On Colorblind Friendly Plotting

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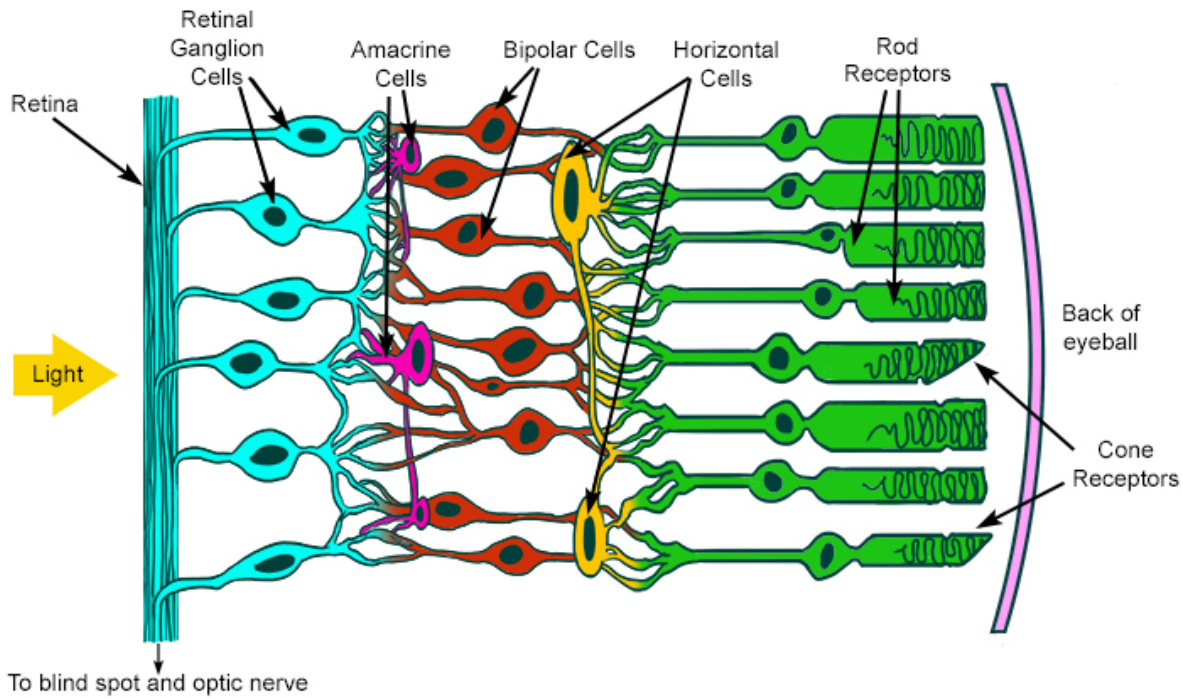
The visual system works via a set of sensors in your eye called *rods* and *cones*

Rods are super sensitive to low levels of light – they're known as your 'light / dark' detectors.

Cones are sensitive to different frequencies of light – they're what gives you color vision.



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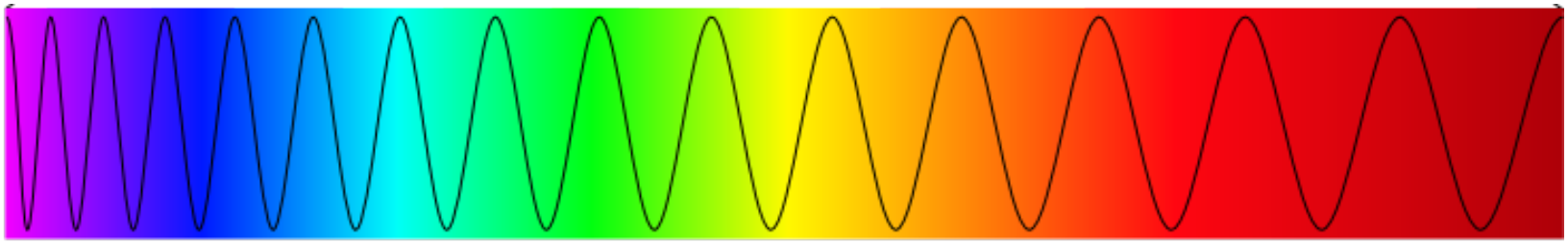
This is true on one level, but it doesn't work the way you think.

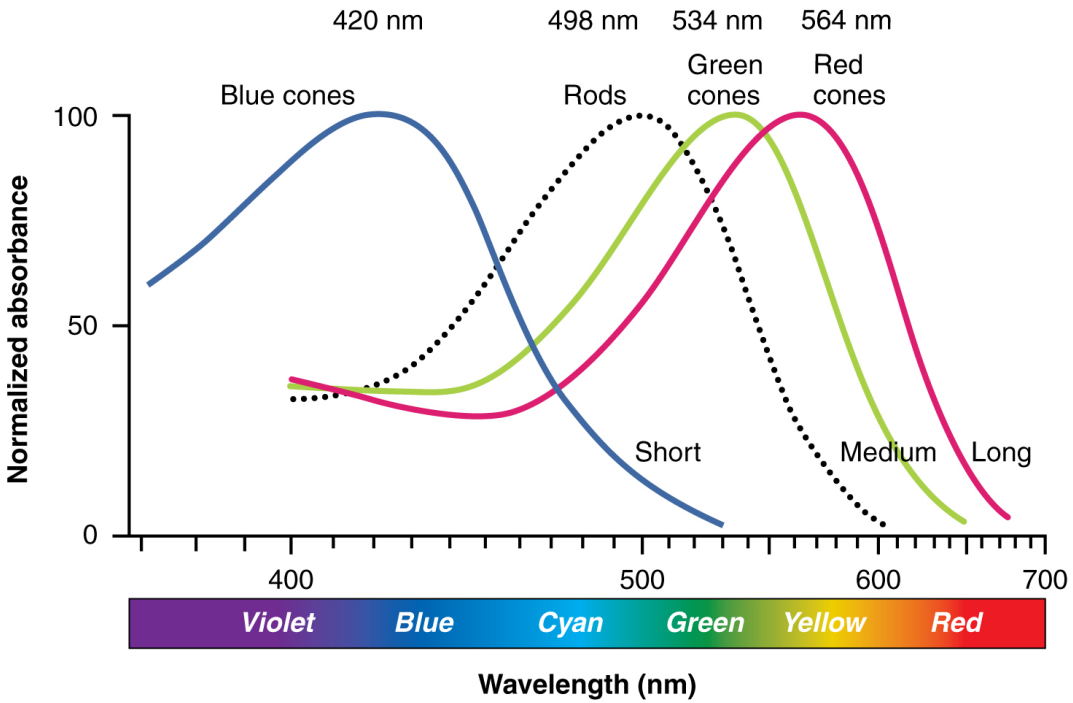
In fact, e*ach* cone sees *all* types of light– they're just different in sensitvity to the various frequencies that make up colors.

Light is a spectrum of wavelengths.

Different wavelengths are percieved as different hues.



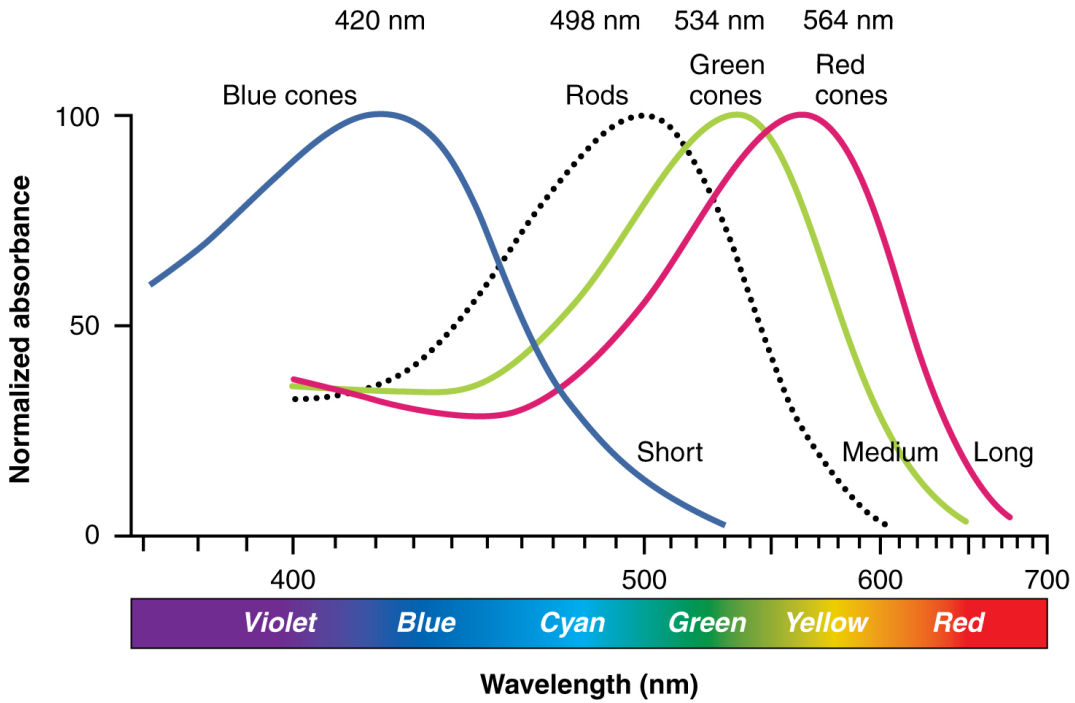
The three cones are sensitive to different wavelengths in this spectrum:



Color perception happens due to wavelengths of light activating each cone differentially.

- Red = lots of activation on long cone, less activation on medium cone, no activation on short cone

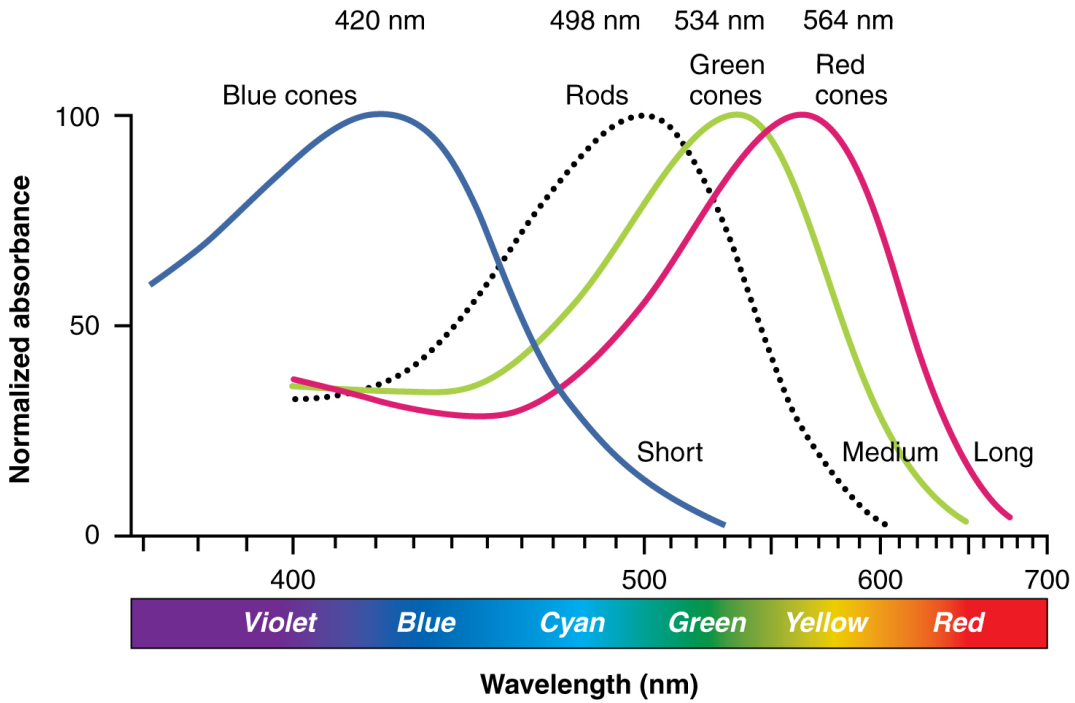
- Blue = lots of activation on short cone, less (and equal) activation on medium and long cones.



This has 2 important implications for data visualisation:

1. *Everybody* percieves hue differences between green/yellow better than blue/violet

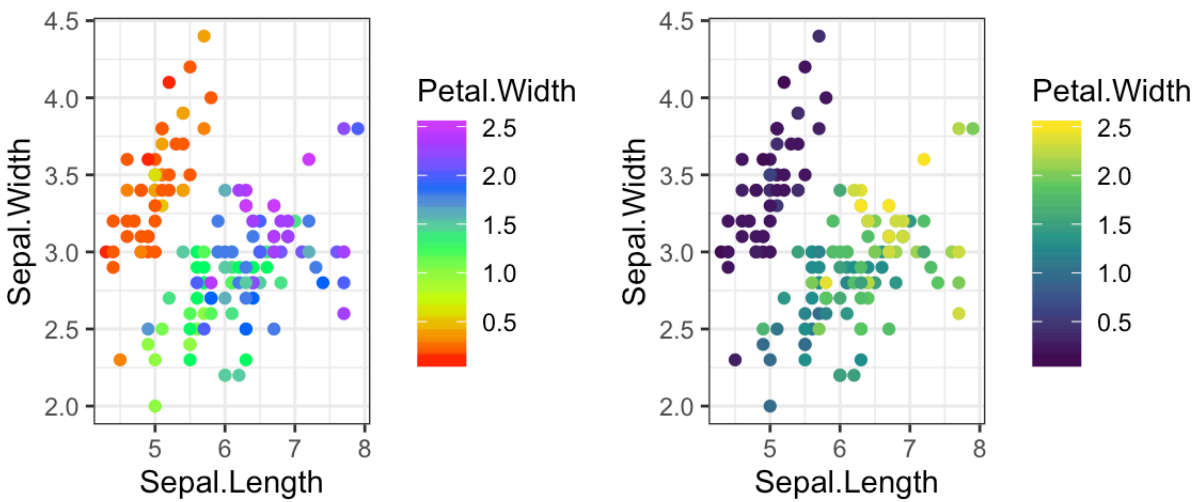
2. When either the green or red cone malfunctions, different wavelengths of light are percieved to be the same hue.



Practical tip 1: Avoid rainbows, use viridis

Here's the same plot using traditional rainbow and the viridis palette (from viridisLite()), which has been designed to be an equal luminance gradient (=good for representing real contrasts)

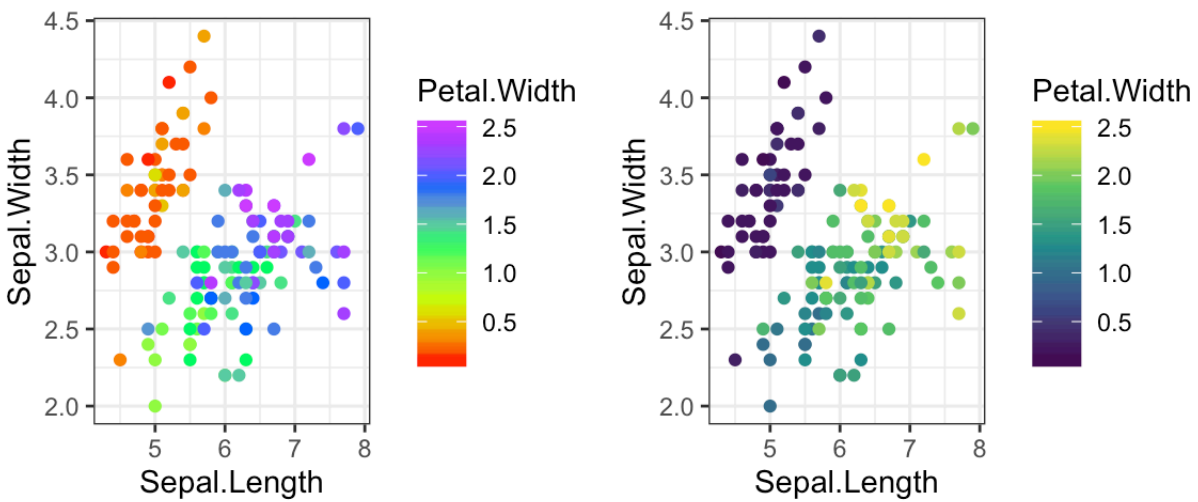
```
p <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Petal.Width))+
  geom_point()+theme_bw()

plot_grid(
p + scale_color_gradientn(colors=rainbow(5)),
p + scale_color_gradientn(colors=viridis(5))
)
```



Practical tip 1: Avoid rainbows, use viridis

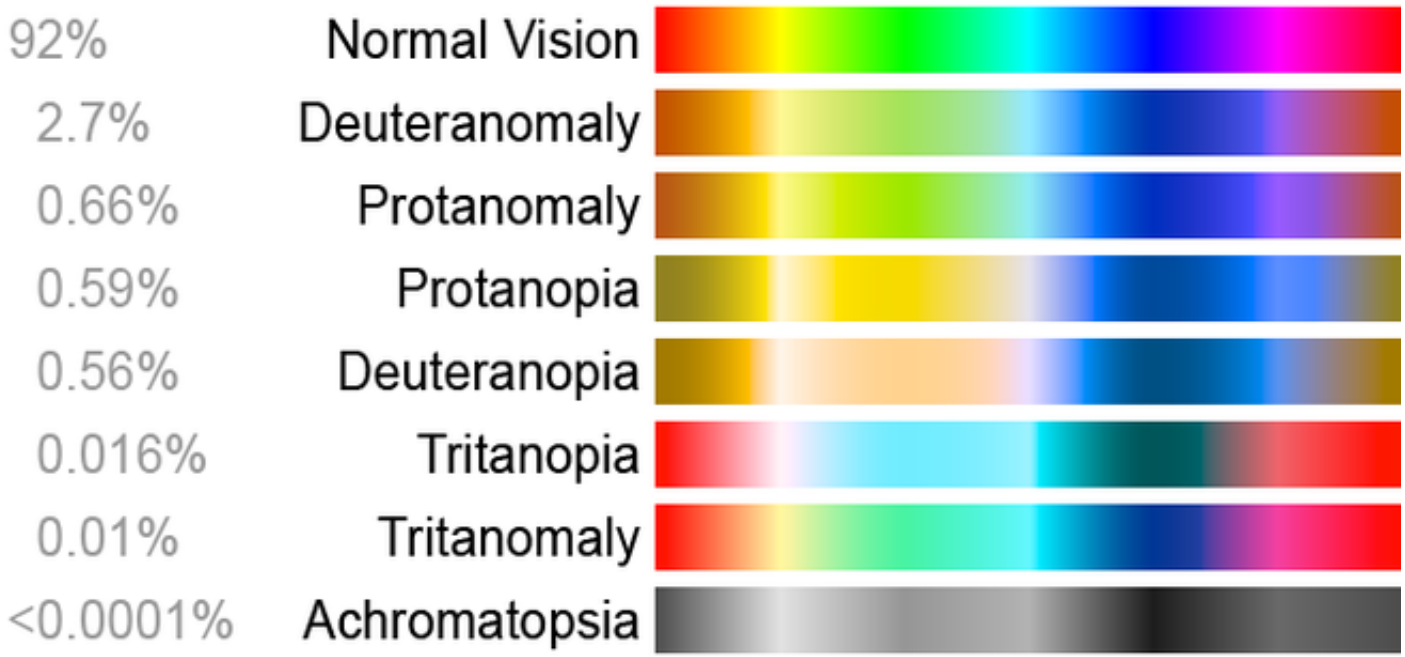
Even for people with 100% normal color vision, rainbows produce perceptual differences that aren't really there, and minimize differences that are.

```
p <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Petal.Width))+
  geom_point()+theme_bw()

plot_grid(
p + scale_color_gradientn(colors=rainbow(5)),
p + scale_color_gradientn(colors=viridis(5))
)
```



Practical tip 2: Avoid contrasting red and green

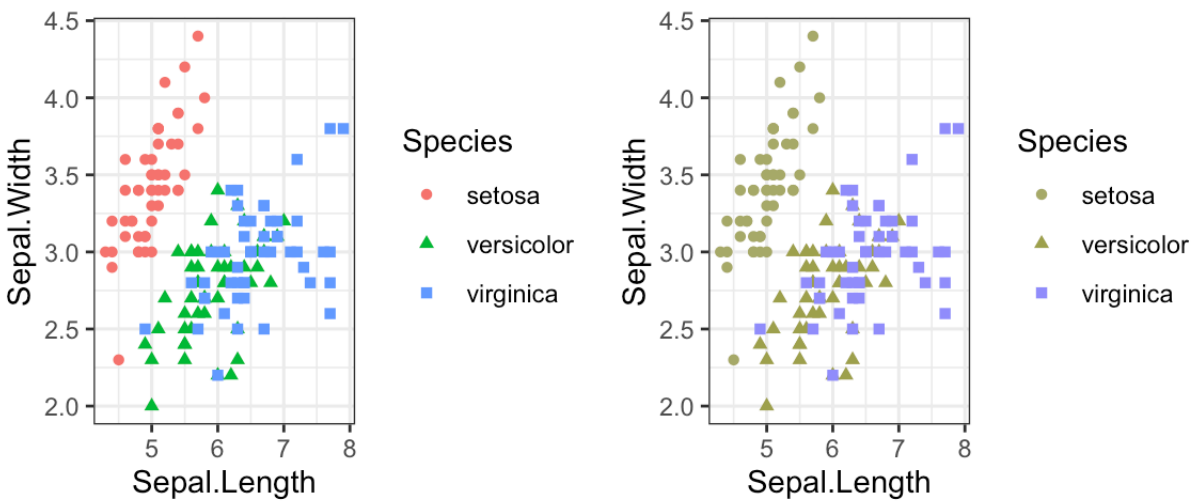
8% of people are colorblind! (Higher for men than women)



Practical tip 2: Avoid contrasting red and green

Here's the traditional default ggplot color scheme with simulated deficiency in the deutan cone (most common form of colorblindness) using package dichromat(). *IT IS VERY BAD*

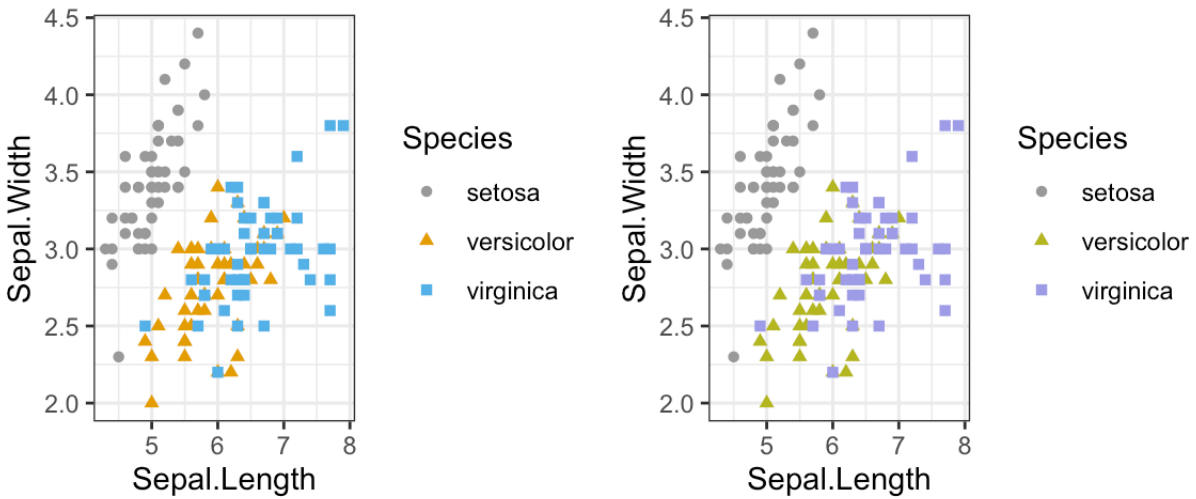
```
p2 <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Species, shape=Species))+
  geom_point()+theme_bw()

plot_grid(
p2 + scale_color_manual(values=c("#F8766D","#00BA38","#619CFF")),
p2 + scale_color_manual(values=dichromat(c("#F8766D","#00BA38","#619CFF"),type="deutan"))
)
```



Practical tip 2: Avoid contrasting red and green

Here's a better option, gotten from http://www.cookbook-r.com/Graphs/Colors_(ggplot2)/

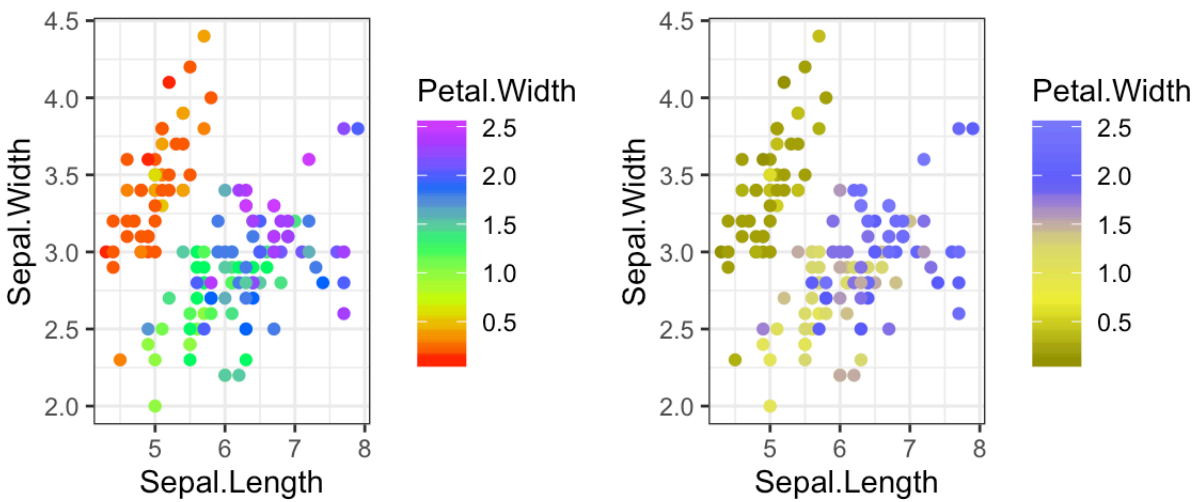
```
plot_grid(
p2 + scale_color_manual(values=c("#999999", "#E69F00", "#56B4E9")),
p2 + scale_color_manual(values=dichromat(c("#999999", "#E69F00", "#56B4E9"),type="deutan"))
)
```



Practical tip 3: Seriously, avoid rainbows

Here's the rainbow plot with simulated deficiency in the deutan cone (most common form of colorblindness) using package dichromat(). *IT IS ALSO PRETTY BAD*

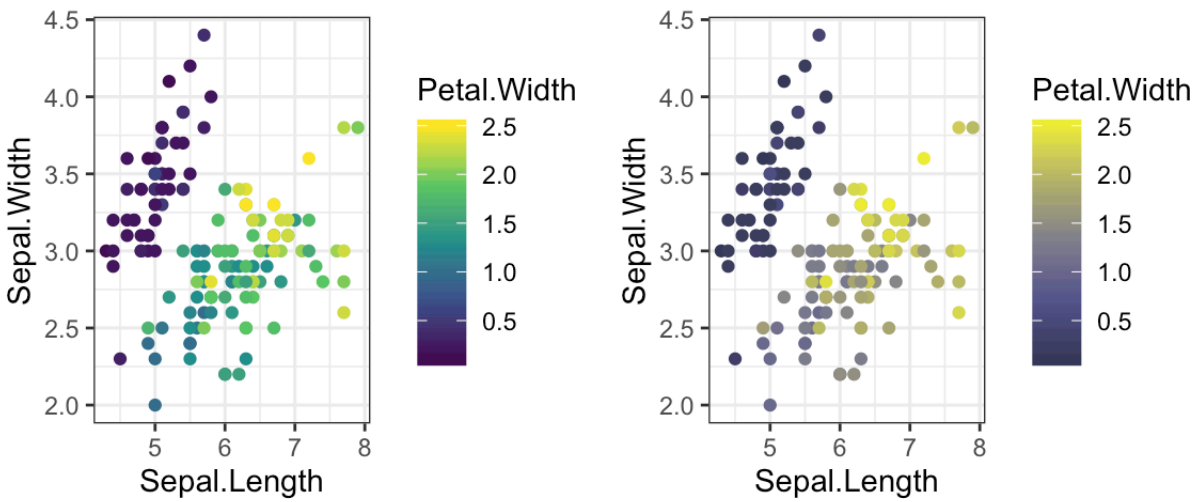
```
p <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Petal.Width))+
  geom_point()+theme_bw()

plot_grid(
p + scale_color_gradientn(colors=rainbow(5)),
p + scale_color_gradientn(colors=dichromat(rainbow(5),type="deutan"))
)
```



Practical tip 3: Seriously, avoid rainbows

Here's the viridis plot with simulated deficiency in the deutan cone (most common form of colorblindness) using package dichromat(). *It looks much less bad!*

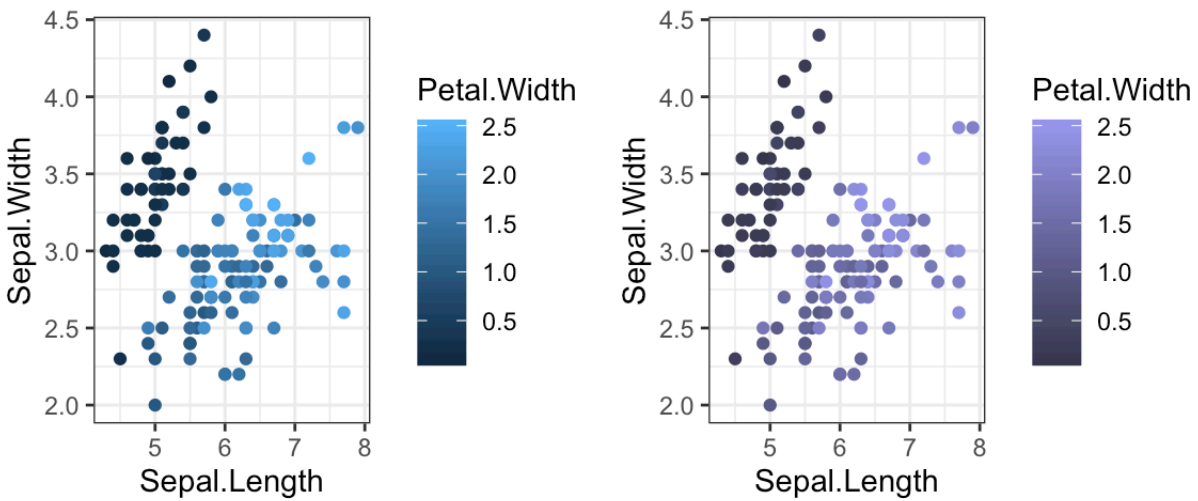
```
p <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Petal.Width))+
  geom_point()+theme_bw()

plot_grid(
p + scale_color_gradientn(colors=viridis(5)),
p + scale_color_gradientn(colors=dichromat(viridis(5),type="deutan"))
)
```



Practical tip 3: Seriously, avoid rainbows

Here's the default continuous color palette with simulated deficiency in the deutan cone (most common form of colorblindness) using package dichromat(). *It is actually pretty good!*

```
p <- ggplot(iris,aes(x=Sepal.Length,y=Sepal.Width,color=Petal.Width))+
  geom_point()+theme_bw()

plot_grid(
p + scale_fill_gradient(),
p +
  scale_color_gradient(high=dichromat("#52A9ED",type="deutan"),low=dichromat("#142E47",type="deutan"))
)
```



Plotting Recommendations

1. Avoid default ggplot categorical colors or any palette that contrasts green to red.

   –> Contrasting blue/purple to yellow/orange/red is good (or even MPI green/orange)

   –> Light / dark contrasts are your friend!

2. Use viridis or monochromatic spectrum for continuous colors.

   –> The key is ‘equal luminance’

3. If you have to have a complex palette, use other aesthetics to your advantage.

   –> Map variable to color *and* shape *and* use extra labels.