

Colors in R

STAT 133

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`github.com/ucb-stat133/stat133-fall-2016`

Colors in R

Colors in plots

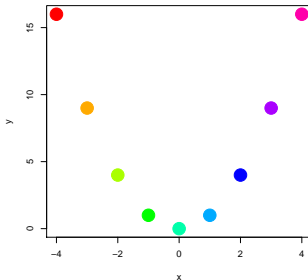
Colors on objects

In R plots, many objects can take on different colors

- ▶ points
- ▶ lines
- ▶ axes (and tick marks)
- ▶ filling areas
- ▶ borders
- ▶ text
- ▶ legends
- ▶ background

Colored points

```
x <- -4:4  
y <- x^2  
plot(x, y, pch = 19, cex = 3, col = rainbow(length(x)))
```



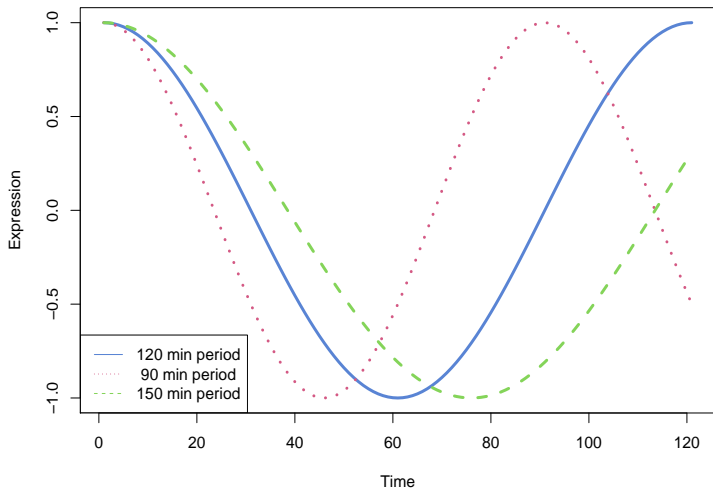
Colored lines

```
# data
Time <- 0:120
Period1 <- cos(2 * pi * Time/120)
Period2 <- cos(2 * pi * Time/90)
Period3 <- cos(2 * pi * Time/150)
Periods <- data.frame(
  Period1 = Period1,
  Period2 = Period2,
  Period3 = Period3)

# graphical parameters
line_cols <- c("#5984d4", "#d45984", "#84d459")
line_types <- c("solid", "dotted", "dashed")

# plot
matplot(Periods, type = "l", xlab = "Time", ylab = "Expression"
  , col = line_cols, lty = line_types, lwd = 3)
legend("bottomleft",
  c("120 min period", " 90 min period", "150 min period"),
  col = line_cols, lty = line_types)
```

Colored lines



Colors can dramatically impact how we perceive a graphic and what we see in the data.

Why Colors?

Importance of Color

- ▶ Color isn't just about making your charts look pretty
- ▶ Color can serve as a visual cue just like the height of a bar or the position of a dot
- ▶ R provides a straightforward way to modify colors

Naming Colors

Naming colors

Specifying colors

There are various ways to specify colors in R

- ▶ by using the color's name (in English): e.g. `"turquoise"`
- ▶ by using a hexadecimal string: `"#FFAA00"`
- ▶ by using standard color space functions: e.g. `rgb()`

Function colors()

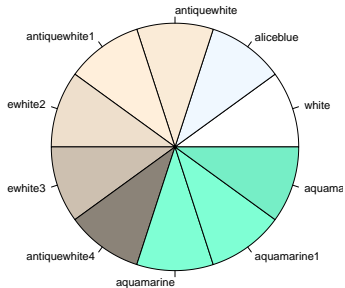
The easiest way to specify a color in R is simply to use the color's name. The R function `colors()` provides the names of 657 available colors

```
# first 30 colors  
colors()[1:30]
```

```
## [1] "white"           "aliceblue"       "antiquewhite"    "antiquewhite1"  
## [5] "antiquewhite2"   "antiquewhite3"   "antiquewhite4"   "aquamarine"  
## [9] "aquamarine1"     "aquamarine2"     "aquamarine3"     "aquamarine4"  
## [13] "azure"           "azure1"          "azure2"          "azure3"  
## [17] "azure4"          "beige"           "bisque"          "bisque1"  
## [21] "bisque2"         "bisque3"         "bisque4"         "black"  
## [25] "blanchedalmond"  "blue"            "blue1"           "blue2"  
## [29] "blue3"           "blue4"
```

Function colors()

```
# first 10 colors()  
pie(rep(1, 10), col = colors()[1:10], labels = colors()[1:10])
```



More colors()

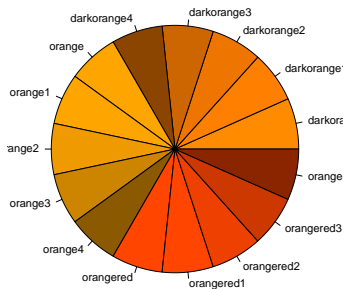
Use `grep()` to get colors of a given name

```
# orangey colors
colors()[grep("orange", colors())]

## [1] "darkorange" "darkorange1" "darkorange2" "darkorange3" "darkorange4"
## [6] "orange" "orange1" "orange2" "orange3" "orange4"
## [11] "orangered" "orangered1" "orangered2" "orangered3" "orangered4"
```

Orangey colors()

```
# orangey colors()
oranges <- colors()[grep("orange", colors())]
pie(rep(1, length(oranges)), col = oranges, labels = oranges)
```



657 R built-in colors

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175
176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250
251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275
276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325
326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350
351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375
376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425
426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475
476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525
526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575
576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625
626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657																		

```

# Code by Earl F. Glynn
SetTextContrastColor <- function(color) {
  ifelse( mean(col2rgb(color)) > 127, "black", "white")
}
TextContrastColor <- unlist(lapply(colors(), SetTextContrastColor))

colCount <- 25 # number per row
rowCount <- 27

op <- par(mar = c(0, 0, 4, 0))
plot(c(1, colCount), c(0, rowCount), type = "n", axes=FALSE,
      ylab = "", xlab = "", ylim = c(rowCount, 0))
title("657 R built-in colors")
for (j in 0:(rowCount-1))
{
  base <- j * colCount
  remaining <- length(colors()) - base
  RowSize <- ifelse(remaining < colCount, remaining, colCount)
  rect((1:RowSize)-0.5, j-0.5, (1:RowSize)+0.5, j+0.5,
       border = "black", col = colors()[base + (1:RowSize)])
  text((1:RowSize), j, paste(base + (1:RowSize)), cex = 0.7,
       col = TextContrastColor[base + (1:RowSize)])
}
par(op)

```

<http://research.stowers-institute.org/efg/R/Color/Chart/index.htm>

Gray colors()

Note that there is a wide range of gray (grey) colors:

```
# gray and grey colors
grays <- colors()[grep("gr[a|e]y", colors())]
length(grays)

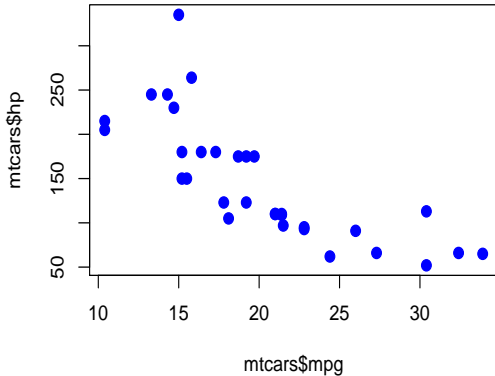
## [1] 224

head(grays, 10)

## [1] "darkgray"      "darkgrey"      "darkslategray" "darkslategray1"
## [5] "darkslategray2" "darkslategray3" "darkslategray4" "darkslategrey"
## [9] "dimgray"       "dimgrey"
```

Example

```
# color argument 'col'  
plot(mtcars$mpg, mtcars$hp, pch = 19, col = "blue", cex = 1.2)
```



RGB Color Model

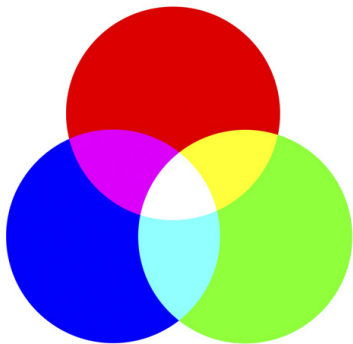
RGB Colors

About RGB color

- ▶ Computers create the colors we see on a monitor by combining 3 primary colors of light:
 - red
 - green
 - blue
- ▶ This combination is known as **RGB color model**
- ▶ Each color light is also referred to as a **channel**

Red-Green-Blue

A computer screen displays a color by combining red light, green light and blue light, the so-called RGB model.



RGB Colors

Values of RGB colors

- ▶ Any color you see on a monitor can be described by a series of 3 numbers (in the following order):
 - a red value
 - a green value
 - a blue value
- ▶ e.g. red=30, green=200, blue=180

RGB Colors

Values of RGB colors

- ▶ The amount of light in each color channel is typically described on a scale from 0 (none) to 255 (full-blast)
- ▶ Alternatively, scales can be provided as percent values from 0 (none) to 1 (100%)

RGB Colors

Some reference colors:

RGB Values	Color
(255, 0, 0)	red
(0, 255, 0)	green
(0, 0, 255)	blue
(0, 0, 0)	black
(255, 255, 255)	white

The closer the three values get to 255 (100%), the closer the resulting color gets to white

rgb() colors

R provides the function `rgb()` to specify RGB colors

```
# 0 to 1 (default scale)
```

```
rgb(red = 1, green = 0, blue = 0)
```

```
## [1] "#FF0000"
```

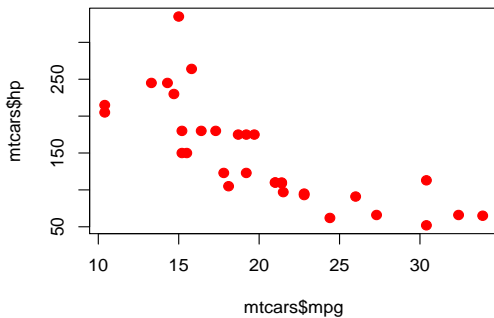
```
# 0 to 255
```

```
rgb(red = 255, green = 0, blue = 0, maxColorValue = 255)
```

```
## [1] "#FF0000"
```

Example

```
# color argument 'col'
plot(mtcars$mpg, mtcars$hp, pch = 19, cex = 1.2,
     col = rgb(255, 0, 0, max = 255))
```



Colors in Hexadecimal Notation

Hex Colors

Storing RGB colors in decimal notation would require 9 digits:

255 | 255 | 255

Hex Colors

Storing RGB colors in decimal notation would require 9 digits:

255 | 255 | 255

In order to have a more efficient storage system, computers use
hexadecimal digits

Hex Colors

Colors in hexadecimal notation

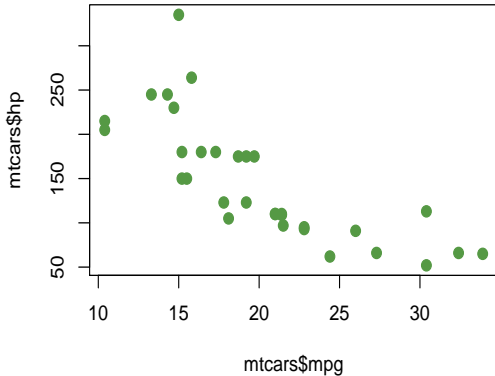
A color can also be specified as a string beginning with a hash symbol "#" and followed by six hexadecimal digits

- ▶ "#FF0000" (red)
- ▶ "#00FF00" (green)
- ▶ "#0000FF" (blue)
- ▶ "#FF6347" (tomato)

This is actually the output format of `rgb()`

Example

```
# color argument 'col'  
plot(mtcars$mpg, mtcars$hp, pch = 19, cex = 1.2,  
      col = "#559944")
```



Hexadecimal code

Hexadecimal: numeral system with base 16, or *hex*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

Hexadecimal code

R uses the hexadecimal system to name colors

- ▶ The hexadecimal representation uses 16 different symbols
- ▶ The 16 symbols are all 10 digits (0-9) and 6 first letters (A-F)
- ▶ The digits 0-9 represent values zero to nine
- ▶ The letters A, B, C, D, E, F (or a, b, c, d, e, f) represent values ten to fifteen

Hexadecimal Notation

Decimal and Hexadecimal

##	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
## decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
## hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

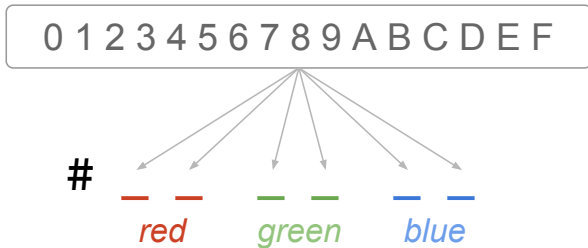
Two hexadecimal digits together can make $16 \times 16 = 256$ different values (from 0 to 255)

Six hexadecimal digits together can make $16^6 = 16,777,216$ different values.

Hexadecimal code

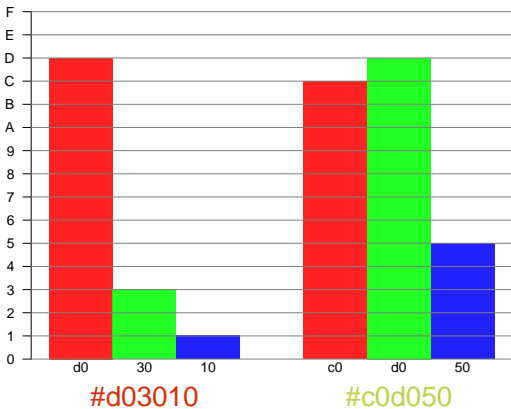
Hexadecimal color: #975015

- ▶ # declares that this “is a hex number”
- ▶ The other six are really three sets of pairs
- ▶ Each pair controls one primary additive color
- ▶ The first pair corresponds to red
- ▶ The second pair corresponds to green
- ▶ The last pair corresponds to blue



There are 256 possible shades each of red, green, and blue

RGB Hexadecimal Notation

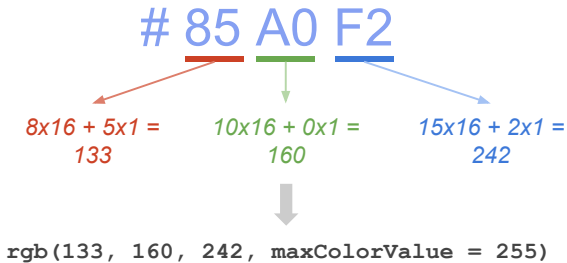


Hexadecimal code

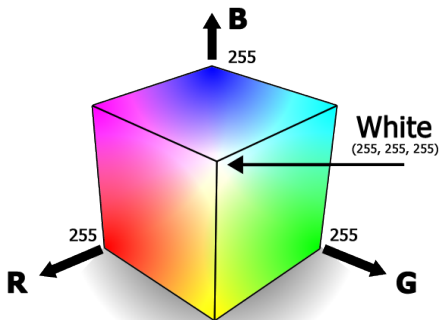
Hexadecimal digits

- ▶ **0** is the smallest representation of a color (absence of color)
- ▶ **F** is 15 times the intensity of color 0
- ▶ **00** is equal to zero hue
- ▶ **FF** is equal to a pure color
- ▶ **#000000** black
- ▶ **#FFFFFF** white
- ▶ equal digits produce a shade of gray

RGB and Hex



RGB Cube Representation



<http://drmoron.org/is-black-a-color/>

Your turn

Orange in hex-code is:

A) #FFA500

B) #3EDCD9

C) #A500FF

D) #E88472

Your turn

What color is RGB: 89, 132, 212

A) Orange

B) Blue

C) Black

D) Yellow

RGB Inconvenience

RGB drawbacks

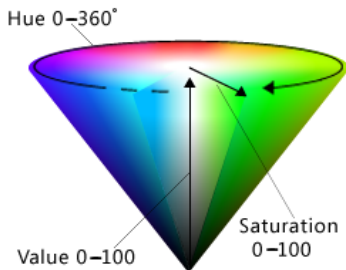
- ▶ The RGB color model is the most commonly used
- ▶ However, specifying RGB colors is not intuitive
- ▶ It is not straightforward how to make a color stronger, darker or lighter with RGB values
- ▶ It is also hard to “read” RGB values (and being able to identify the corresponding hue)

Cylindrical-coordinate Representations

Cylindrical Models

- ▶ An alternative to RGB values is the **HSV** model
- ▶ HSV: Hue (color), Saturation, Value
- ▶ HSV rearranges the geometry of RGB following cylindrical coordinates

HSV representation



Cylindrical-coordinate Representations

HSV Models

- ▶ Hue values are measured in degrees around the circle
 - Red at 0 degrees
 - Green at 120°
 - Blue at 240°
 - other colors in between
- ▶ Saturation is a percentage value from 0 (gray) to 1 (full blast)
- ▶ Value is also a percentage value from 0 (darkest) to 1 (lightest)

Function `hsv()`

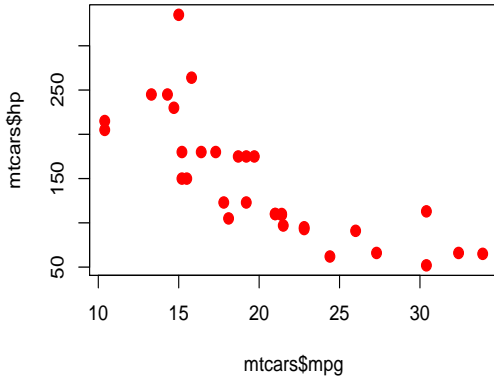
R provides the function `hsv()` which takes an HSV triplet

```
hsv(h = 1, s = 0.8, v = 0.9)
```

Note that the Hue value ranges from 0 (0 degrees) to 1 (360 degrees)

Example

```
# hsv color  
plot(mtcars$mpg, mtcars$hp, pch = 19, cex = 1.2,  
      col = hsv(h = 1, s = 1, v = 1))
```



HSV

About HSV

- ▶ HSV is a more intuitive system
- ▶ HSV is also more perceptually relevant
- ▶ Once you select a hue, it is easy to make it stronger, darker, or lighter

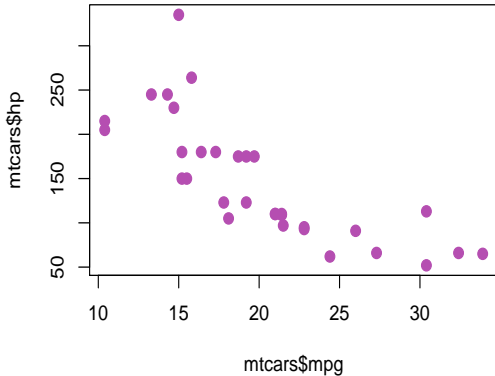
Other Representations

HCL Model

- ▶ Another model is **HCL**
- ▶ HCL: Hue, Chroma, Luminance
- ▶ Hue values are measured in degrees around the circle
 - Red at 0 degrees
 - Green at 120°
 - Blue at 240°
 - other colors in between
- ▶ Luminance is also a percentage value from 0 (darkest) to 100 (lightest)
- ▶ Chroma depends on Hue and Luminance

Example

```
# hcl color  
plot(mtcars$mpg, mtcars$hp, pch = 19, cex = 1.2,  
      col = hcl(h = 3550, c = 75, l = 50))
```



Color Space

HSV Colors by space model

R provides the functions `hsv()` and `hcl()`

- ▶ **HSV** (Hue, Saturation, Value) triplet:
`hsv(h = 1, s = 0.8, v = 0.9)`
- ▶ **HCL** (Hue, Chroma, Luminance) triplet:
`hcl(h = 1, c = 35, l = 85)`

Color Space Models

Color Model

A **color model** is an abstract mathematical model describing the way colors can be represented as tuples of numbers, typically as three or four values or color components.

About colors

RGB Model

The **RGB model** uses an additive color mixing with primary colors of red, green, and blue, each of which stimulates one of the three types of the eye's color receptors.

RGB usefulness

Mixtures of light of these primary colors cover a large part of the human color space and thus produce a large part of human color experiences.

Semitransparent Colors

Semitransparent Colors

Color transparency

All R colors are stored with an **alpha** transparency channel.

- ▶ An alpha value of 0 means fully transparent
- ▶ An alpha value of 1 means fully opaque

Semitransparent Colors

Alpha values

When using any of the color space functions, transparency is indicated with the parameter `alpha`:

- ▶ `rgb(1, 0, 0, alpha = 0.5)`
- ▶ `hsv(h = 1, s = 0.8, v = 0.8, alpha = 0.5)`
- ▶ `hcl(h = 0, c = 35, l = 85, alpha = 0.5)`

Semitransparent Colors

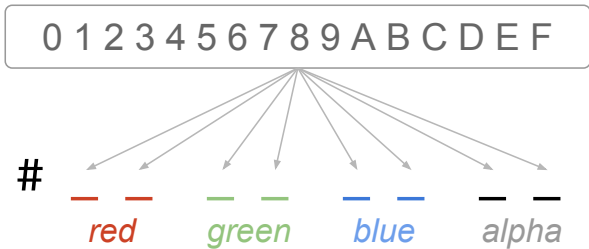
Hex color transparency

When using hexadecimal notation, transparency is indicated by using a hexadecimal string of **eight digits**. The last two digits indicate transparency:

- ▶ a hex digit "00" indicates an alpha value of 0 (fully transparent)
- ▶ a hex digit "FF" indicates an alpha value of 1 (fully opaque)

For example, "#FFA50080" specifies a semitransparent orange. Note that "#FFA500" is equivalent to "#FFA500FF"

Hex notation with alpha channel



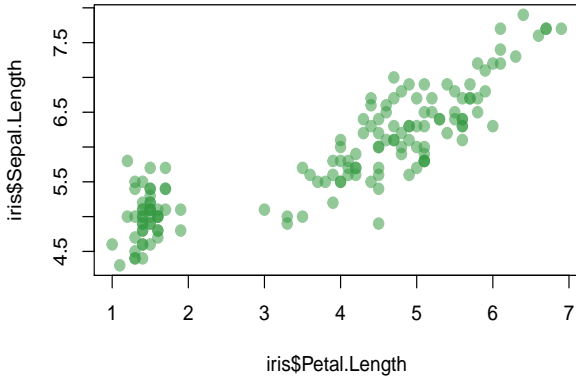
Transparency

Use transparency for overlapping data

- ▶ The number of lines or points on a graph can obscure other values that lie behind them.
- ▶ One option to present many overlapping values is to make the color values partially transparent

Example

```
# transparent color  
plot(iris$Petal.Length, iris$Sepal.Length,  
     pch = 19, cex = 1.2, col = "#33994088")
```



Converting Colors

Converting colors functions

R provides a set of functions for converting between different color spaces

function	package
<code>col2rgb()</code>	"grDevices"
<code>hex2RGB()</code>	"colorspace"
<code>convertColor()</code>	"grDevices"

```

# turquoise into RGB
col2rgb("turquoise")

##           [,1]
## red        64
## green     224
## blue      208

# turquoise (hex) into RGB
library("colorspace")

## Loading required package: methods

hex2RGB("#40E0D0")

##           R           G           B
## [1,] 0.2509804 0.8784314 0.8156863

# color 'red' sRGB into Luv
convertColor(t(col2rgb("red")/255), from = "sRGB", to = "Luv")

##           L           u           v
## [1,] 53.48418 175.3647 37.80017

```

Color Palettes

Color Sets

Converting colors functions

Usually more than one color is required within a single plot, and in such cases we need to select colors that are aesthetically pleasing or related in some way. For this, R provides several ways to specify or create color schemes and palettes.

R Default Palettes

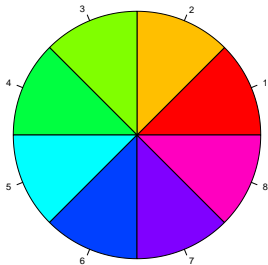
Basic Color Palettes

R provides a set of functions to generate basic color sets.

- ▶ `rainbow()`
- ▶ `heat.colors()`
- ▶ `topo.colors()`
- ▶ `terrain.colors()`
- ▶ `cm.colors()`
- ▶ `gray.colors()`

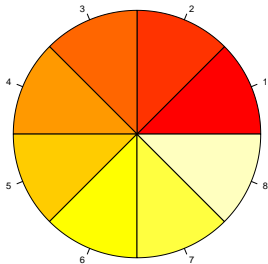
Function rainbow()

```
# 8 colors rainbow  
n <- 8  
pie(rep(1, n), col = rainbow(n))
```



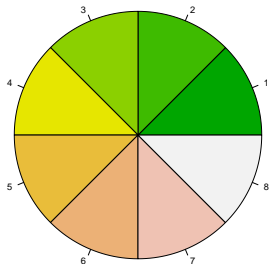
Function `heat.colors()`

```
# heat colors (8 values)  
n <- 8  
pie(rep(1, n), col = heat.colors(n))
```



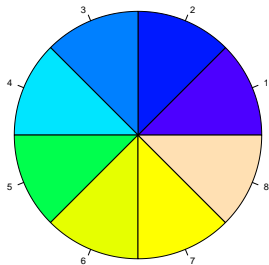
Function `terrain.colors()`

```
# terrain colors (8 values)  
n <- 8  
pie(rep(1, n), col = terrain.colors(n))
```



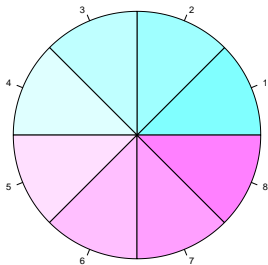
Function `topo.colors()`

```
# topo colors (8 values)  
n <- 8  
pie(rep(1, n), col = topo.colors(n))
```



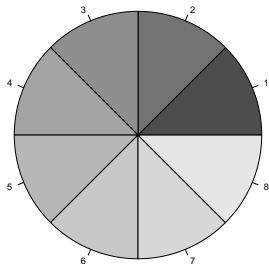
Function `cm.colors()`

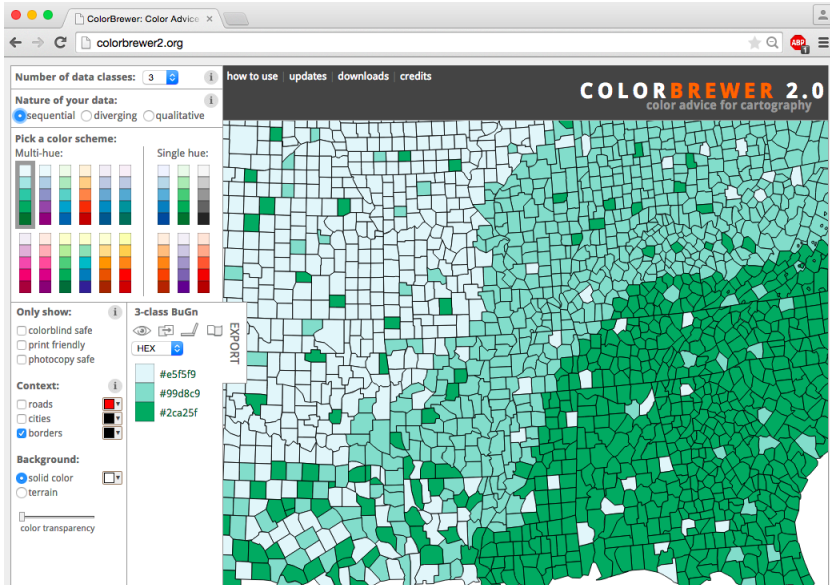
```
# cyan-magenta colors (8 values)  
n <- 8  
pie(rep(1, n), col = cm.colors(n))
```



Function `gray.colors()`

```
# gray colors (8 values)  
n <- 8  
pie(rep(1, n), col = gray.colors(n))
```



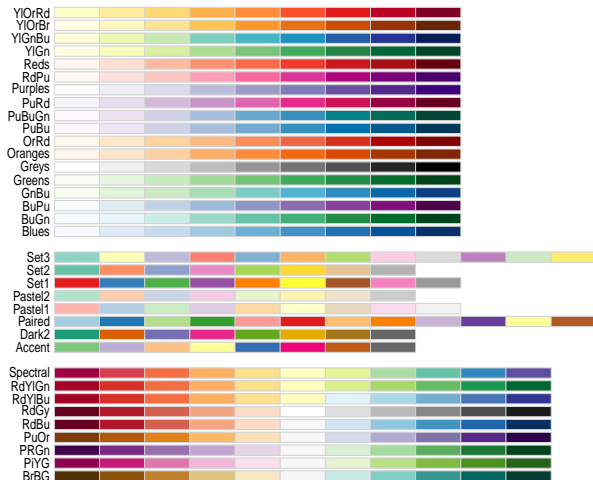


Color Brewer

The R package "RColorBrewer" (by Erich Neuwirth) provides nice color schemes designed by Cynthia Brewer and described at <http://colorbrewer2.org>

```
# remember to install RColorBrewer first!  
library(RColorBrewer)  
  
# display available schemes  
display.brewer.all()
```

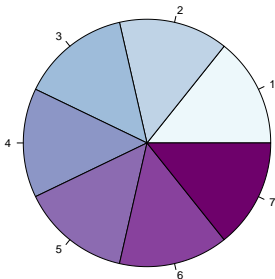
R Color Brewer Schemes



Brewer palette

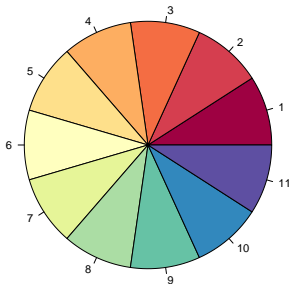
The main function of "RColorBrewer" is `brewer.pal()` that allows you to select a color palette by specifying the name and size of the palette.

```
# palette "BuPu" (blue-purple)
n <- 7
pie(rep(1, n), col = brewer.pal(n, "BuPu"))
```



Brewer palette

```
# palette "Spectral"  
n <- 11  
pie(rep(1, n), col = brewer.pal(n, "Spectral"))
```



More about color spaces

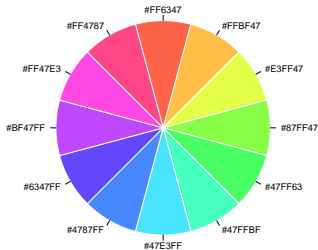
- ▶ The package "colorspace" provides functions to create colors in a variety of color spaces, plus functions to convert between color spaces.
- ▶ Another useful package is "munsell", which is designed on the Munsell color space.
- ▶ There is also the "dichromat" package that provides a series of palettes that are suitable for people with color blindness deficiencies.

Color Wheel

Color Wheel

Understanding the Color Wheel

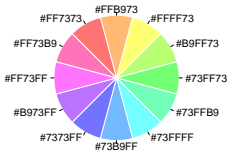
The color wheel helps you visualize the relationships that colors have to one another. The wheel shows different colors evenly apart.



Color Wheel

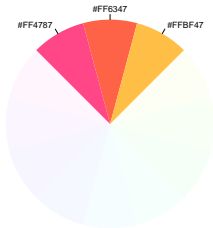
The R package "colortools" provides the function `wheel()`. The function takes the name of a color, and produces a corresponding color wheel with the specified number of slices.

```
# remember to install colortools first!  
library(colortools)  
# color wheel for 'tomato'  
wheel("#FFB973", bg = "white")
```



```
## [1] "#FFB973" "#FFFF73" "#B9FF73" "#73FF73" "#73FFB9" "#73FFFF" "#73B9FF"  
## [8] "#7373FF" "#B973FF" "#FF73FF" "#FF73B9" "#FF7373"
```

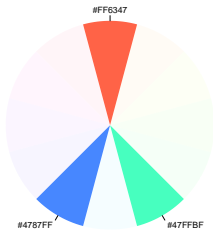
```
# Adjacent (analogous)
adjacent("tomato", title = FALSE)
```



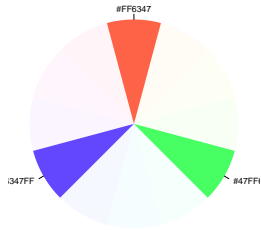
```
# Complementary
complementary("tomato", title = FALSE)
```



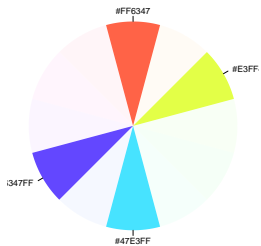
```
# split complementary  
splitComp("tomato", title = FALSE)
```



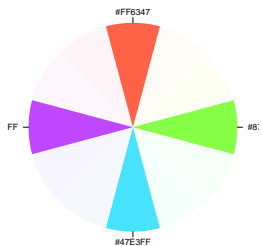
```
# triadic  
triadic("tomato", title = FALSE)
```



```
# tetradic  
tetradic("tomato", title = FALSE)
```



```
# square  
square("tomato", title = FALSE)
```



Ramp Palettes

`colorRampPalette()`

R also offers the functions `colorRamp()` and `colorRampPalette()`. They are not color set generators, but color set **function** generators.

Ramp Palettes

colorRamp()

colorRamp() produces a function for creating colors based on a sequence of values in the range 0 to 1. The output is a numeric matrix of RGB color values

```
red_green <- colorRamp(c("red", "green"))  
red_green( (0:4)/4 )
```

```
##           [,1]    [,2] [,3]  
## [1,] 255.00    0.00    0  
## [2,] 191.25   63.75    0  
## [3,] 127.50  127.50    0  
## [4,]  63.75  191.25    0  
## [5,]   0.00  255.00    0
```

Ramp Palettes

colorRampPalette()

colorRampPalette() produces a function that generates n colors

```
orange_blue <- colorRampPalette(c("orange", "blue"))
orange_blue(5)

## [1] "#FFA500" "#BF7B3F" "#7F527F" "#3F29BF" "#0000FF"
```

Colors and Graphic Devices

Color appearance

The final appearance of a color can vary considerably depending on whether it appears on a screen, printed on paper, or displayed through a projector.

Device Dependency of Color

The colors that R sends to a graphics device are **sRGB** colors; the reason is that most computer monitors are set up to work with sRGB model.

Some Resources

- ▶ Color-Hex

<http://www.color-hex.com/>

- ▶ Paletton

<http://paletton.com>

- ▶ Adobe color scheme

<https://color.adobe.com/create/color-wheel/>



Color-hex gives information about **colors** including color models (RGB,HSL,HSV and CMYK), Triadic colors, monochromatic colors and analogous colors calculated in color page. Color-hex.com also generates a simple css code for the selected color. Html element samples are also shown below the color detail page. Simply type the 6 digit color code in the box above and hit enter.

Users Latest Favorite Colors



#990000



#000000



#259073



#00fd02



#e40ceb



#3b5998



#3cbcb7



#259073



#99a8ba



#325176

