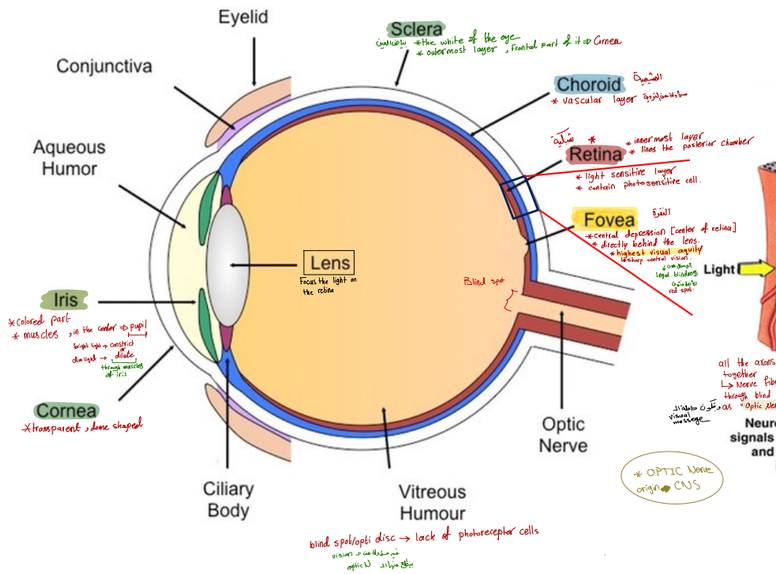
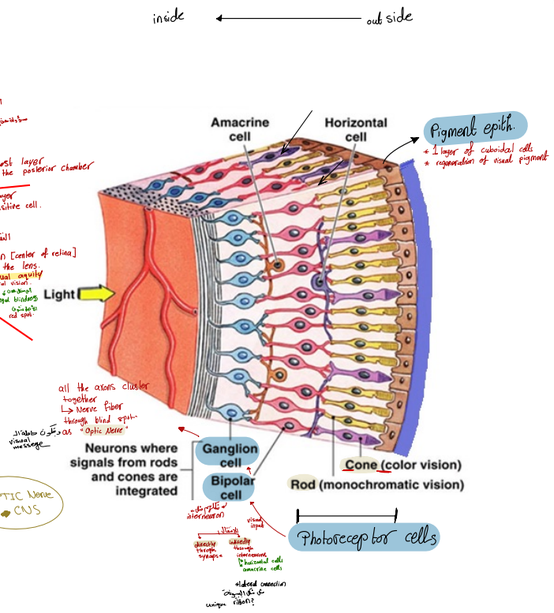
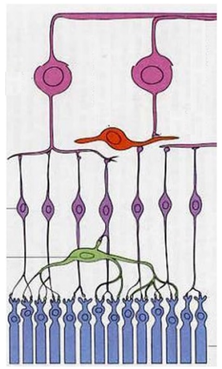
Biochemistry of Vision 1

The Structure of Human Eye

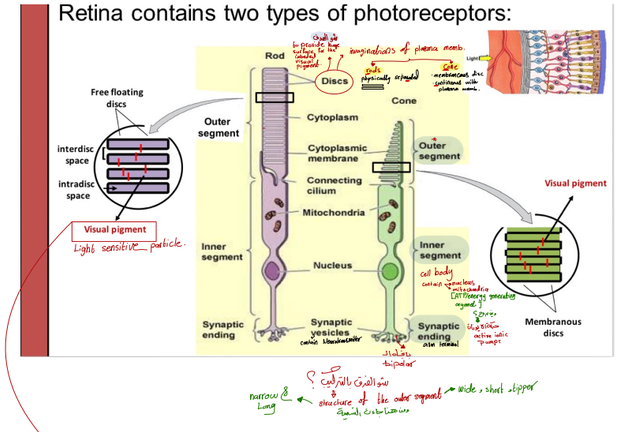


The Structure of Retina

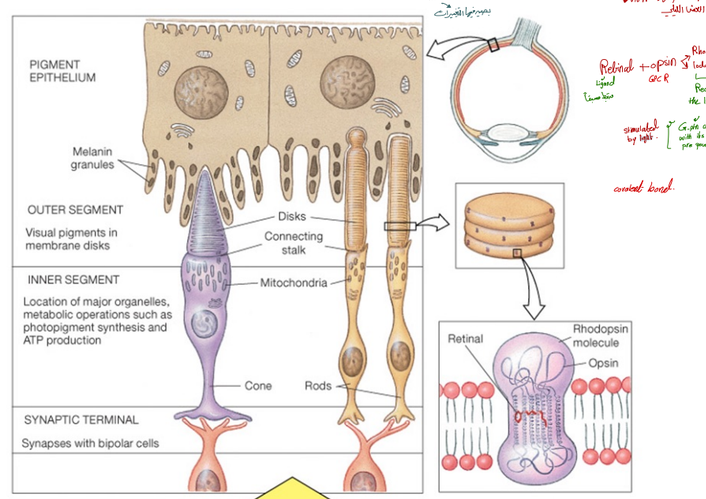




Photoreceptor cells



Visual Pigment



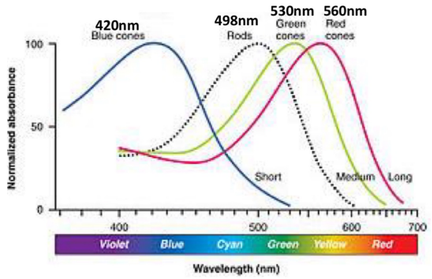
Iodopsine

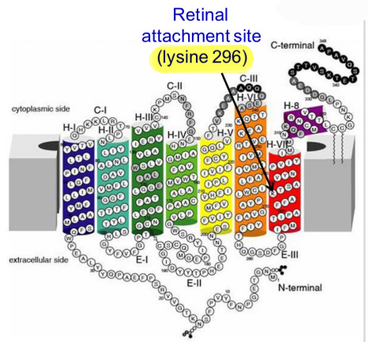
visual pigment of the cones

Photopsin

3 types of cone cells → give us → color vision

1. L cones (photopsin I + retinal) **red** light, 560nm
2. M cones (photopsin II + retinal) **green** light, 530nm
3. S cones (photopsin III + retinal) **blue** light, 420nm

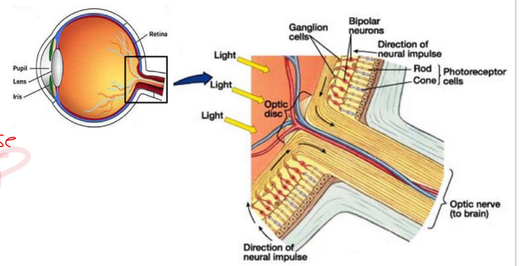




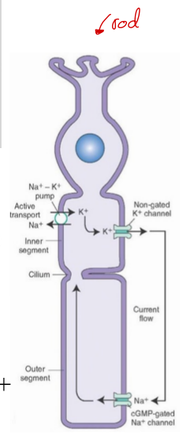
Phototransduction

• Phototransduction is the process by which the light detected by photoreceptor cells in the retina is converted into electrical (or cellular) signals.

vision process



Phototransduction Cascade



• In the absence of light, the photoreceptor cell is in the depolarized state with membrane potential of -40 mV. This depends on:

1. Non-gated K+ channel: outflux of K+ (ongoing outward K+ current)
3. cGMP-gated Na+ channel: influx of Na+ (inward Na+ current known as dark current)
3. Na+- K+ pump: it is an active transport requires ATP (to transfer 3 Na+ out and 2 K+ in)

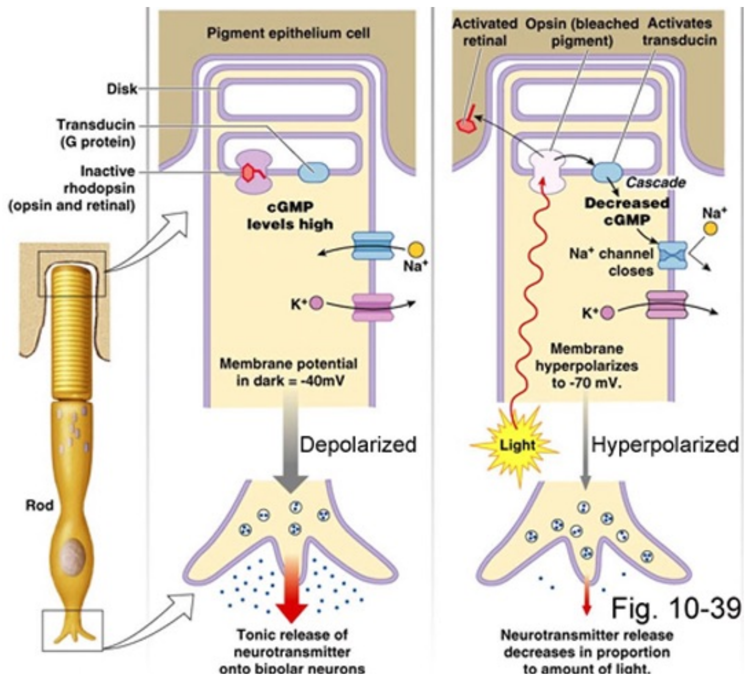
∴ Inhibitory Neurotransmitter

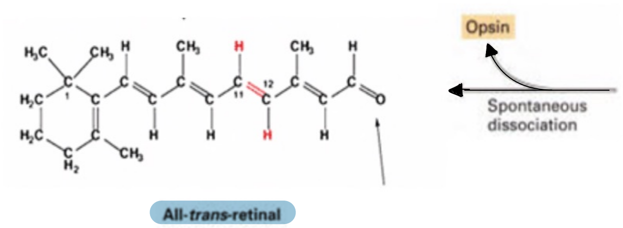
Bipolar → switch of

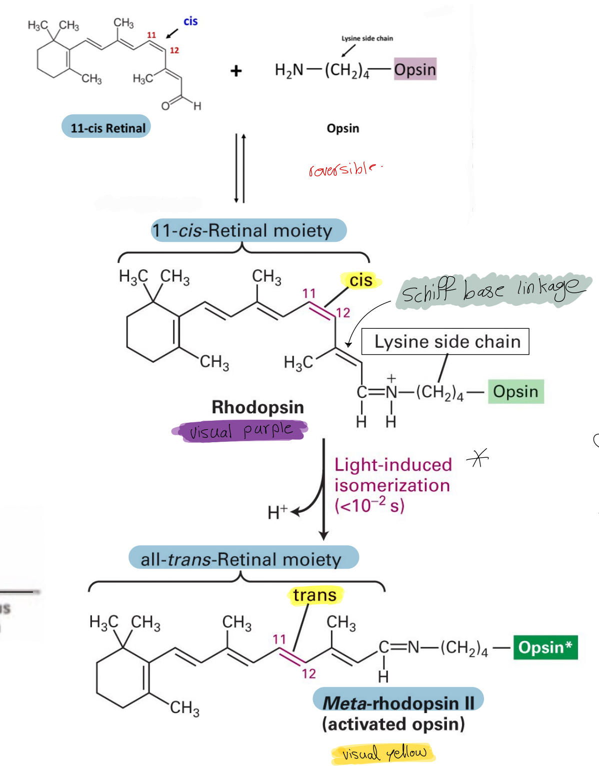
Biochemistry of Vision 2

* In the presence of light
Changes → rhodopsin
↓ cGMP , Na channels → closed   dark current → stop
⇒ Hyperpolarization
rate of neurotransmitter ↓ ⇒ Bipolar switch on
⇒ visual message

Phototransduction Cascade





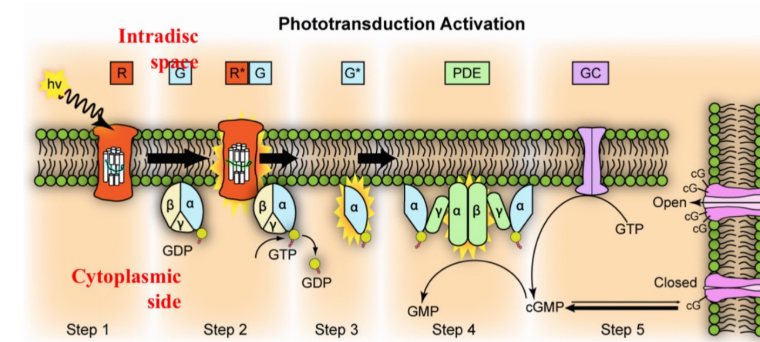


cis
↓ Photoisomerization
trans

* absorption spectrum shift [visible → UV] <400
Bleaching

G-protein signaling pathway

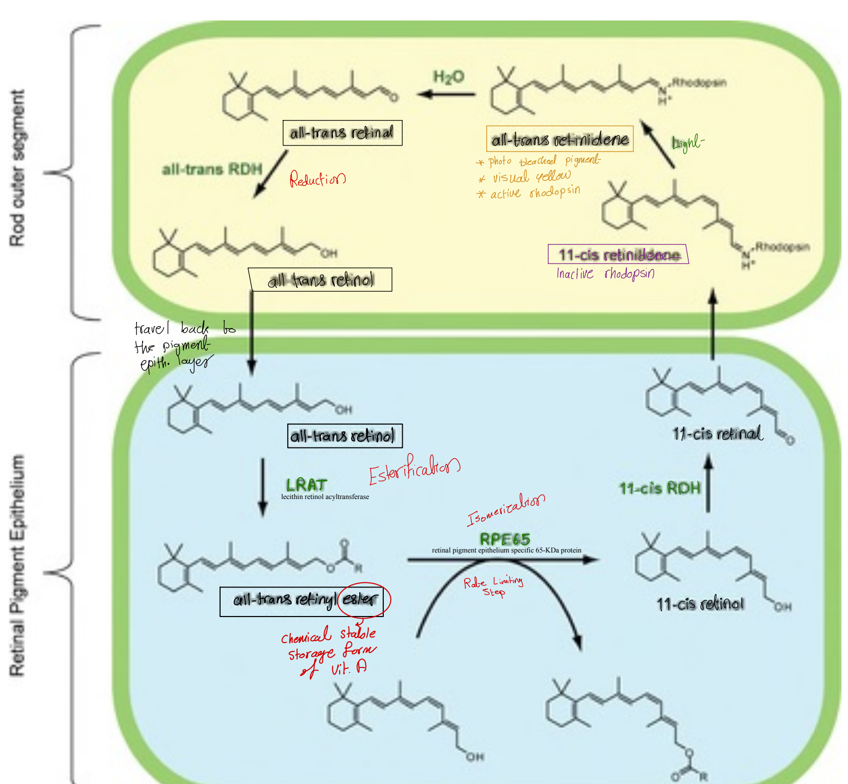
Gpp → G-protein
*In photoreceptor cells → transducin
*In last bud cells → ....
α β γ
when activated GDP → GTP



GTPα activate PDE
cGMP → GMP
↓cGMP
- Hyperpolarization
- switche on ⇒ Bipolar cells
GC synthesis of cGMP from GTP
cGMP depends on ⇒ synthesis GC vs Degradation PDE
Light → PDE > GC

Rods	Cones
Used for scotopic vision (vision under low light conditions) or night vision	Used for photopic vision (vision under high light conditions) or day vision
Very light sensitive	Not very light sensitive
Loss causes night blindness	Loss causes legal blindness
Low visual acuity (poor resolution) as many rods are connected to one bipolar cells showing a high degree of convergence	High visual acuity; better spatial resolution as each cone is connected to one bipolar cell
Not present in fovea	Concentrated in fovea
Outer segment is rod shaped	Outer segment is cone shaped
Confer achromatic or monochromatic vision	Confer color vision (trichromatic vision)
Stacks of membrane-enclosed disks are unattached to cell membrane directly	Disks are attached to outer membrane
About 120 million rods distributed around the retina (peripheral vision)	About 6 million cones distributed in each retina (central vision)
One type of photosensitive pigment (Rhodopsin)	Three types of photosensitive pigments in humans (blue, green and red cones)

Regeneration of Visual Pigment



Esterification → * Provide chemical stable storage form of vit A * Pre-required step for the isomerization, Limiting step to provide a substrate for this enzyme

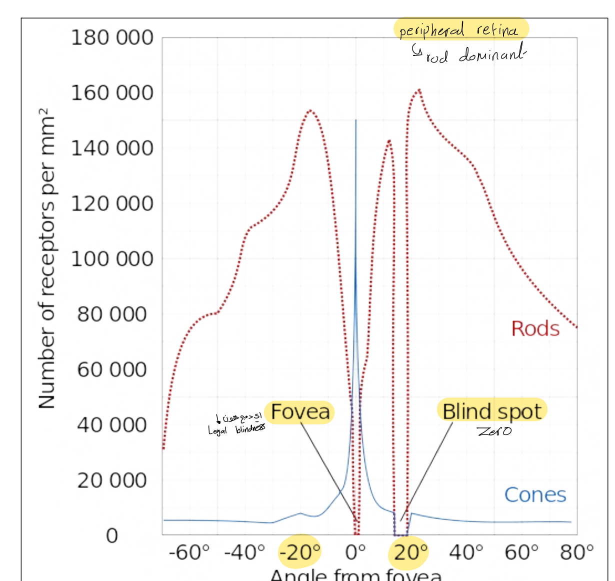
Light and Dark Adaptation

• Visual adaptation:
is the ability of visual system to automatically adjust its sensitivity to accommodate a change in light intensity. Two types:
1. Dark adaptation: is the slow recovery of visual sensitivity (20-30 min) after exposure to a bright/strong light (i.e. when you move from the light to the dark).
2. Light adaptation: is the adaptation to increased level of illumination (i.e. when you move from the dark to the light, 5 min).

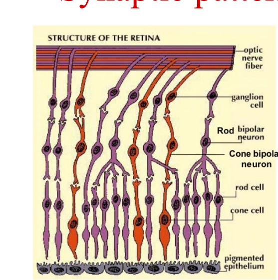
• Mechanisms underlying light /dark adaptation:
1. Pupil size to adjust amount of light reaching the retina
2. Switch-over between rods and cones
3. Bleaching / regeneration of photopigments

Photoreceptor cells

Retina contains two types of photoreceptors:
1. Rod cells: about 120 million, function in dim light (night vision) and do not perceive color, with high sensitivity and low resolution
2. Cone cells: about 6 million, function in bright light (daytime vision)and are responsible for color vision, with low sensitivity and high resolution



Synaptic pattern of Photoreceptors



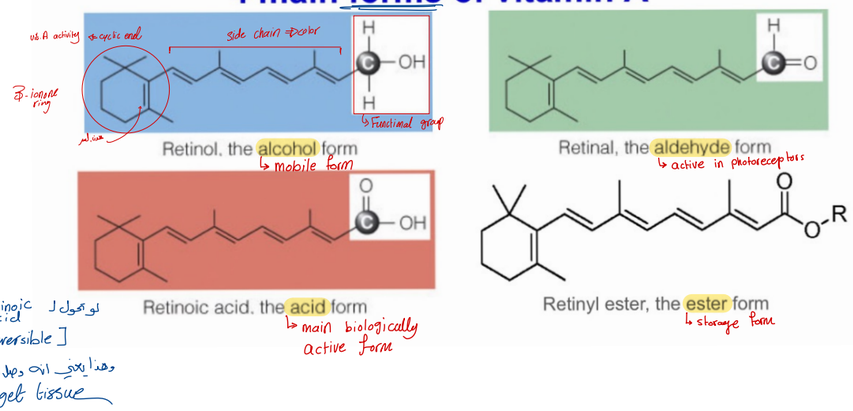
High degree of convergence reduces resolution in rod system, whereas 1:1 relationship of cones to bipolar and ganglion cells increases the resolution or visual acuity.

Vitamin A and Visual Cycle

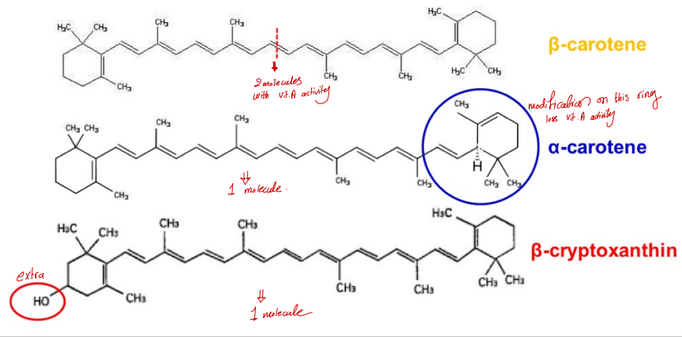
Vision
Bone remodelling
Skin health

↑ in pregnant woman ⇒ congenital anomalies

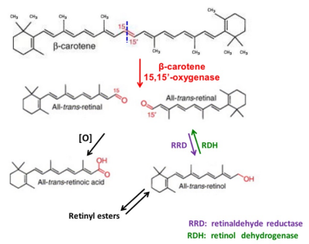
4 main forms of vitamin A



- Provitamin A: like some carotenoids which can be converted/ metabolized in the body to retinoids with vitamin A activity. They are found in plant sources (e.g. carrot)



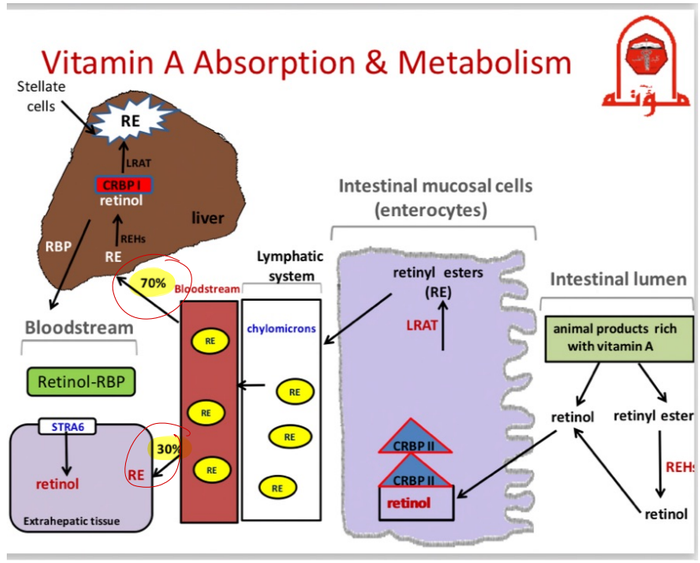
Potency of β-carotene x2 ↓ α-carotene & β-cryptoxanthin

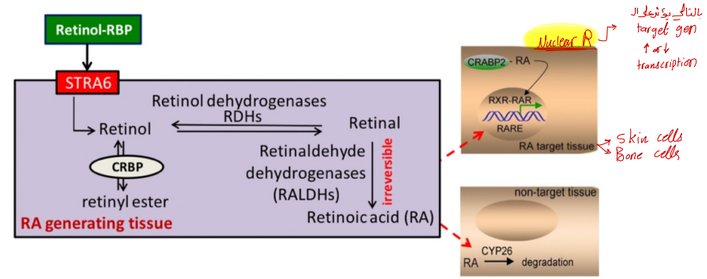


- Only a limited amount of the provitamin carotenoids (plant sources) can be absorbed intact. These are stored in body tissues such as adipose cells of fat depots throughout the body. To date, the only side effect of excess beta-carotene supplementation appears to be yellowing of the skin.
- Carotenoids are largely converted to retinol (vitamin A) during intestinal absorption in the mucosal cell.

Liver ← Vit A ← من أغذية المصدر

Vitamin A Absorption & Metabolism





Physiological Roles of Vitamin A

* Vision — شكل الـ retinal
* Embryo development (شكل → retinoic acid)
  ↳ organogenesis (1st trimester)
  ⇢ Teratogenic [vit A → Narrow index, easy to cause toxicity]
* Antioxidant — شكل الـ β-carotene
* Reproduction ⇄ male / female
  · spermatogenesis
  · Fertilization
* Bony remodeling
  ↑ resorption
  ↓ growth
  [vit A toxicity → عند الأطفال تأثيرها على النمو]

Vitamin A and Visual Cycle

- Retinoids: are a class of chemical compounds that are related chemically to vitamin A. They are widely used in medicine as they have diverse functions in the body
  - First generation: retinal, retinol, tretinoin (all *trans* retinoic acid, Retin-A) , isotretinoin (Roaccutane, UK and Accutane, USA) and alitretinoin

  - Second generation: etretinate and its metabolite acitretin
  - Third generation: tazarotene, bexarotene and

Contraindicated in pregnancy → Teratogenic
6 months after stop of ... to complete clearance

Ada palene