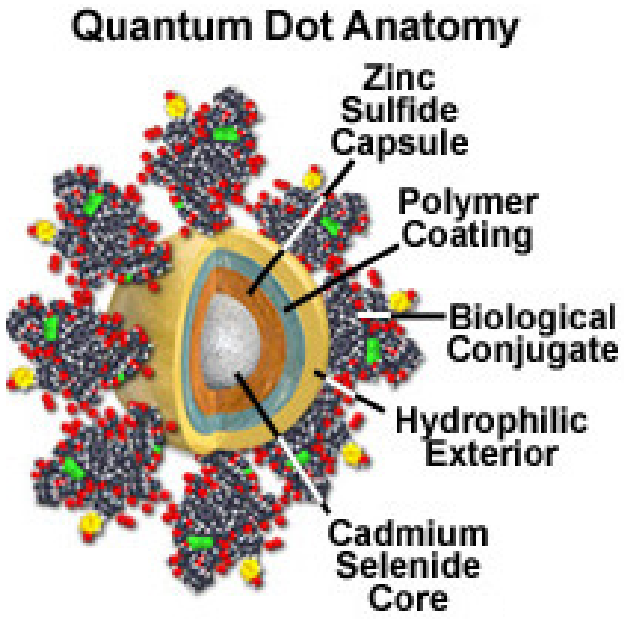


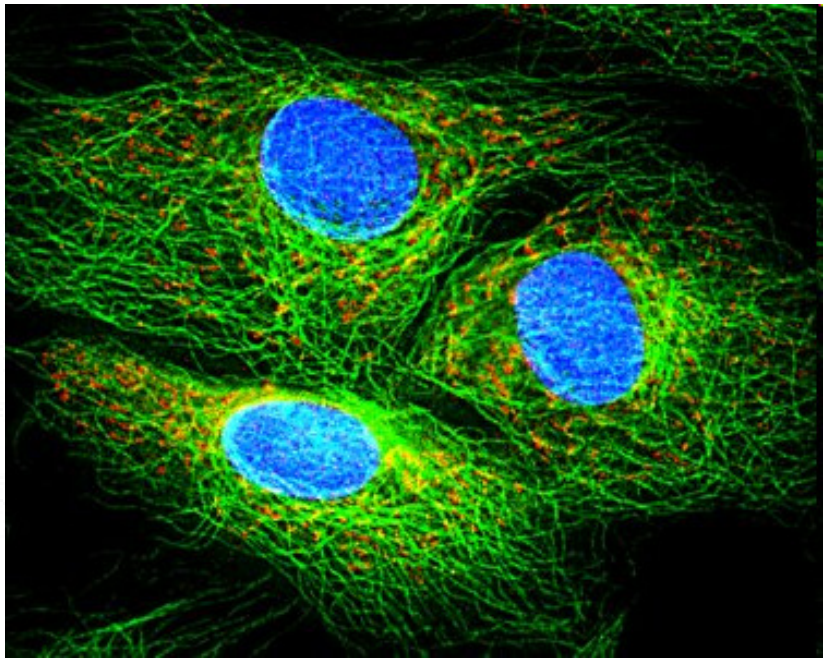






Functionalized with biological conjugates

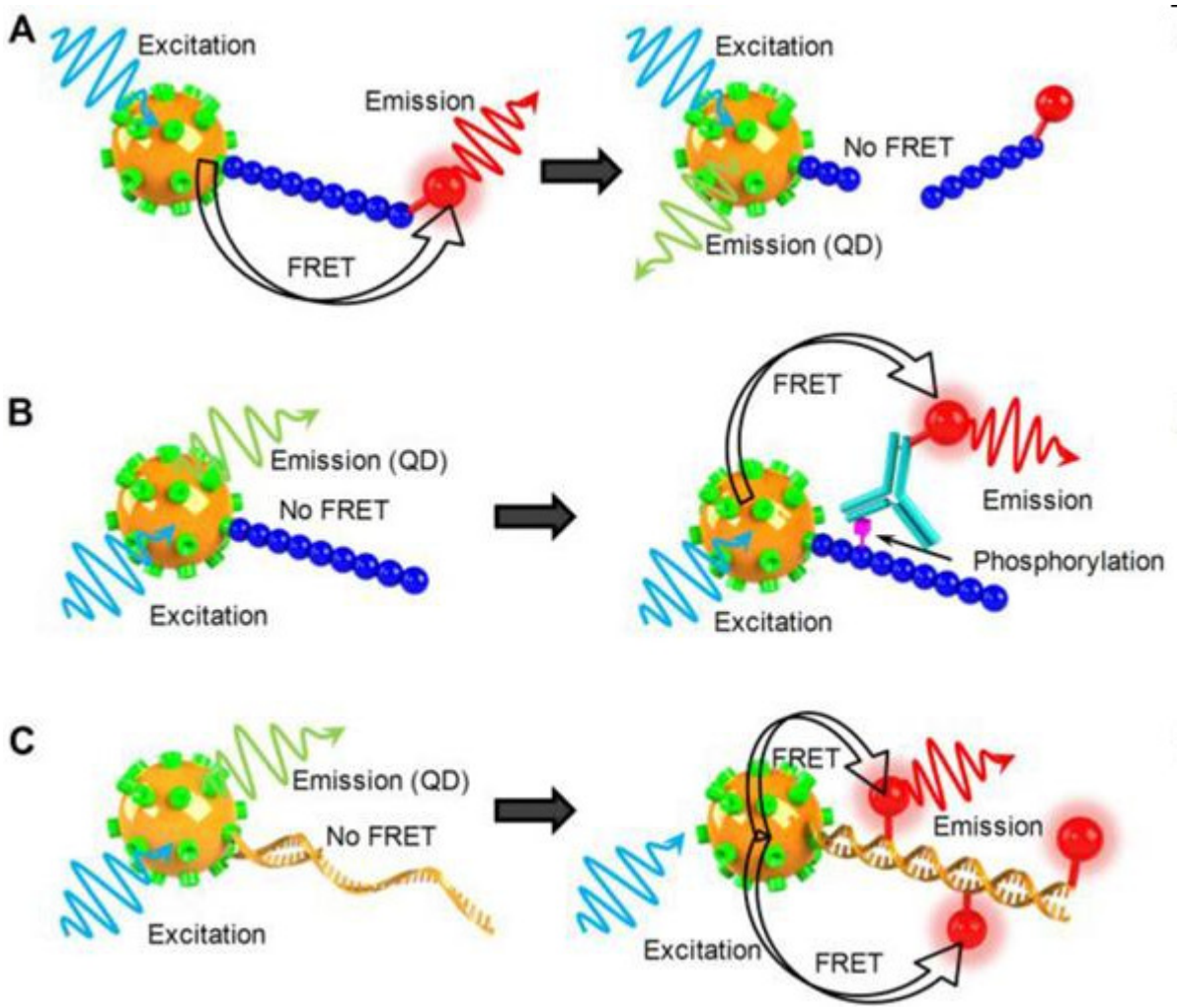




bio-conjugate = enzyme, antibody, etc.

fluorescent sensors, cell imaging, etc.

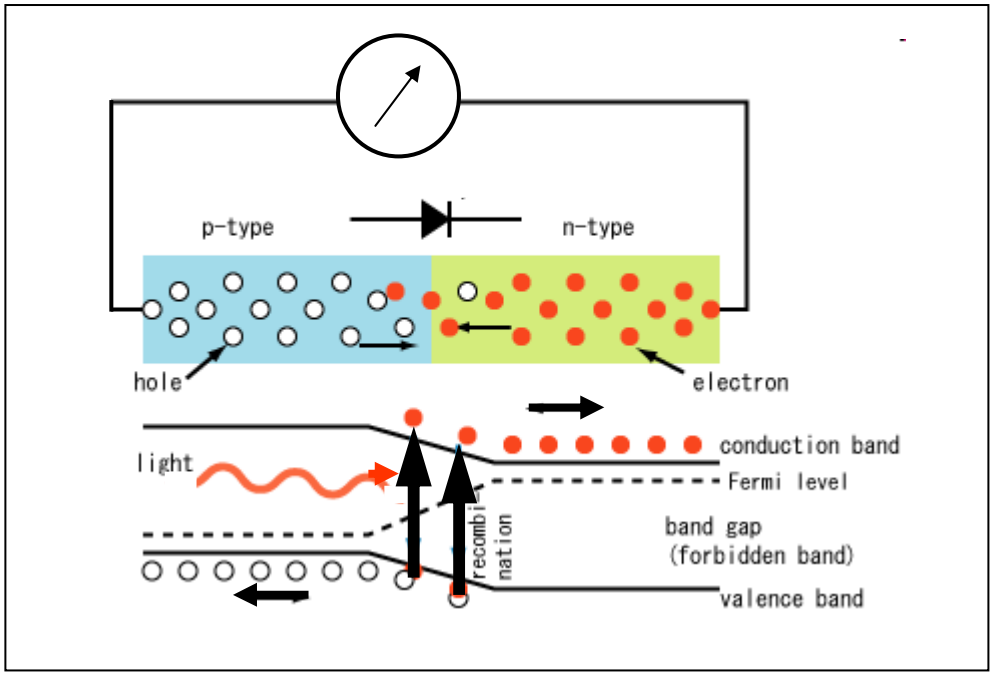
Study of enzyme activity



Protease

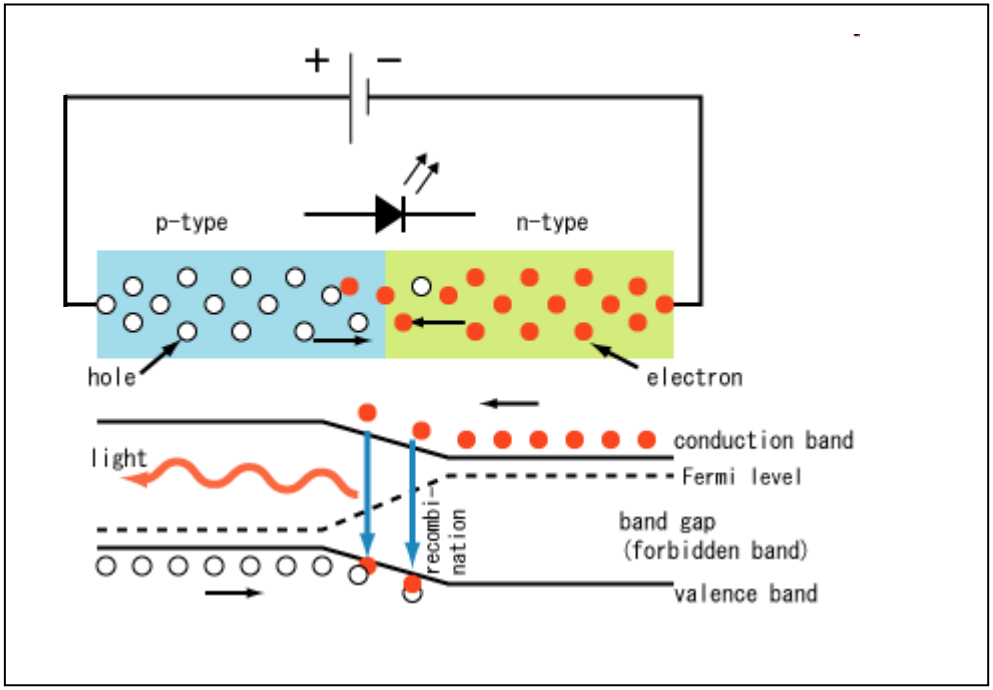
Protein kinase

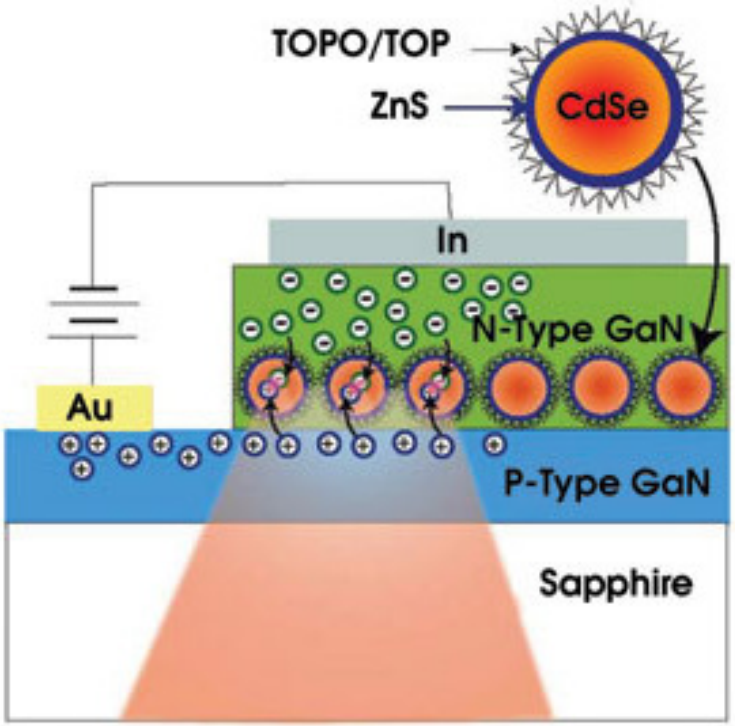
DNA polymerase



p-n photodiode

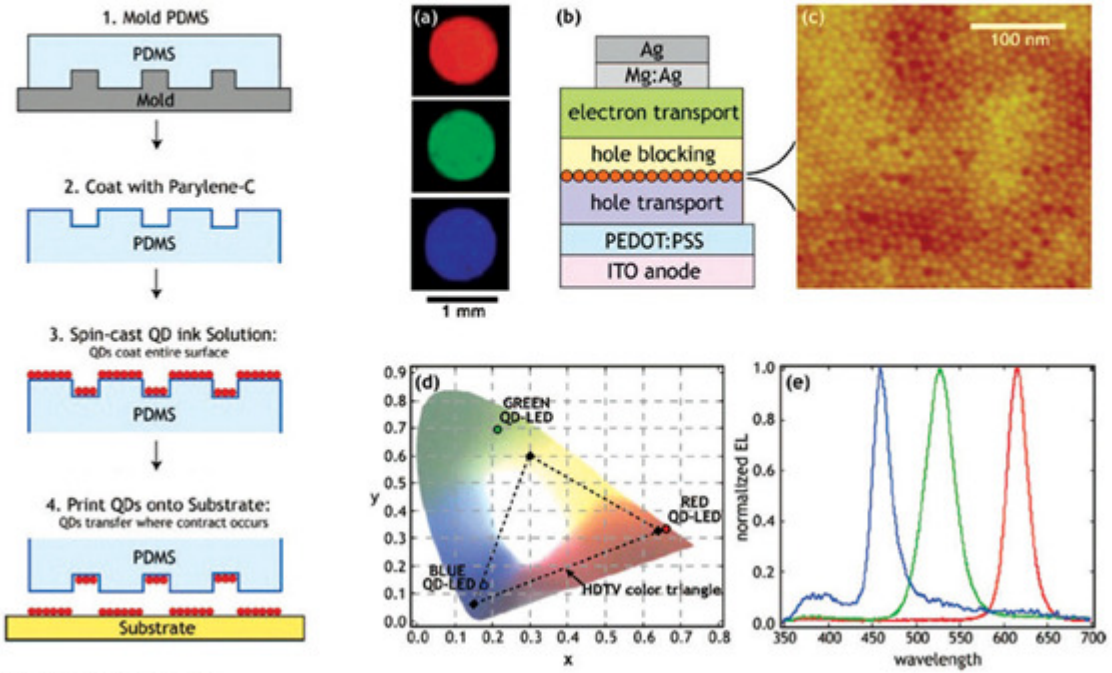
p-n light emitting diode (LED)



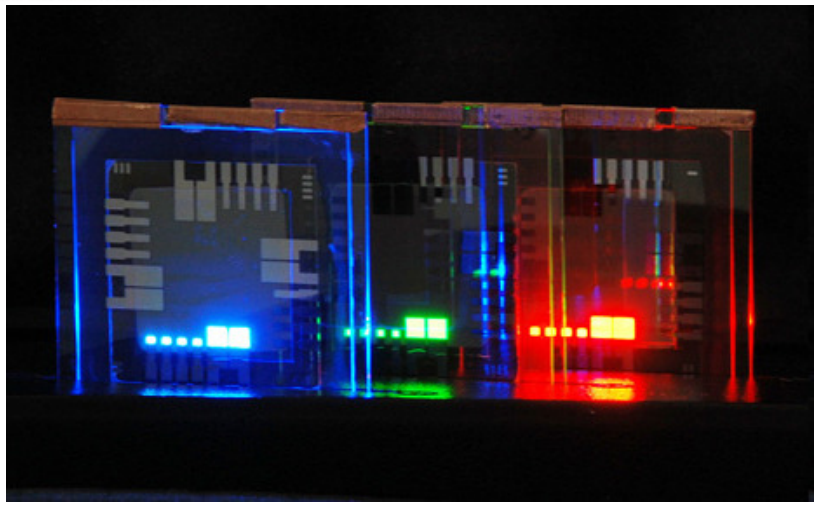


Quantum dot light emitting diode
(QDLED)

Contact Printing of Quantum Dot Light-Emitting Devices



Nano Lett., Vol. 8, No. 12, 2008



Displays, TV screens ….