low light ← Rods:- 120 million
Cones:- 5 - 6 million → bright light

③ Colors:-

- Luminance → refers to amount of light that comes to eye.
- Lightness Constancy → Ability of visual system to perceive the true reflect of an object, regardless of changes in light.
- Simultaneous Constrast → Phenomena which says perception of color and shade is not absoute but relative to surrounding context.
  ↓
  we see colors or shades as it is affected by surroundings.
- Luminance Channel →
  - Controlling luminance is primary rule of design
  - No edges without lightness difference
  - No shading without lightness variation
  - Has higher spatial sensitivity (eye notice brightness change easily than change in color)
- Purpose of color → To (label, measure, decorate, represent)
- Function of color → identify, group, layer, highlight.
- trichromacy → possessing three independent channels for color information
- Opponent-Process Model → our perception of color is controlled by activity of two types of opponent systems.
  achromatic / chromatic.
  achromatic ↓ no hue (black, white, gray)
  chromatic ↓ have hue.
  ↓
  opposite colors are not perceived together.

① How human percieve colors.
② How we see colors using opposite pairs.

- Color deficiencies (color Blindness)
  - Protanope = faulty red cones
  - Deuteranope = faulty green cones
  - Tritanope = faulty blue cones

• What can be produced on monitor / printer
(RGB) (CMYK)

gamut of my moniter != gamut of someone else != gamut of printer.
Specific range or subset of colors that particular device can display.

5 Color Gamut & Models → Color model is a way to represent & define colors within that space.

- Primary Colors (Red, Blue, Yellow) can be mixed to create all other colors.
- Secondary colors (Purple, Green, Orange) created by primaries.
  R+B B+Y Y+R
- Color Space → Range of colors that can be represented in a specific system like RGB.
  (e.g CIELAB) (entire range of colors humans can see)
- Color Cube → Color cube is a 3-dimensional representation of a color model.
- • Relation of color cube and space → • Color cube is visual representation ~~within~~ specific color space like RGB.

not all colors spaces are cubes.

Computer Programs we see a color wheel (not a cube)

- Redefining Colors Spaces (w.r.t human eye)
  - Represent all spectral colors perceivable by human eye / seen by human eye.
- Strange shape to represent all colors that human eye can see is because it corresponds to CIE Chromaticity Diagram. / Perceptual uniformity.
- Color Model (representation of color using some basis)
  - HSL (Hue-Saturation-Lightness) → Hue captures pure color.
    - ~~Saturation captures amount~~ of white mixed with the color
    - Lightness captures amount of black mixed with a color.
    (color pickers are often circular)
  - HSV (Hue-Saturation-Value) → • Similar to HSL but replaces lightness with Value (brightness)
    Same but focus on brightness instead of lightness.

- Rainbow Color Map
  - Color Map is poor choice →
    - No perceptual ordering (don't follow natural logical order) (confusion)
    - No luminance variation (Brightness of colors doesn't change evenly)
    - Misleading perception of transitions (sudden change in ~~color might make~~ people think there's sudden change in data, even when data is smooth).

- Colormap → Specifies mapping between colors & data values

  ↓

  follow expressiveness principle.

  Types:-
  - Binary (Y/n)
  - Categorical
  - Diverging (Highlights variations)
  - Sequential

- Categorical vs Ordered
  - Categorical ↓ Hue is used as it has no natural order
  - Ordered ↓ Saturation & luminance are better for ordered / continuous data. (e.g. ranking)

Categorical	Sequential	Diverging
• For categorical or nominal data	Best for ordered data. (from low to high)	Best for meaningful midpoint or diverging point.

- Bivariate → displays 2 variables combination of two sequential color schemes.

  combines 2 sequential colormaps.

VAW/SYLKHS

Weber's Law:

$\frac{\Delta S}{S} = \text{constant} \sim 1$

difference ← ΔS; S → background intensity

- Categorial Colormap guidelines
  - Don't use too many colors
  - Background has a color too
  - Be aware of luminance
  - Namable colors help.
- Ordered Colormaps (used for ordinal or quantitative attributes)

(Till slide 43)

- Color design Rules:

(1) R_1 → Vivid (bright & saturated) colors + attention

(2) R_2 → Too many vivid colors are not good, use less.

(3) R_3 → Make foreground vivid and background dull for ~~good contrast~~

(4) R_4 → To make colors easier to tell which is apart, use different HSL

(5) R_5 →
- Small lightness differences are easier to notice at dark end.
- larger differences are needed at bright end (Weber's law)

(6) R_6 → Small objects are harder to distinguish by color.

(7) R_7 → Complementary colors (blue & orange) Contrast the most ~~but mix into neutral gray~~

(8) R_8 → Some colors (yellow) look more saturated naturally

(9) R_9 →
- ~~brighter lights are in yellow range~~
- blues & reds appear dimmer.

(10) R_{10} → For labeling, stick to 6-7 simple, recognizable colors.

(11) R_{11} →
- Warm colors (red, yellow) Create Excitement
- Cool colors (blue, green) create calm.

(12) R_{12} → Changing lightness or saturation does not affect perceived hue.

(13) R_{13} → objects of similar hue are seen as part of same group.