Retinal Processing of Visual Information

- Convergent vs. divergent pathways
- Receptive field properties of retinal neurons
- Antagonistic center-surround features of bipolar (BP) cells and retinal ganglion cell (RGC) receptive fields
- “On-center/off-surround” and “off-center/on-surround” cells provide enhanced:
  - Contrast detection
  - Temporal resolution
- Roles of different interneuron types in determining RGC receptive field properties
Receptive Fields of Rod & Cone Bipolar Cells

Convergent connections
- low spatial resolution
- high sensitivity

Divergent connections
- high spatial resolution
- low sensitivity
- “multiplexing” or parallel pathways

=> Multiple outputs from the retina…
Receptive fields of retinal interneurons and ganglion cells are overlapping, as in a Seurat painting... 

La Tour Eiffel - Georges Seurat, 1889

... created in “little dots.”
Overlapping Receptive Fields…
Receptive Fields of RGCs Are **Not** Homogeneous

```
“On-center/off-surround” cell
  or
  “on-center” cell or “on” cell

“Off-center/on-surround” cell
  or
  “off-center” cell or “off” cell

Concentric, antagonistic “center-surround” arrangement
```
Response Properties of On and Off Cells

Fig. 26-7, Kandel et al., 4th edition
Center-Surround Receptive Fields Enhance Contrast Detection

“looks” brighter here

RGC Response

“looks” darker here

the difference
Center-Surround Receptive Fields

- Enhance contrast at dark-light borders
- On- and off-center retinal ganglion cells provide better temporal resolution than either one alone
  - Can respond to both rapid increases and decreases in light intensities
    - On cells: increase rate of firing at stimulus onset
    - Off cells: increase rate of firing at stimulus offset
On- and Off-Bipolar Cells Drive On- and Off-Ganglion Cells

- **On-center bipolar cells**
  sign-inverting (-) synapse with photoreceptor cell
- **Off-center bipolar cells**
  sign-conserving (+) synapse with photoreceptor cell
- Bipolar cell-ganglion cell synapse: sign conserving

*Fig. 10.15, Purves et al., Neuroscience, 3rd edition*
Different Types of Interneurons Are Used to Connect Retinal Ganglion Cells with Photoreceptor Cells from the Center and Surround

- **Center**: direct/vertical pathway from photoreceptor cell to bipolar cell
- **Surround**: lateral inhibitory pathway via horizontal cells to photoreceptor cell in center

*Fig. 26-6, Principles of Neuroscience, Kandel et al., 4th edition*
Circuitry underlying Antagonistic Surround

- Center cone is inhibited by surround cone via GABAergic input from horizontal cell (HC)
  - Stimulation of surround cone -> cell hyperpolarizes, releases less glu on HC
  - HC hyperpolarizes, releases less GABA on center cone
  - => Center cone depolarizes (antagonizes light response)
- Same mechanism for on- and off-center cells (antagonistic effect is on the photoreceptor cell!)

Fig. 10.19, Purves et al., Neuroscience, 3rd edition
Two General Classes of Retinal Ganglion Cells

<table>
<thead>
<tr>
<th>Magnocellular (M) cells</th>
<th>Parvocellular (P) cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>large dendritic arbors, large receptive fields</td>
<td>small dendritic arbors, small receptive fields</td>
</tr>
<tr>
<td>achromatic</td>
<td>wavelength selective</td>
</tr>
<tr>
<td>information about gross features and movement</td>
<td>information about color and fine spatial detail</td>
</tr>
<tr>
<td>innervate layers 1 &amp; 2 of LGN</td>
<td>innervate layers 3-6 of LGN</td>
</tr>
</tbody>
</table>

⇒ *Parallel pathways used to process information about form, motion, color, etc….*