universität innsbruck

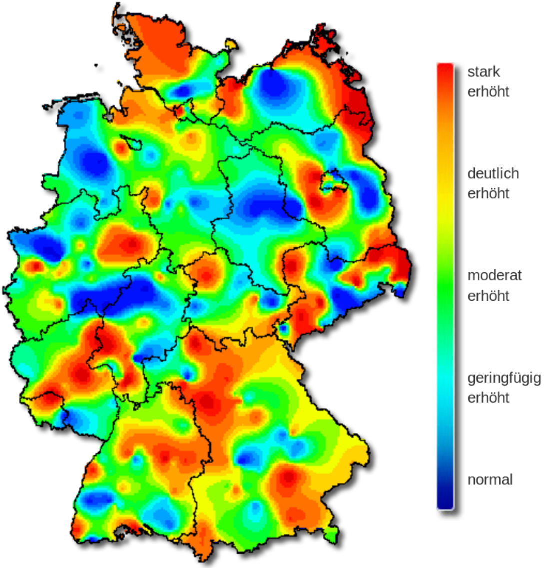
colorspace

A Toolbox for Manipulating and Assessing Color Palettes

Achim Zeileis, Jason C. Fisher, Kurt Hornik, Ross Ihaka, Claire D. McWhite, Paul Murrell, Reto Stauffer, Claus O. Wilke

http://colorspace.R-Forge.R-project.org/

Motivation



Map: Influenza severity in Germany (week 8, 2019).

Source: Arbeitsgemeinschaft Influenza, Robert-Koch-Institut.

Reported in: SPIEGEL Online, Tagesschau, . . .

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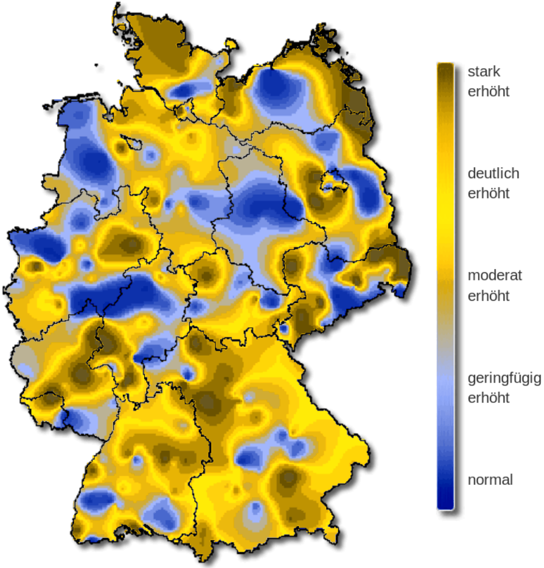

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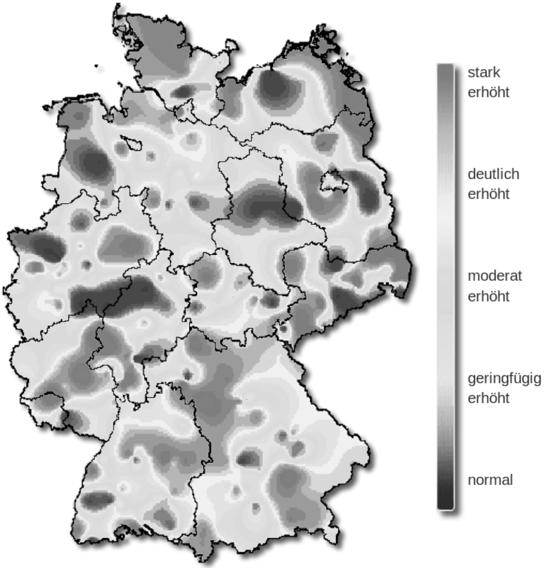

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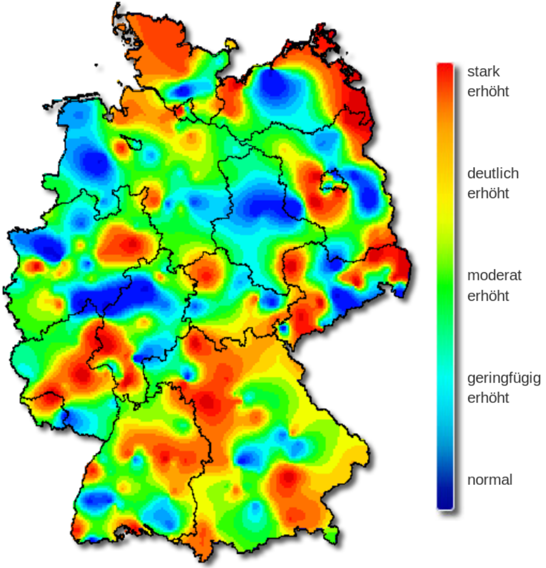

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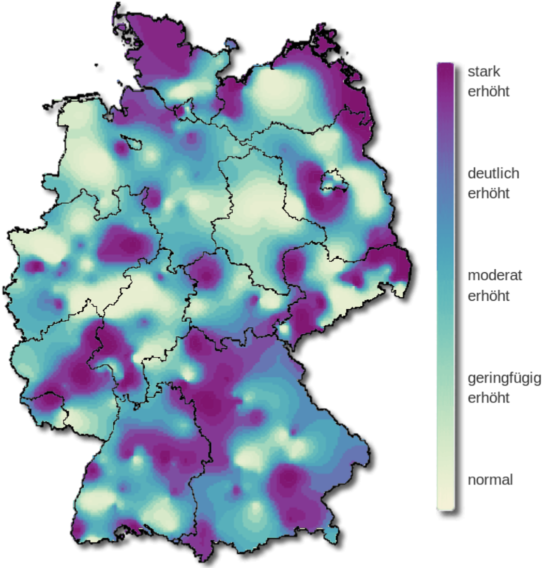

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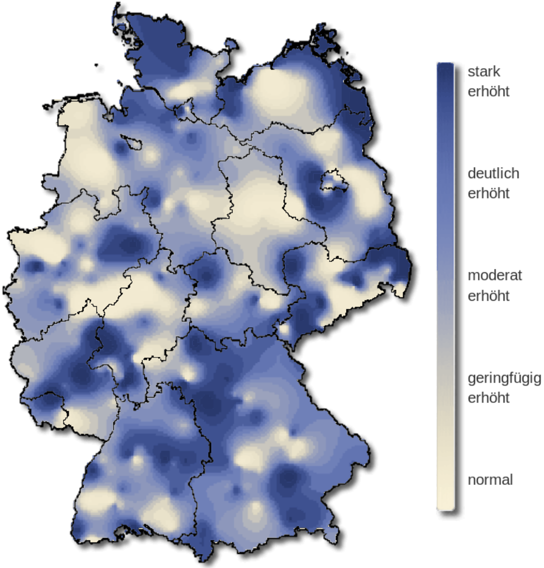

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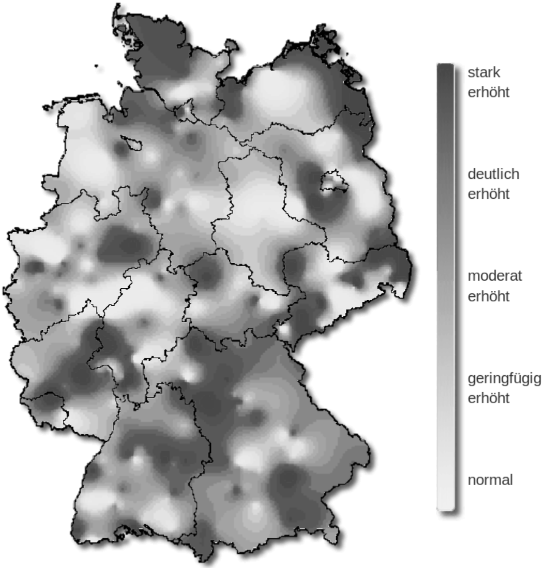

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Need tools for:

- Construction of palettes with better perceptual properties.
- Assessment of color palettes.
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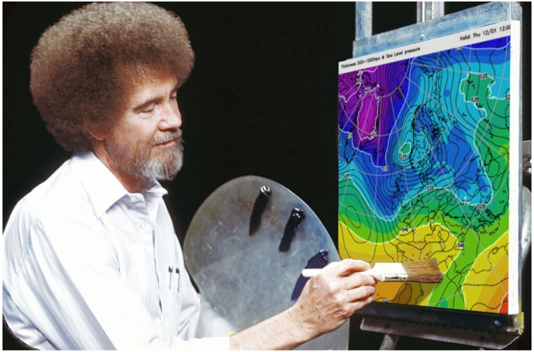


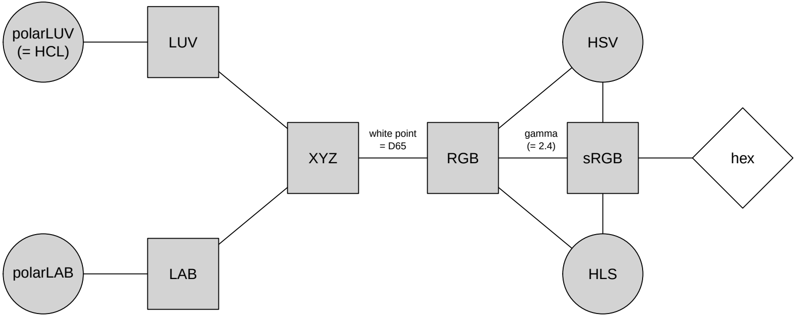
BOB ROSS INC.

Because Bob Ross would not approve of this!

Color spaces

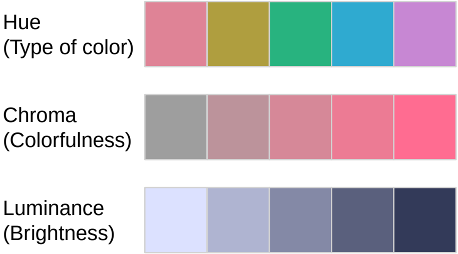
Origin of the package: Convert colors between various three-dimensional representations of color.

In particular: From the perceptually-based HCL (Hue-Chroma-Luminance) to standard Red-Green-Blue (sRGB, and corresponding hex codes) space.



HCL vs. RGB

HCL: Polar coordinates in CIELUV. Captures perceptual dimensions of the human visual system very well.



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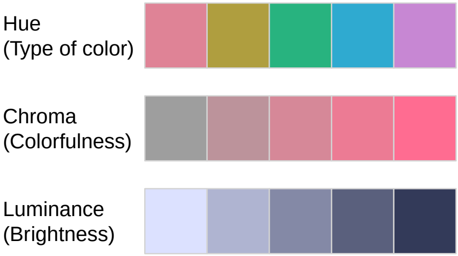
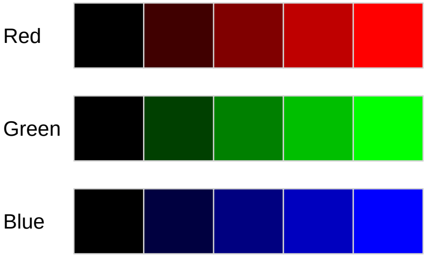
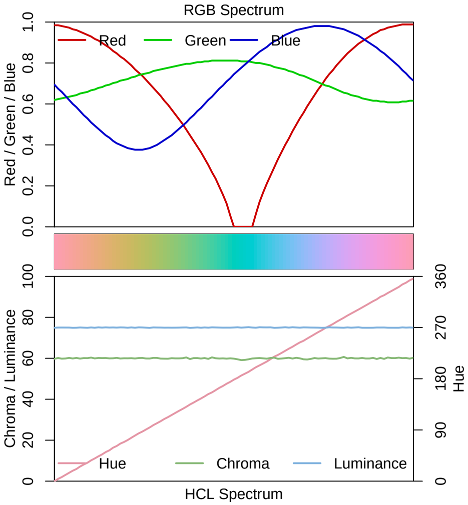


RGB: Motivated by how computers/TVs used to generate and still represent color.



HCL vs. RGB: The End of the Rainbow



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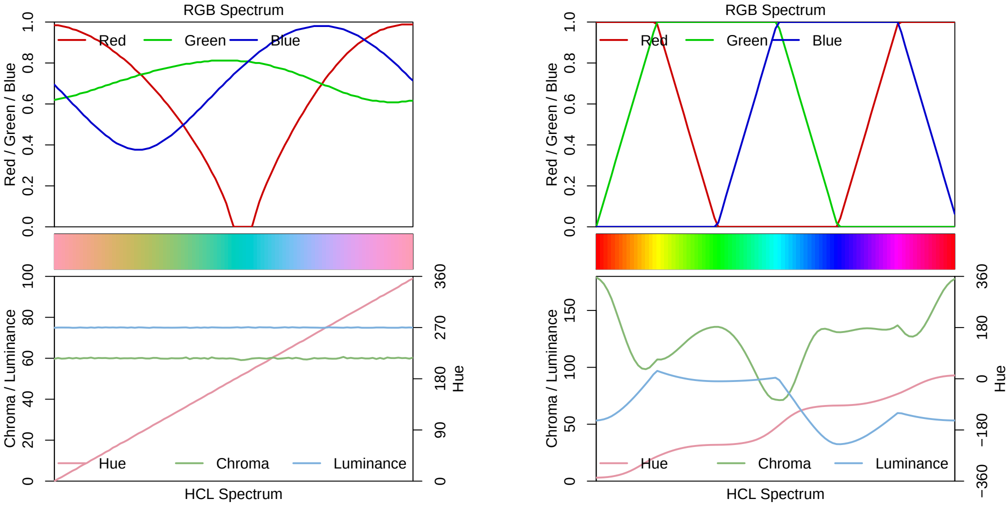


Color palettes: Somewhere over the Rainbow

Qualitative (Set 2)

Color

Desaturated

Sequential (Blues 3)

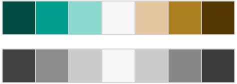
Color

Desaturated

Diverging (Green−Brown)

Color

Desaturated



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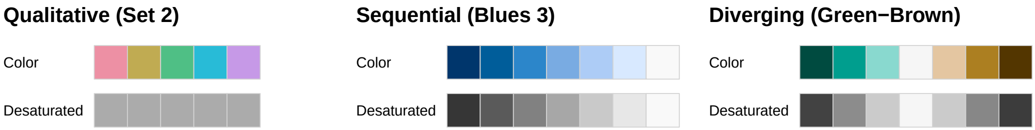

Qualitative: For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

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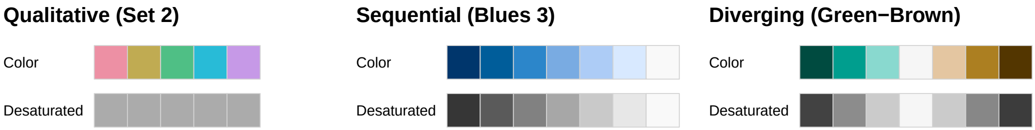

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Sequential: For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

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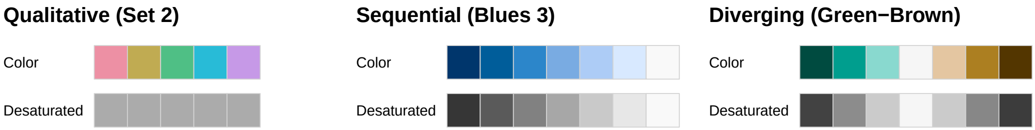

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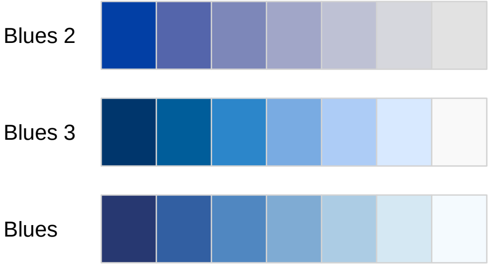
Sequential: For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

Diverging: For ordered/numeric information around a central neutral value, i.e., where colors diverge from neutral to two extremes. Function: `diverging_hcl()`.

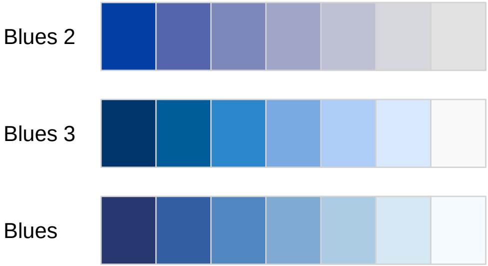
Color palettes: Somewhere over the Rainbow

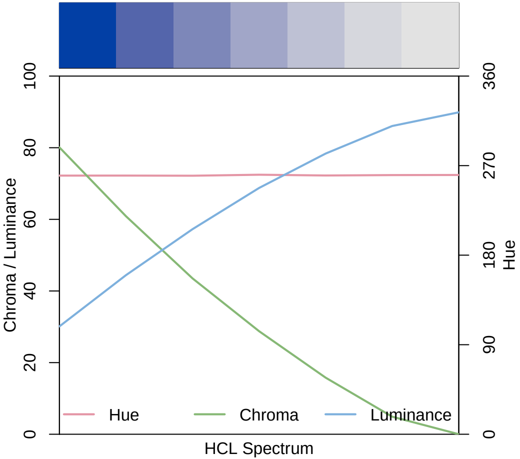
Sequential: Luminance contrast is crucial (dark to light or vice versa).



Color palettes: Somewhere over the Rainbow

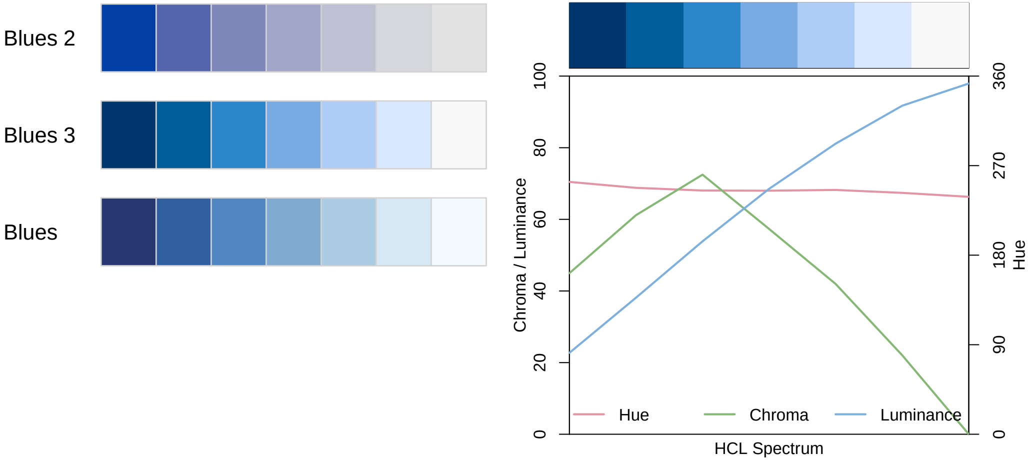
Blues 2: Single hue. Decreasing chroma with increasing luminance.





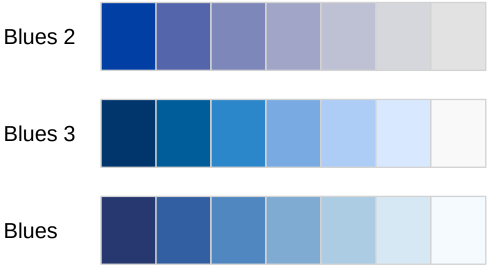
Color palettes: Somewhere over the Rainbow

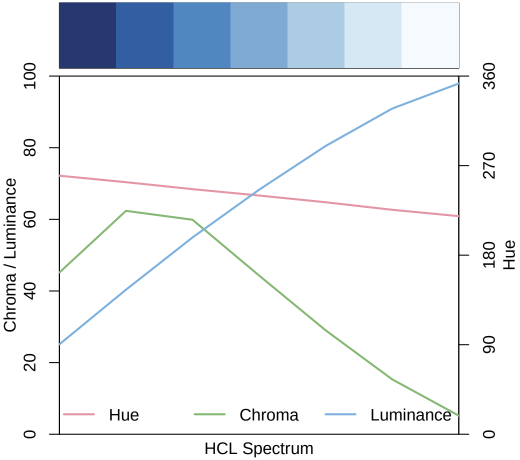
Blues 3: Single hue. Triangular chroma to achieve higher luminance contrast.



Color palettes: Somewhere over the Rainbow

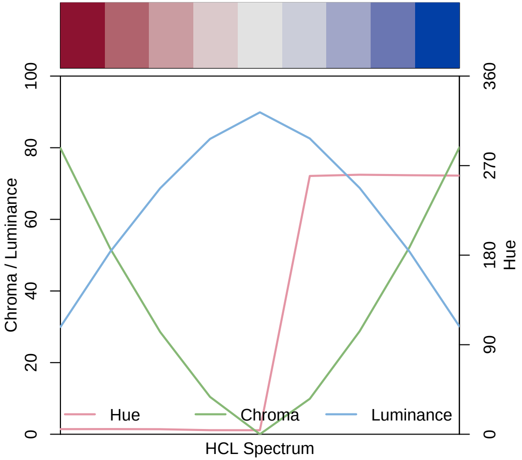
Blues: Multi hue. Triangular chroma. High luminance contrast.





Color palettes: Somewhere over the Rainbow

Diverging: Combine two sequential palettes with balanced chroma/luminance.



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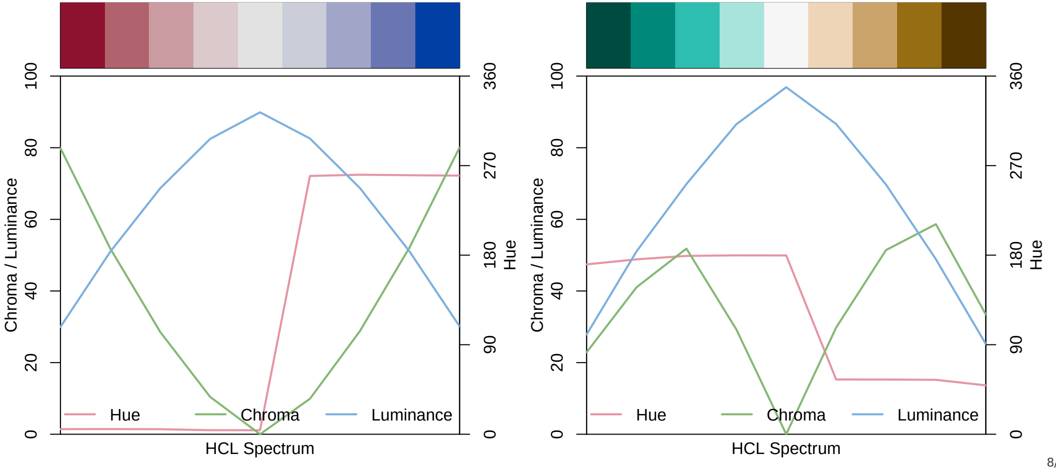


Color palettes: Somewhere over the Rainbow

```
R> hcl_palettes(plot = TRUE)
```

Statistical graphics

Base:

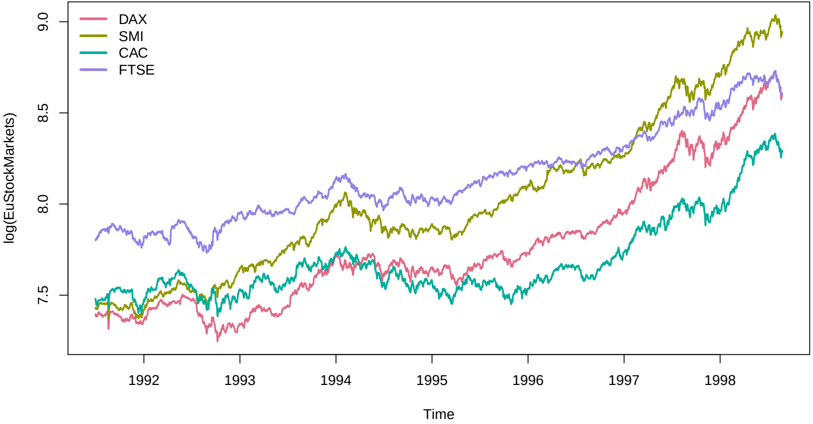
- HCL palette functions return hex color vector.
- Typically passed to `col =` argument of base plotting functions.

ggplot2:

- Scales of type `scale_<aesthetic>_<datatype>_<colorscale>()`.
- `<aesthetic>` is `fill` or `color`/`colour`.
- `<datatype>` is `discrete` or `continuous`.
- `<colorscale>` is `qualitative`, `sequential`, `diverging`, or `divergingx`.

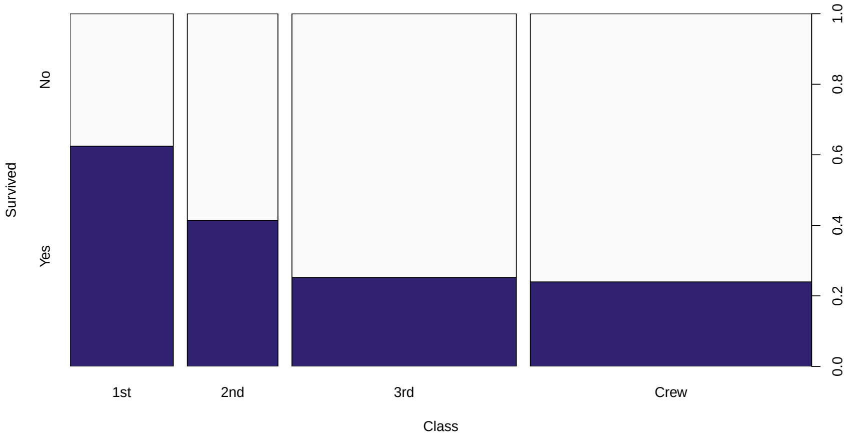
Statistical graphics: Base

```
R> q4 <- qualitative_hcl(4, palette = "Dark 3")
R> plot(log(EuStockMarkets), plot.type = "single", col = q4, lwd = 2)
R> legend("topleft", colnames(EuStockMarkets), col = q4, lwd = 3, bty = "n")
```



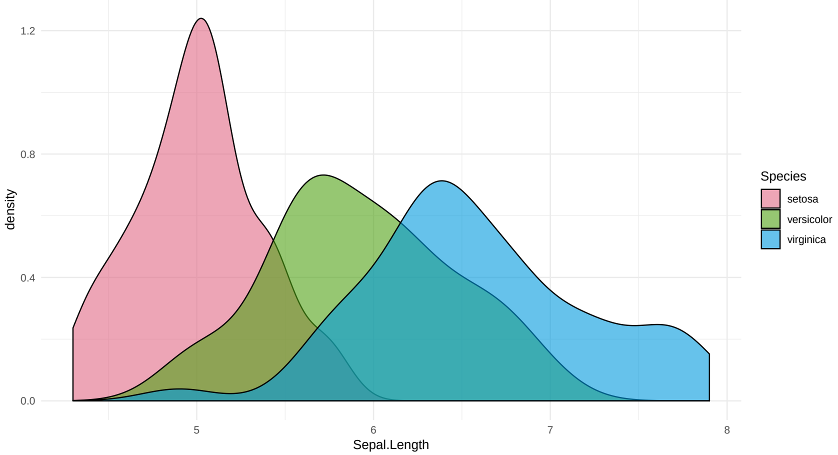
Statistical graphics: Base

```
R> ttnc <- margin.table(Titanic, c(1, 4))[, 2:1]
R> spineplot(ttnc, col = sequential_hcl(2, palette = "Purples 3"))
```



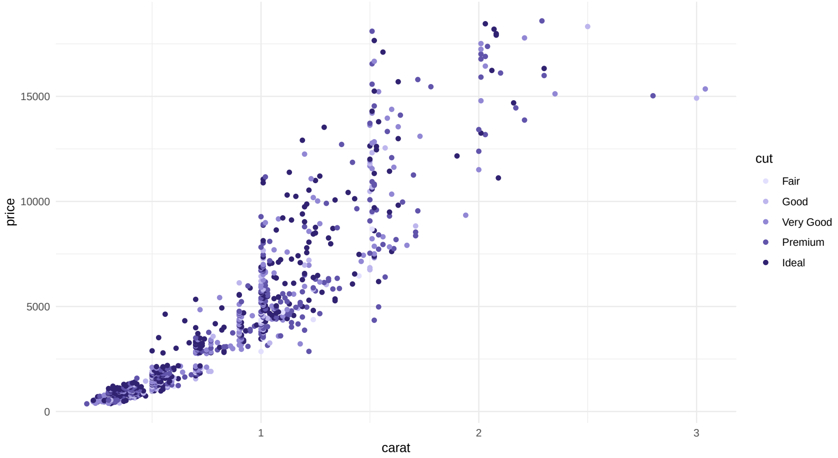
Statistical graphics: ggplot2

```
R> library("ggplot2")
R> ggplot(iris, aes(x = Sepal.Length, fill = Species)) + geom_density(alpha = 0.6) +
+    scale_fill_discrete_qualitative(palette = "Dark 3")
```



Statistical graphics: ggplot2

```
R> dsamp <- diamonds[1 + 1:1000 * 50, ]
R> ggplot(dsamp, aes(carat, price, color = cut)) + geom_point() +
+    scale_color_discrete_sequential(palette = "Purples 3", nmax = 6, order = 2:6)
```



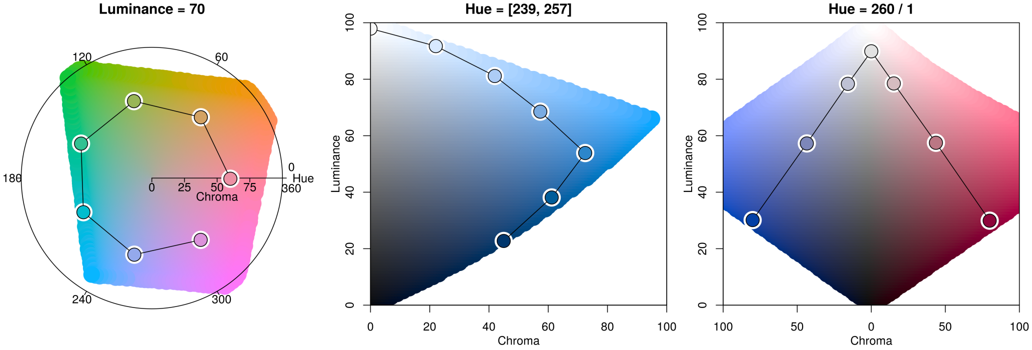
Visualization and assessment

Visualizations: Based on vector of colors.

- `swatchplot()`: Color swatches.
- `specplot()`: Spectrum of HCL and/or RGB trajectories.
- `hclplot()`: Trajectories in 2-dimensional HCL space projections.
- `demoplot()`: Illustrations of typical (and simplified) statistical graphics.

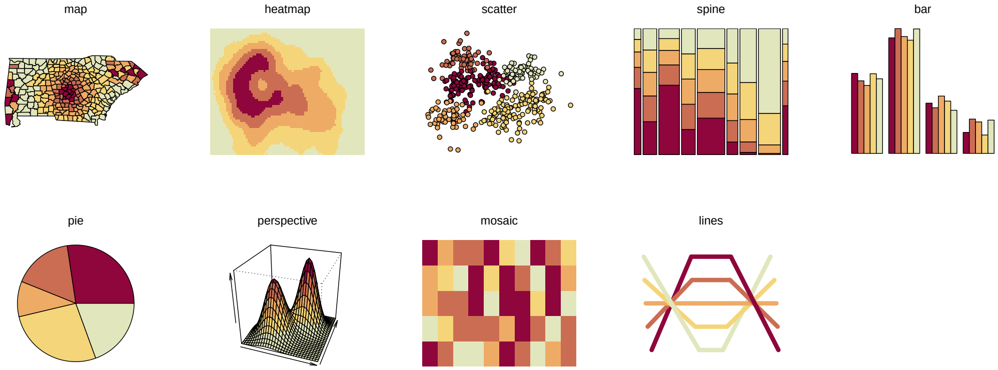
Visualization and assessment: `hclplot()`

```
R> hclplot(qualitative_hcl(7, palette = "Set 2"))
R> hclplot( sequential_hcl(7, palette = "Blues 3"))
R> hclplot(  diverging_hcl(7, palette = "Blue-Red"))
```



Visualization and assessment: `demoplot()`

```
R> cl <- sequential_hcl(5, palette = "Heat")
R> demoplot(cl, type = "...")
```

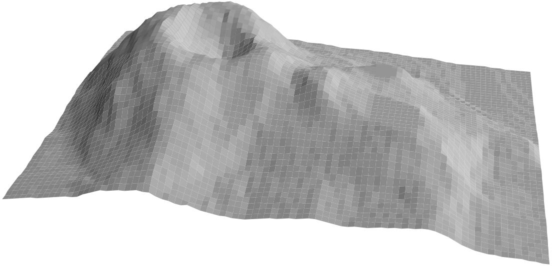


Color vision deficiency

Emulate: Color vision deficiencies.

- `deutan()`: Deuteranopia (green deficient).
- `protan()`: Protanopia (red deficient).
- `tritan()`: Tritanopia (blue deficient).

Example: Maunga Whau `volcano` data.



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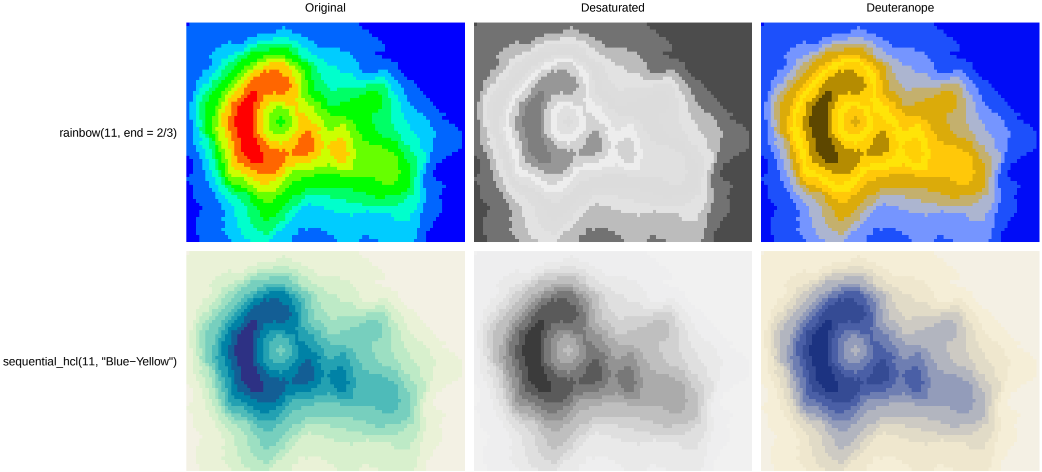
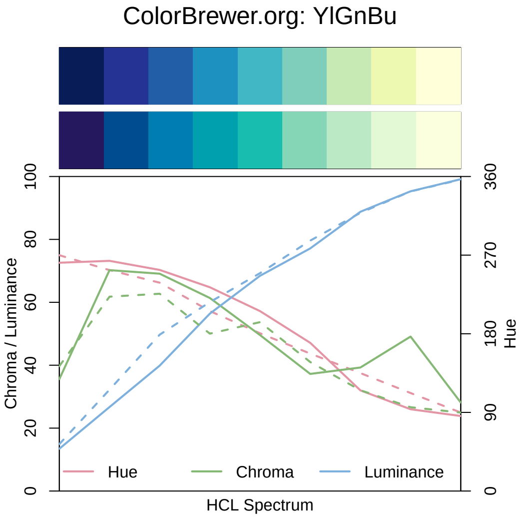


Approximations of other palettes



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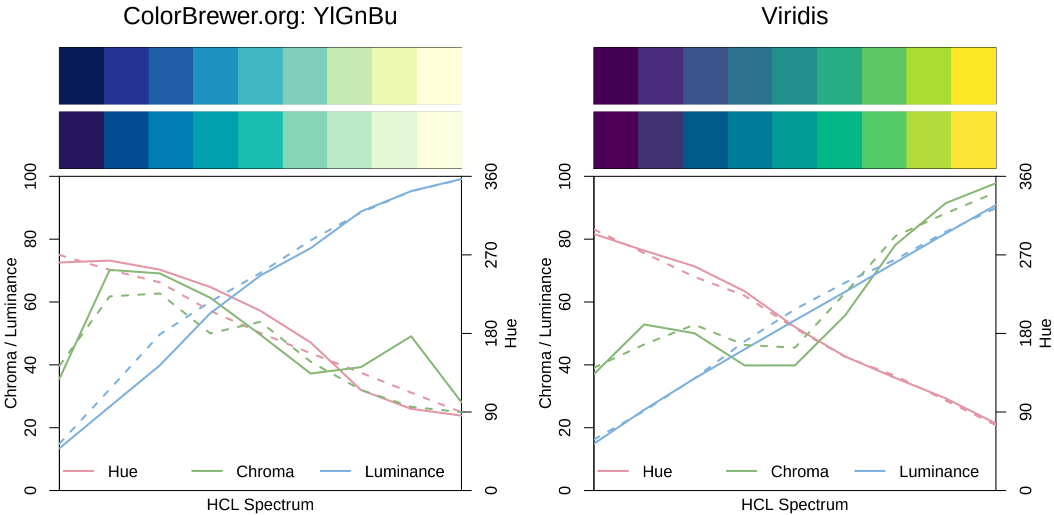


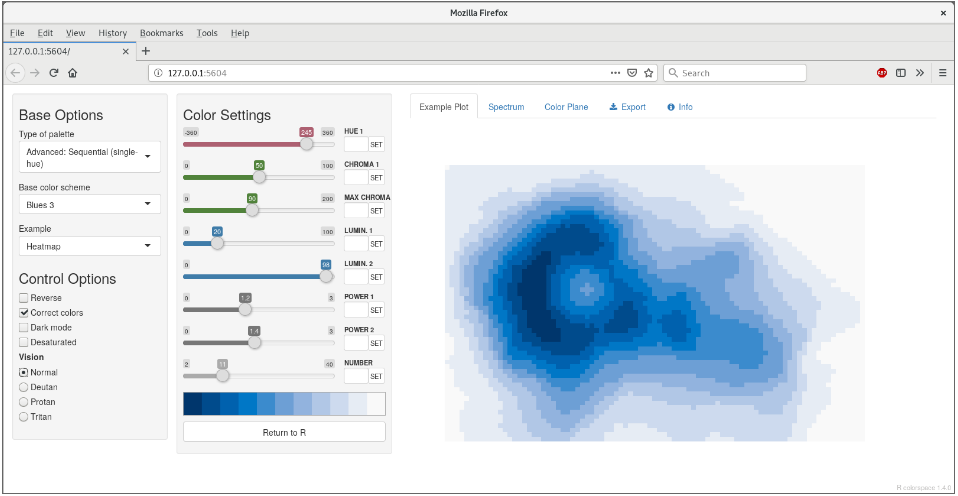
Color apps

Facilitate exploration: Graphical user interfaces as shiny apps.

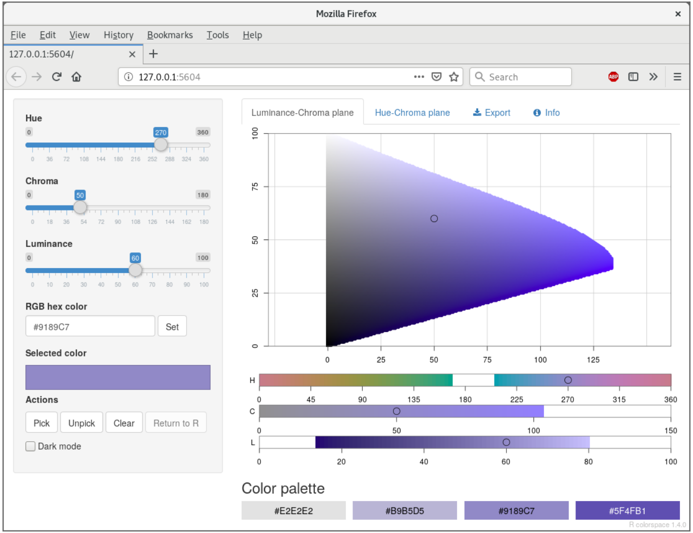
- *Palette constructor:* `choose_palette()` or `hclwizard()` (also in tcltk).
- *Color picker:* `choose_color()` or `hcl_color_picker()`.
- *Color vision deficiency emulator:* `cvd_emulator()`.

Online versions: `http://hclwizard.org/`

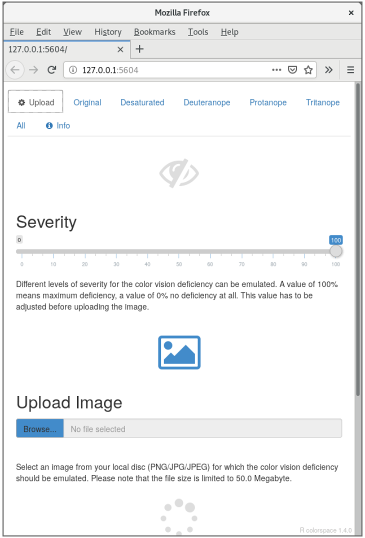
Color apps: `choose_palette()` / `hclwizard()`

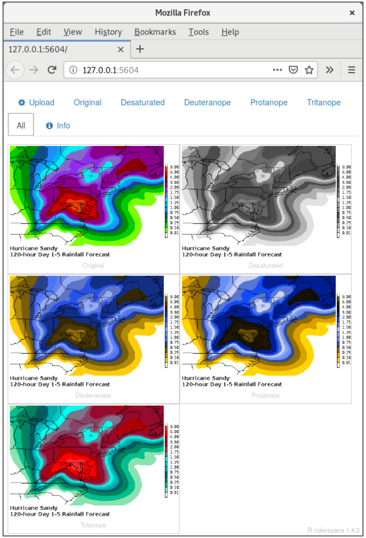


Color apps: `choose_color()` / `hcl_color_picker()`



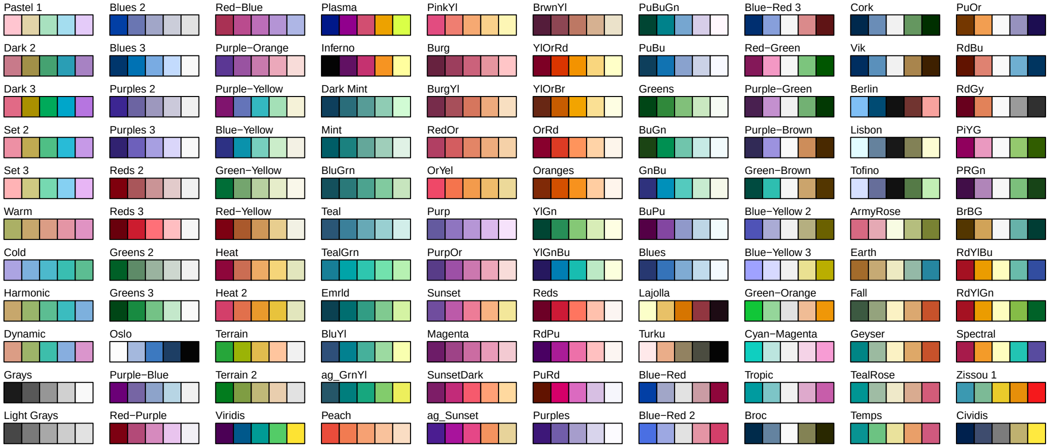
Color apps: `cvd_emulator()`





Base R

In 3.6.0: All prespecified palettes also via `grDevices::hcl.colors()`.



Base R: Why you might not need our package after all

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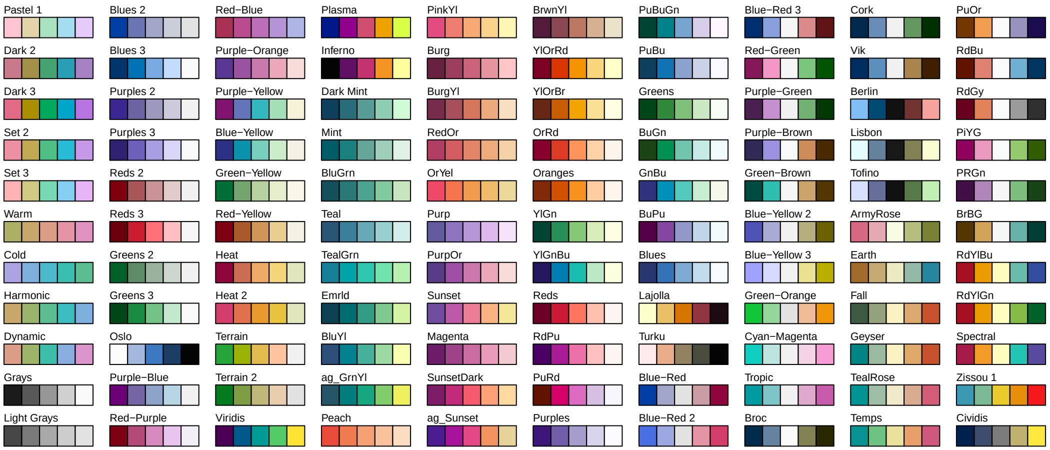

Recommendations

Colors and palettes:

- Do not overestimate the effectiveness of color.
- Choose type of palette based on the data to be visualized.
- For areas use light colors (higher luminance, lower chroma).
- For points/lines darker colors are needed (lower luminance, higher chroma).
- For palettes with more colors stronger luminance contrasts are needed.
- Triangular chroma trajectories useful for distinguishing central colors.

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R packages:

- *colorspace* facilitates exploration, manipulation, and assessment.
- HCL approximations of palettes from *RColorBrewer*, *rcartocolor*, *scico*, . . .
- Prespecified palettes are also easily available in base R.

References

Zeileis A, Fisher JC, Hornik K, Ihaka R, McWhite CD, Murrell P, Stauffer R, Wilke CO (2019). “colorspace: A Toolbox for Manipulating and Assessing Colors and Palettes.” arXiv:1903.06490, arXiv.org E-Print Archive. `http://arxiv.org/abs/1903.06490`

Zeileis A, Hornik K, Murrell P (2009). “Escaping RGBland: Selecting Colors for Statistical Graphics.” *Computational Statistics & Data Analysis*, **53**, 3259–3270. `doi:10.1016/j.csda.2008.11.033`.

Stauffer R, Mayr GJ, Dabernig M, Zeileis A (2015). “Somewhere over the Rainbow: How to Make Effective Use of Colors in Meteorological Visualizations.” *Bulletin of the American Meteorological Society*, **96**(2), 203–216. `doi:10.1175/BAMS-D-13-00155.1`