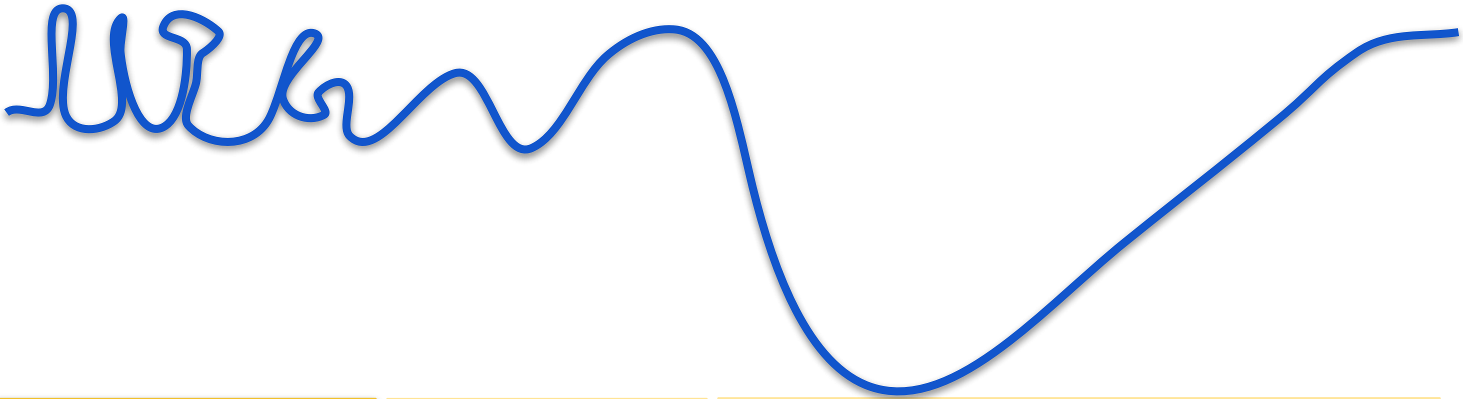
# Computing with Signals



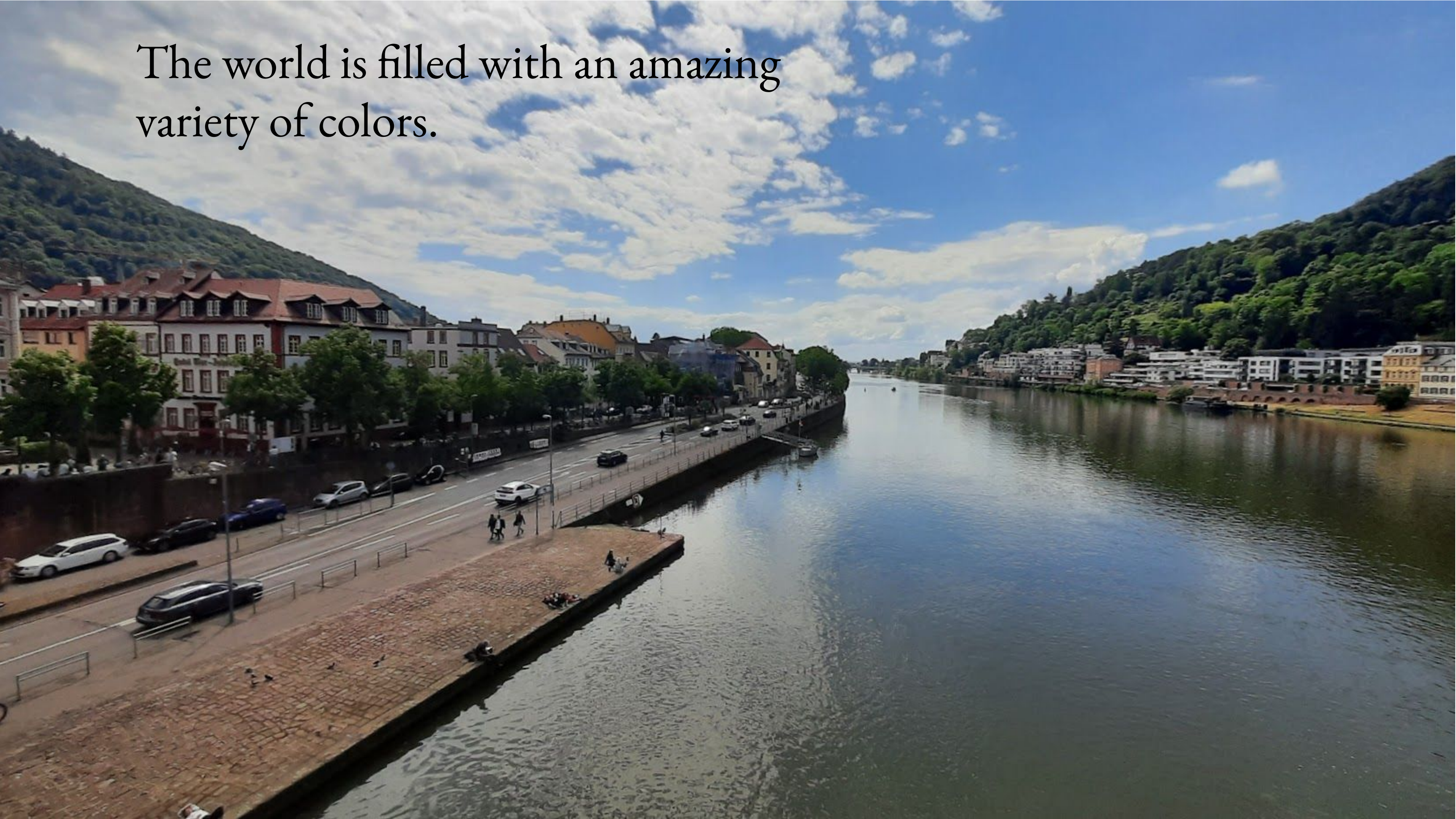
# DA 623

Jan - May 2024 | IIT Guwahati

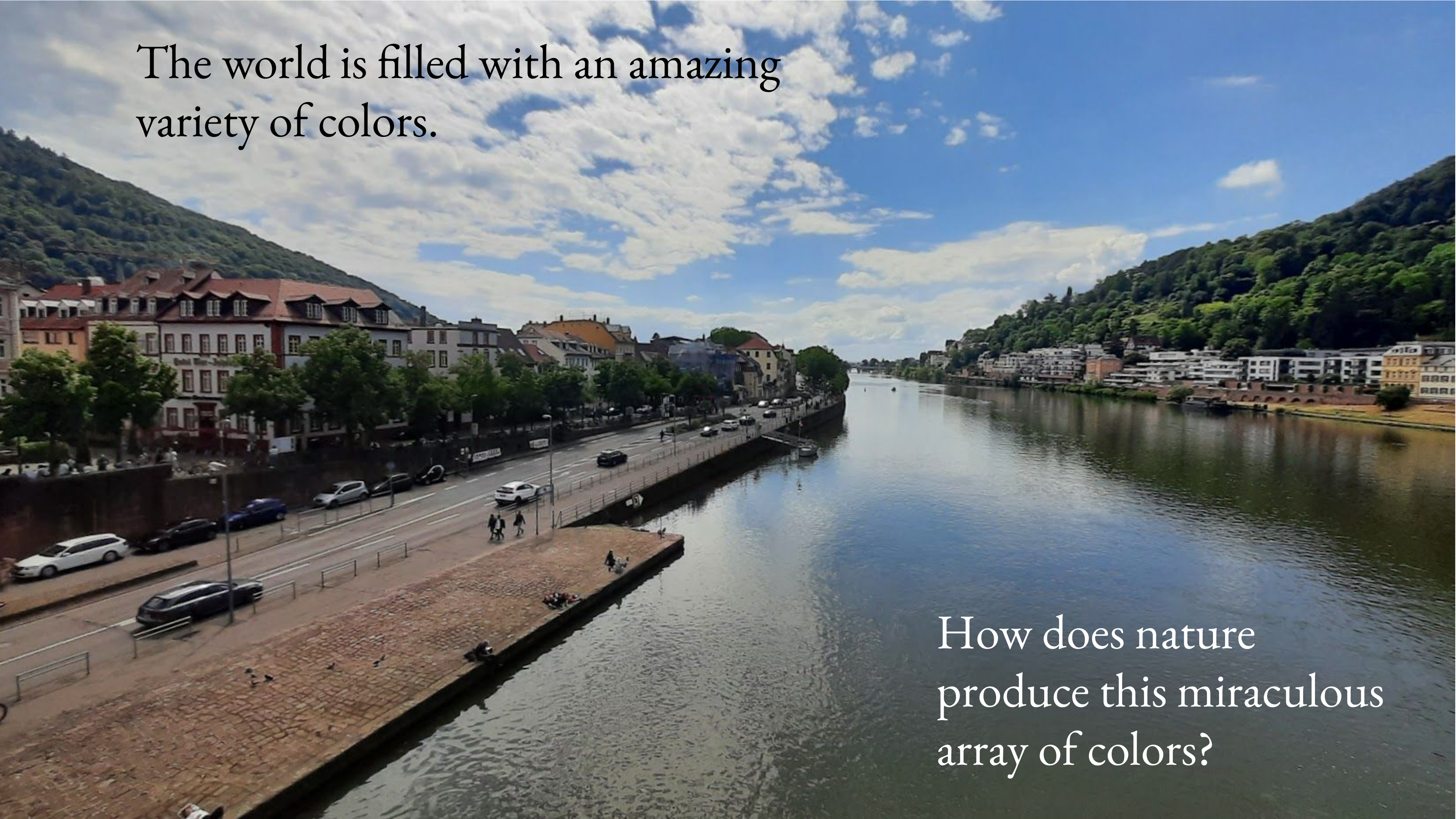
Instructors: Neeraj Sharma

Lecture-16

The world is filled with an amazing variety of colors.



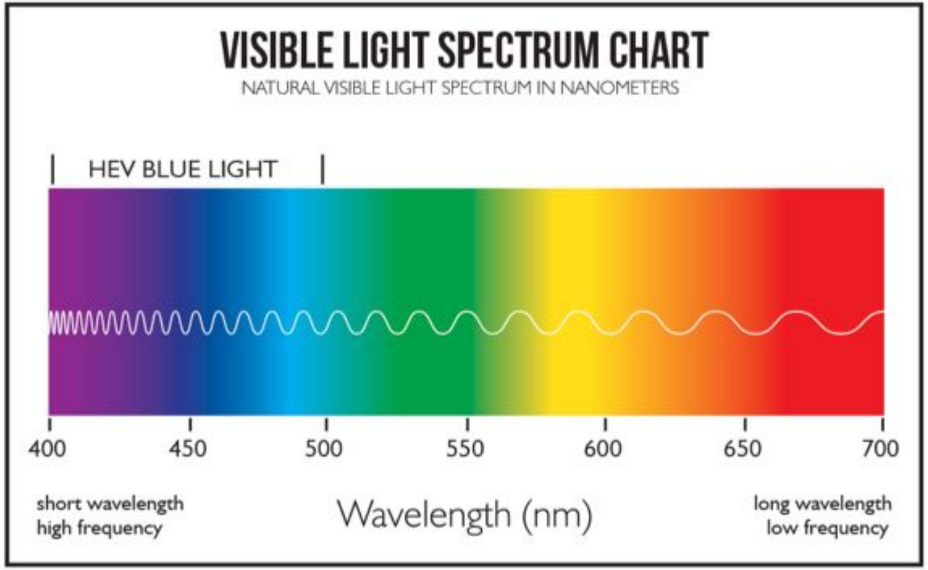
The world is filled with an amazing variety of colors.



How does nature produce this miraculous array of colors?

Colors are wavelengths of light that are within a visible range for the human eye.

The light reflected by a colored object travels as waves, sensed by the human eyes.
(rods and cones cells help).



# How do objects absorb some wavelengths and emit others?

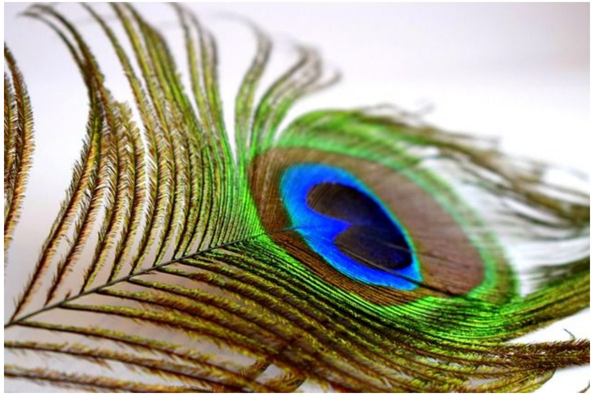
An object's natural colors are often determined by the structure of the chemicals within.

Some of the most common molecules in nature are carotenoids, chlorophyll, and anthocyanin, which are known collectively as pigments due to their color-producing properties and are responsible for various shades of orange, green, and purple.

These and many other chemical compounds create unique colors through absorbing certain light wavelengths and reflecting others.

However, another intrinsic component of color production is the physical structure of the colored surface itself.

The structure of a surface can manipulate the way that light reflects off of it, which can also cause drastic variations in the color produced.



Examples: bird wings, butterfly wings, and flowers such as buttercups produce novel natural colors through structural manipulation of light.

According to the pigment of a peacock feather alone, the peacock feathers should be brown.

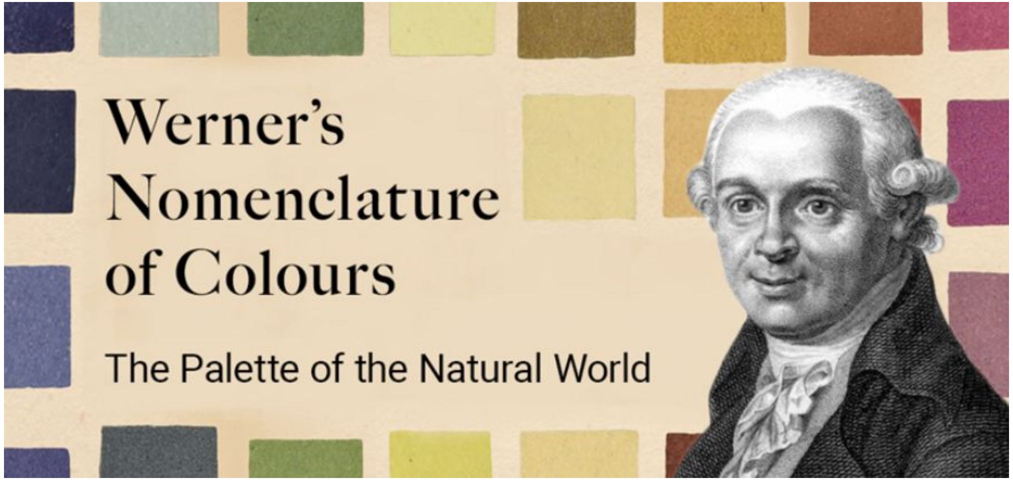
The structure of the feather itself interferes with the light and creates colors besides those of natural pigments. A peacock feather is made up of many small, flat branches that are pocked with bowl-shaped indentations.

These branches are also covered with microscopic lamellae, or thin plate-like layers, that create a scattering effect on the light that shines on the feather.

Light scattering is the effect of the shape and structure of a surface on the way light is reflected.

In the 18th century, German geologist **Abraham Gottlob Werner** set out to establish a standard reference guide to colour for use in the general sciences.

He created a colour classification system using the minerals that he observed as a distinguished geologist.



## YELLOWS.

| No. | Names | Colours | ANIMAL | VEGETABLE | MINERAL |
|---|---|---|---|---|---|
| 62 | *Sulphur Yellow.* | | *Yellow Parts of large Dragon Fly.* | *Various Coloured Snap dragon.* | *Sulphur* |
| 63 | *Primrose Yellow.* | | *Pale Canary Bird.* | *Wild Primrose* | *Pale coloured Sulphur.* |
| 64 | *Wax Yellow.* | | *Larva of large Water Beetle.* | *Greenish Parts of Nonpareil Apple.* | *Semi Opal.* |
| 65 | *Lemon Yellow.* | | *Large Wasp or Hornet.* | *Shrubby Goldylocks.* | *Yellow Orpiment.* |
| 66 | *Gamboge Yellow.* | | *Wings of Goldfinch. Canary Bird.* | *Yellow Jasmine.* | *High coloured Sulphur.* |
| 67 | *Kings Yellow.* | | *Head of Golden Pheasant.* | *Yellow Tulip. Cinque foil.* | |
| 68 | *Saffron Yellow.* | | *Tail Coverts of Golden Pheasant.* | *Anthers of Saffron Crocus.* | |

## *YELLOWS.*

No. 62. Sulphur Yellow, is lemon yellow mixed with emerald green and white. W.

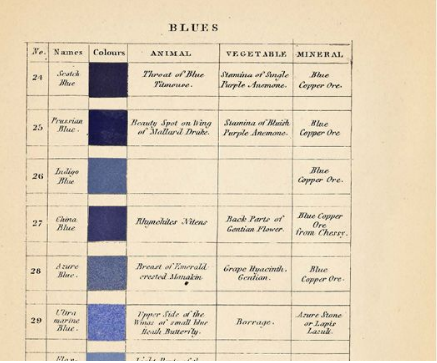
63. Primrose Yellow, is gamboge yellow mixed with a little sulphur yellow, and much snow white.

64. Wax Yellow, is composed of lemon yellow, reddish brown, and a little ash grey. W.

65. Lemon Yellow, the characteristic colour of the yellow series of Werner, the colour of ripe lemons; W. it is found to be a mixture of gamboge yellow and a little ash grey: being a mixed colour, it cannot be adopted as the characteristic colour; the characteristic colours of the blues, reds,

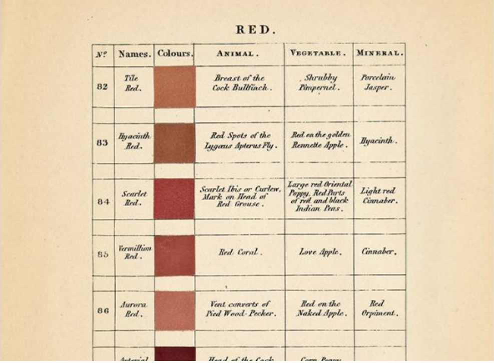
Patrick Syme later enhanced and extended Werner's work.

This collection included all of the most common colours or tints that appear in nature, with each colour swatch accompanied by examples from the animal, vegetable and mineral kingdoms.



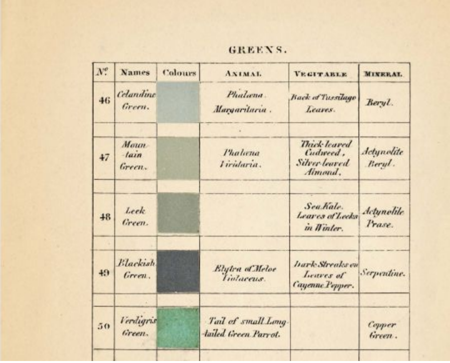
BLUES

| No. | Names | Colours | ANIMAL | VEGETABLE | MINERAL |
|---|---|---|---|---|---|
| 24 | Scotch Blue | | Throat of Blue Titmouse. | Stamina of Single Purple Anemone. | Blue Copper Ore. |
| 25 | Prussian Blue. | | Beauty Spot on Wing of Mallard Drake. | Stamina of Bluish Purple Anemone. | Blue Copper Ore |
| 26 | Indigo Blue | | | | Blue Copper Ore. |
| 27 | China Blue | | Rhynchites Nitens | Back Parts of Gentian Flower. | Blue Copper Ore from Chessy. |
| 28 | Azure Blue. | | Breast of Emerald crested Manakin | Grape Hyacinth. Gentian. | Blue Copper Ore. |
| 29 | Ultra marine Blue. | | Upper Side of the Wings of small blue Heath Butterfly. | Borrage. | Azure Stone or Lapis Lazuli. |



RED.

| Nº | Names. | Colours. | ANIMAL. | VEGETABLE. | MINERAL. |
|---|---|---|---|---|---|
| 82 | Tile Red. | | Breast of the Cock Bullfinch. | Shrubby Pimpernel. | Porcelain Jasper. |
| 83 | Hyacinth Red. | | Red Spots of the Lygæus Apterus Fly. | Red on the golden Rennette Apple. | Hyacinth. |
| 84 | Scarlet Red. | | Scarlet Ibis or Curlew. Mark on Head of Red Grouse. | Large red Oriental Poppy. Red Parts of red and black Indian Peas. | Light red Cinnaber. |
| 85 | Vermillion Red. | | Red Coral. | Love Apple. | Cinnaber. |
| 86 | Aurora Red. | | Vent converts of Pied Wood-Pecker. | Red on the Naked Apple. | Red Orpiment. |



GREENS.

| Nº | Names | Colours | ANIMAL | VEGITABLE | MINERAL |
|---|---|---|---|---|---|
| 46 | Celandine Green. | | Phalæna Margaritaria. | Back of Tussilago Leaves. | Beryl. |
| 47 | Moun-tain Green. | | Phalæna Viridaria. | Thick-leaved Cudweed. Silver-leaved Almond. | Actynolite Beryl. |
| 48 | Leek Green. | | | Sea Kale. Leaves of Leeks in Winter. | Actynolite Prase. |
| 49 | Blackish Green. | | Elytra of Meloe Violaceus. | Dark Streaks on Leaves of Cayenne Pepper. | Serpentine. |
| 50 | Verdigris Green. | | Tail of small Long-tailed Green Parrot. | | Copper Green. |

The Pantone Color Matching System is largely a standardized color reproduction system; as of 2019 it has 2161 colors.

By standardizing the colors, different manufacturers in different locations can all refer to the Pantone system to make sure colors match without direct contact with one another.

# Color features: Luminance

- The "grayscale" image is often computed as the average of R, G, and B intensities, i.e., $I[x', y'] = \frac{1}{3}(R(x', y') + G(x', y') + B(x', y'))$
- The human eye, on the other hand, is more sensitive to green light than to either red or blue.
- The intensity of light, as viewed by the human eye, is well approximated by the standard ITU-R BT.601:

$$Y(x', y') = 0.299R(x', y') + 0.587G(x', y') + 0.114B(x', y')$$

- The signal $Y(x', y')$ is called the **luminance** of light at pixel $(x', y')$.

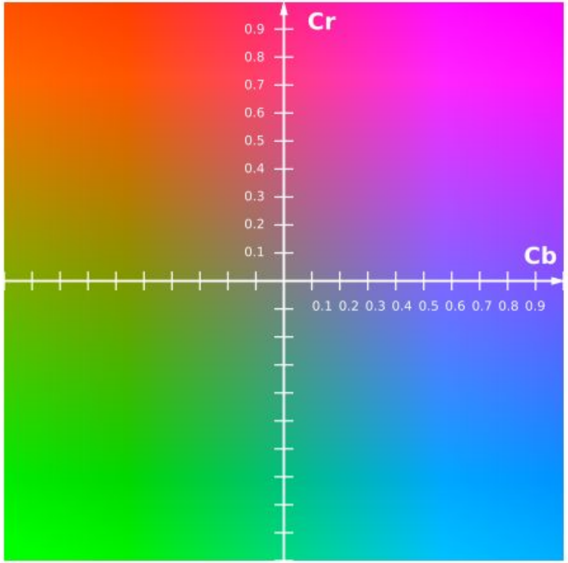
# Color features: YPrPb

- The human eye is much more sensitive to spatial variation in luminance (brightness) than to spatial variation in chrominance (color)
- For this reason, the JPG image coding standard represents luminance, Y(x',y'), at twice the spatial resolution of chrominance:
  - First, JPG converts (R,G,B) into (Y,Pr,Pb), where Pr and Pb represent the "degree of redness" and "degree of blueness."
  - Second, JPG downsamples Pr(x',y') and Pb(x',y'), so that they have ½ as many rows and ½ as many columns as Y(x',y').
- For computer vision, we can use the same logic: represent Pr and Pb at half the resolution that we use for luminance.

# Color features: Chrominance

- Chrominance = color-shift of the image.
- We measure $P_R$=red-shift, and $P_B$=blue-shift, relative to luminance (luminance is sort of green-based, remember?)
- We want $P_R(x', y')$ and $P_B(x', y')$ to describe only the color-shift of the pixel, not its average luminance.
- We do that using

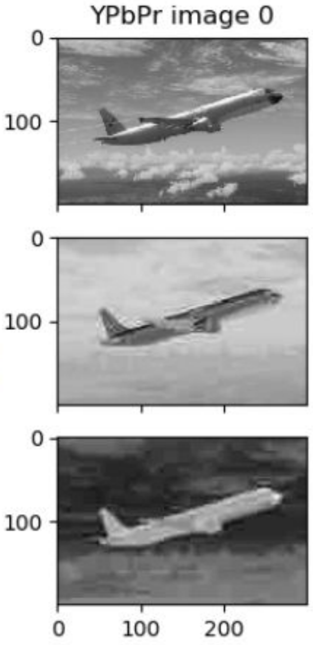
$$\begin{bmatrix} Y \\ P_B \\ P_R \end{bmatrix} = \begin{bmatrix} \vec{v}_Y \\ \vec{v}_B \\ \vec{v}_R \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

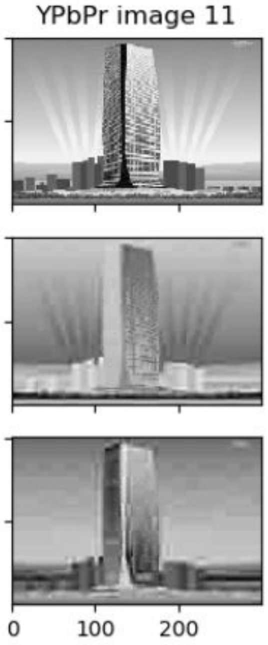



Cr and Cb, at Y=0.5

# Color features: Chrominance

$$\begin{bmatrix} Y \\ P_B \\ P_R \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.168736 & -0.331264 & 0.5 \\ 0.5 & -0.418688 & -0.081312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

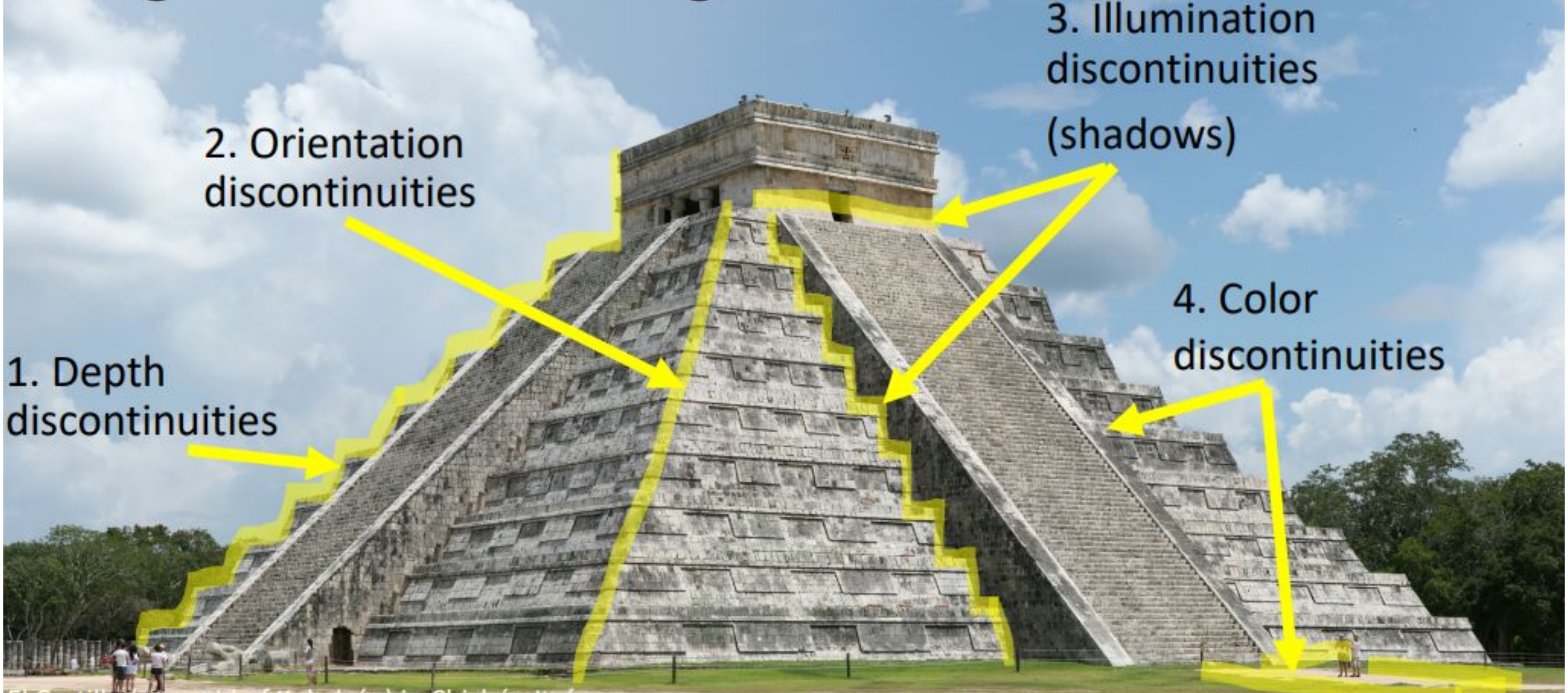



gives $sum(\vec{v}_R) = sum(\vec{v}_B) = 0$. You don't need to memorize those numbers, but you should know that

- Y = weighted average(R,G,B)
- Pr = (1/2) (R – weighted average(G,B))
- Pb = (1/2) (B – weighted average(R,G))

# Things that look like edges




El Castillo (pyramid of Kukulcán) in Chichén Itzá