Retinal Circuit and Processing
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• Overview of the retinal circuit
• Receptive field (RF) of retinal ganglion cells (RGC)
• Neural circuitry underlying the RGC receptive field

Lens defects:
Myopia (nearsightedness) – focusing in front of retina, corrected by concave lens
Hyperopia (farsightedness) – focusing behind the retina, corrected by convex lens
Presbyopia – hardening of the lens due to aging (reduced accommodation), cannot have near vision, corrected by convex lens
Astigmatism: nonuniform curvature (in one axis), image blurred, corrected by cylindrical lens

Fovea: high spatial resolution
Periphery: low spatial resolution
The Basic Retinal Circuit

1. Receptor Cells (Graded potential) (Input)
2. Bipolar Cells (Graded potential)
3. Ganglion Cells (action potential) (Output)
4. Horizontal Cells (Graded potential)
5. Amacrine Cells (Graded/action potential)
6. Pigment cells

Convergence and divergence of connections

Receptive field of RGC

Stephen Kuffler

Receptive field of RGC

Fig. 4. Receptive field and transient responses in retinal ganglion cell (Kuffler, 1953)
Features of RGC center-surround interactions

1) There are two types of RFs: ON center/OFF surround, OFF center/ON surround.

2) Surround stimulation actively inhibits response to center stimulation; maximal response can be evoked only with an optimally sized spot.

Receptive field

• Definition: the area of the retina (or visual field) in which light signals evoke responses
• It depends largely on the synaptic inputs to the cell, which in turn depends on dendritic field of the cell
• Fovea: small RF (~0.1°), high resolution; Periphery: large RF (3-5°), low resolution (1° = 0.25 mm on the retina)

Ganglion Cell types:
• M cells: large RF, fast response, color blind;
• P cells: small RF, slower response, color sensitive.
Center/surround RF explains some visual illusions

Mach band

More illusions… Hermann’s grid

Center/surround RF also explains spatial frequency tuning
M and P RGC cells have different spatial frequency selectivity

Direct pathway: Photo receptor → Bipolar → RGC

+ excitatory synapse, preserve response direction
- inhibitory synapse, flip response direction

Direct pathway is responsible to the RF center

How does glutamate activate or inhibit bipolar cells?

- Off center bipolar cell – glutamate is excitatory, opens glutamate receptor-channel similar to the excitatory synapse.
- On center biopolar cell – glutamate is inhibitory, opens K+ channel or closes cGMP-gated channel, by reducing cGMP through a metabotropic glutamate receptor (G-protein coupled receptor) that activate cGMP phosphodiesterase.
Indirect pathway mediated by horizontal is responsible to the antagonistic RF surround.

There are other indirect pathway mediated by amacrine cells (use dopamine, ACh, indolamine).

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Summary of retinal circuit:

**Direct pathway**

- Photoreceptor → Horizontal cell → Photoreceptor

**Indirect pathway**

- Bipolar cell → Amacrine cell → Ganglion cell