Retinal isomerization in rhodopsin moves the β-ionone ring.

How does photon energy is stored in rhodopsin?

Internal (bonded) and interaction energy of retinal with its surrounding.

Isomerization of retinal allows helix VI to rotate freely.

Torque applied to rotate helix VI before (red) and 5 ns after isomerization (blue).

Major conformational Changes in 10 ns

Color Vision

Visual receptors of rhodopsin family are classified based on their color sensitivity.

Comparison of color visual receptors and rhodopsin

Each of the human cone receptors is only 40% identical with human rhodopsin.

The human blue color receptor is only 40% identical with the human green and red receptors.

Only 15 out of 364 residues of human green and red cone receptors are different.
Green to red

Electrostatic interaction of retinal and the binding pocket, in favor of excited state or in disfavor of the ground state.

Too bad we do not have the structures, but we could use Rh.

VMD examination of rhodopsin and color visual receptors

Sequence alignment of color receptors

Color vision in other mammals

Sequences are all available and one could mutate them in rhodopsin, and try to explain the effect of amino acid exchange on the spectral properties.

Physics of Color Deficiency

Males are afflicted more often than females!

Signal transduction over a 5 nm distance

Photoinduced isomerization = Ligand binding

Ligand induced conformational changes is the main mechanism of activation of GPCRs
Olfaction

The organization and components are very similar to vision. So we expect similar receptor architecture for olfaction.

Olfactory Receptors

A few hundred types of ORs are present in human beings. Each neuron has only one type of OR.

Cell Signaling of Olfaction

Signaling in vision

cGMP

Ligands for Olfactory Receptors

Small molecules - Stereoselective binding

Olfactory Receptor Genes

Rat gene: more than 1000 ORs
All functional

Human genome: 500-750 Ors (One of the largest gene family in human beings)
More than half are pseudogenes

Single cells too can smell and see!

The response of bacterium is moving toward or away from the signal.
Proton motive force - not ATP

Effective motion of the bacterium in the absence of any signal: **RANDOM WALK**

A motile bacterium can move 10 times its body length in one second.

Effective motion of the bacterium in the absence of any signal: **RANDOM WALK**

Animations:

Chemotaxis
Archaeal Sensory Rhodopsins

- Bacteriorhodopsin (bR)
- Halorhodopsin (hR)
- Sensory rhodopsin I (sRI)
- Sensory rhodopsin II (sRII)

Oxygen and light together could be very harmful for the cell

In aerobic condition: electrogenic pumps are not needed (bR/hR)
Attractant response is not needed (sRI)

These proteins are repressed: sRII (repellent sensory rhodopsin) is expressed to help find the dark and avoid oxidative damage to the cell.
Maximal absorption of sRII (498 nm) matches the highest intensity wavelength of sunlight at the surface of the Earth.

In anaerobic condition: bR/hR/sRI are expressed; and sRII is suppressed.

Bacterial Rhodopsins

Single protein of PM (568 nm)

Slower cycle in sRI and sRII

sRI: Attracted to light at > 520 nm; repelled by to UV – anoxic condition
sRII: Repelled by < 500 nm – (490 nm) constitutively produced – phoborhodopsin
Htr – similar to chemo-receptors

Structure of the Sensory rhodopsin II/transducer complex:
A molecular basis for transmembrane signalling

Cytoplasmic view

Activation is based on the interaction of Helix F and TM2

Dark color: high B factor, mobile
Inherent proton pump activity of sR-II is blocked after complex formation with HtrII.

Structure is strikingly very similar to Np-sR-II alone; only Tyr199 is different (90 degree rotated). Interface mainly vdW, only a few H-bonds.

Remarkable similarity between bR and sR-II, why different functions? If you decouple it from Htr-II, it functions as a proton pump!

Displacement of helices F and G in bR is responsible for the opening of the cytoplasmic half channel and entrance for water molecules necessary for reprotonation of retinal Schiff base.

Rotation of helix VI (F) in Rh is one of the major conformational changes triggering the activation of transducin (G-protein).
Similarities of conformational changes in retinal proteins

Outward motion of helix F in sR-II causes the rotation of one of the two helices in the transmembrane region of the transducer and its further conformational change.

Importance of protein-lipid interaction

Kinetic of Rh photocycle

- Rhodopsin (1.2 min)
- Phototransduction (70 s)
- Meta I (50 s)
- Meta II (0.15 sec)
- Lamin/bacteropsin (1 min)

... and probably also the kinetics of sR-II photocycle, can be influenced by the lipid composition of the membrane.

Next week

Membrane channels:

Aquaporins