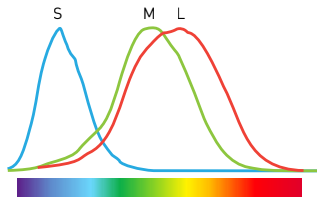
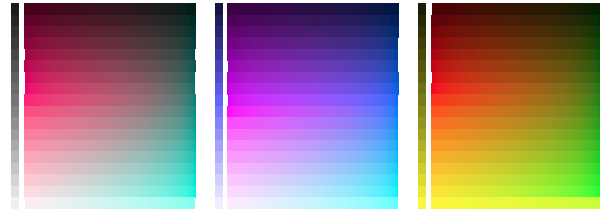
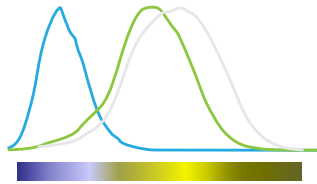


# PHENOMENON OF COLOR BLINDNESS

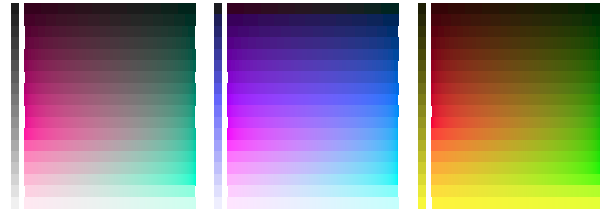
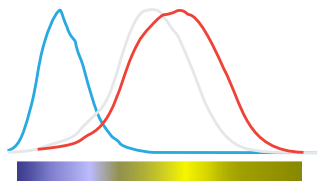
## NORMAL VISION



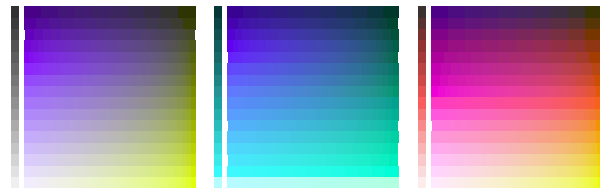
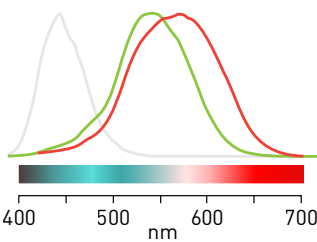
## PROTANOPIA



## DEUTERANOPIA



## TRITANOPIA



# INDISTINGUISHABLE COLORS IN COLOR BLINDNESS

## PROTANOPIA



## DEUTERANOPIA

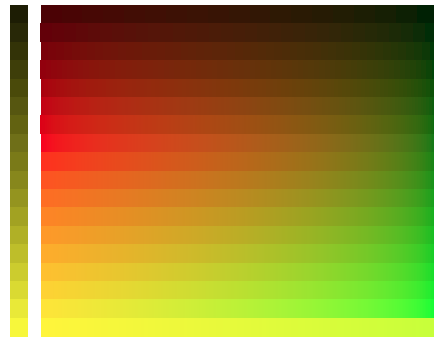
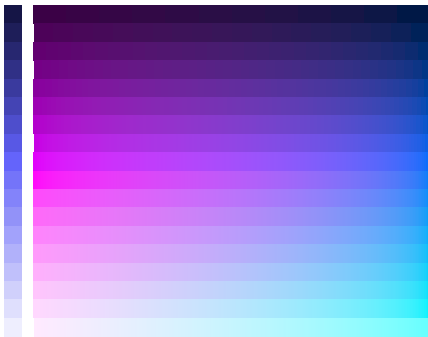
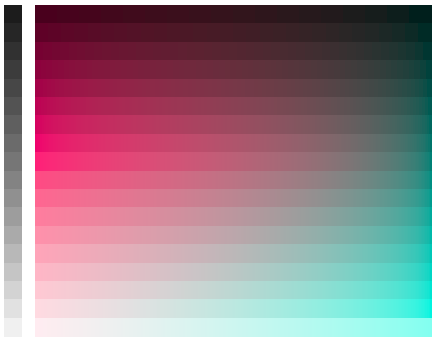


## TRITANOPIA

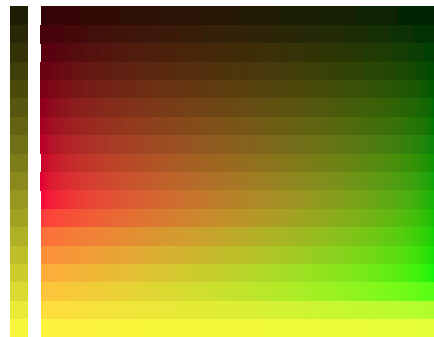
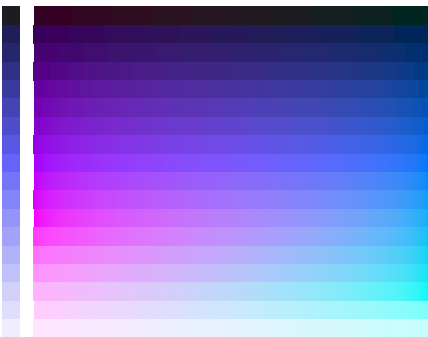
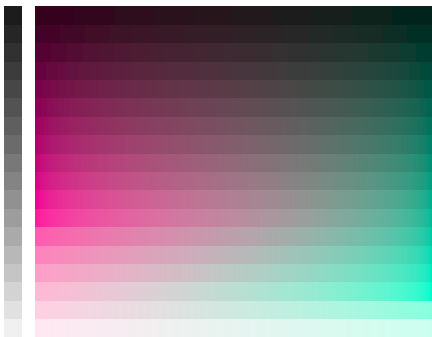


# COLOR EQUIVALENCIES IN COLOR BLINDNESS

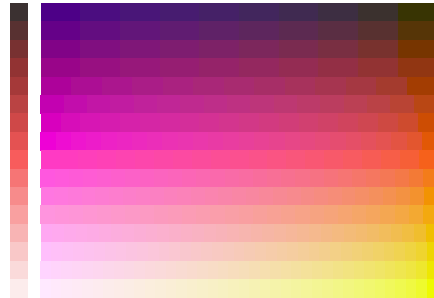
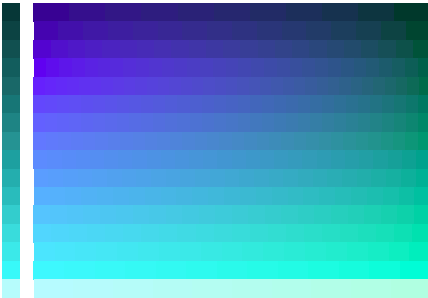
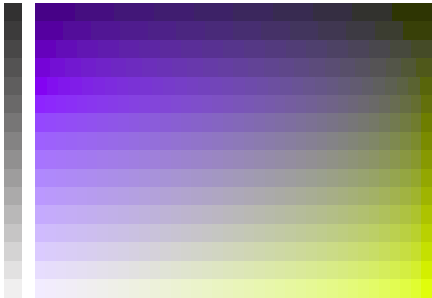
PROTANOPIA









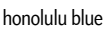





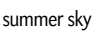





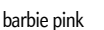





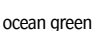

















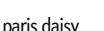


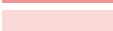
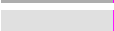
DEUTERANOPIA



TRITANOPIA



# 8-COLOR PALETTE FOR COLOR BLINDNESS

		sRGB	HEX	DEUTERANOPIA	PROTANOPIA	TRITANOPIA	GRAYSCALE
	black	0 0 0	000000				
 <b>1</b>	 honorolulu blue	34 113 178	2271B2	 <b>3</b>	 <b>4</b>		
 <b>2</b>	 summer sky	61 183 233	3DB7E9				
 <b>3</b>	 barbie pink	247 72 165	F748A5				
 <b>4</b>	 ocean green	53 155 115	359B73				
 <b>5</b>	 bamboo	213 94 0	D55E00				
 <b>6</b>	 gamboge	230 159 0	E69F00				
 <b>7</b>	 paris daisy	240 228 66	F0E442				

**1** palette swatch

**2** alternative swatch indistinguishable for deuteranopes

**3** simulation of swatch

**4** all alternatives for swatch

19 May 2020 <http://mkweb.bcgsc.ca/colorblind>

Adapted from Wong, B. (2011) Points of View: Color blindness. *Nature Methods* 8:441.

# 12-COLOR PALETTE FOR COLOR BLINDNESS

	sRGB	HEX	DEUTERANOPIA	PROTANOPIA	TRITANOPIA	GRAYSCALE
<b>1</b> <b>2</b> jazzberry jam	159 1 98	9F0162	<b>3</b> <b>4</b>			
<b>2</b> jeepers creepers	0 159 129	009F81				
<b>2</b> barbie pink	255 90 175	FF5AAF				
<b>2</b> aquamarine	0 252 207	00FCCF				
<b>2</b> french violet	132 0 205	8400CD				
<b>2</b> dodger blue	0 141 249	008DF9				
<b>2</b> capri	0 194 249	00C2F9				
<b>2</b> plum	255 178 253	FFB2FD				
<b>2</b> carmine	164 1 34	A40122				
<b>2</b> alizarin crimson	226 1 52	E20134				
<b>2</b> outrageous orange	255 110 58	FF6E3A				
<b>2</b> bright spark	255 195 59	FFC33B				























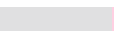

















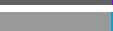







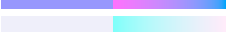

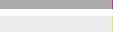




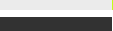




















**1** palette swatch

**2** alternative swatch indistinguishable for deuteranopes

**3** simulation of swatch

**4** all alternatives for swatch

# 15-COLOR PALETTE FOR COLOR BLINDNESS

	sRGB	HEX	DEUTERANOPIA	PROTANOPIA	TRITANOPIA	GRAYSCALE
 tyrian purple	104 2 63	68023F	 			
 deep sea	0 129 105	008169				
 persian rose	239 0 150	EF0096				
 aquamarine	0 220 181	00DCB5				
 azalea	255 207 226	FFCFE2				
 congress blue	0 60 134	003C86				
 veronica	148 0 230	9400E6				
 bleu de france	0 159 250	009FFA				
 shocking pink	255 113 253	FF71FD				
 electric blue	124 255 250	7CFFFA				
 rosewood	106 2 19	6A0213				
 india green	0 134 7	008607				
 tractor red	246 2 57	F60239				
 radioactive green	0 227 7	00E307				
 gargoyle gas	255 220 61	FFDC3D				

- 1 palette swatch
- 2 alternative swatch indistinguishable for deuteranopes
- 3 simulation of swatch
- 4 all alternatives for swatch

# 24-COLOR PALETTE FOR COLOR BLINDNESS

		sRGB		HEX			sRGB		HEX	DEUTERANOPIA		PROTANOPIA		GRAYSCALE	
<b>1</b>	mulberry	86	1	51	560133	<b>2</b>	sherwood green	0	61	48	003D30	<b>3</b>	<b>4</b>		
	french plum	121	1	73	790149		deep opal	0	87	69	005745				
	jazzberry jam	159	1	98	9F0162		robin hood	0	115	92	00735C				
	magenta	199	0	124	C7007C		elf green	0	145	117	009175				
	persian rose	239	0	150	EF0096		jeepers creepers	0	175	142	00AF8E				
	barbie pink	255	90	175	FF5AAF		aquamarine	0	203	167	00CBA7				
	amaranth pink	255	157	200	FF9DC8		vivid opal	0	235	193	00EBC1				
	azalea	255	207	226	FFCFE2		light turquoise	134	255	222	86FFDE				
	christalle	69	2	112	450270		madison	0	48	111	00306F				
	purple heart	101	1	159	65019F		tory blue	0	72	158	00489E				
	french violet	132	0	205	8400CD		royal blue	0	95	204	005FCC				
	electric purple	167	0	252	A700FC		azure	0	121	250	0079FA				
	psychedelic purple	218	0	253	DA00FD		bleu de france	0	159	250	009FFA				
	fuchsia	255	60	254	FF3CFE		capri	0	194	249	00C2F9				
	violet	255	146	253	FF92FD		aqua blue	0	229	248	00E5F8				
	pale mauve	255	204	254	FFCCFE		electric blue	124	255	250	7CFFFA				
	rosewood	90	0	15	5A000F		british racing green	0	64	2	004002				
	hot chile	126	0	24	7E0018		san felix	0	90	1	005A01				
	alabama crimson	164	1	34	A40122		bilbao	0	119	2	007702				
	amaranth red	205	2	45	CD022D		india green	0	149	3	009503				
	carmine	246	2	57	F60239		kelly green	0	180	8	00B408				
	burning orange	255	110	58	FF6E3A		vivid harlequin	0	211	2	00D302				
	frenzee	255	172	59	FFAC3B		radioactive green	0	244	7	00F407				
	gargoyle gas	255	220	61	FFDC3D		lime	175	255	42	AFFF2A				

- 1 palette swatch
- 2 alternative swatch indistinguishable for deuteranopes
- 3 simulation of swatch
- 4 all alternatives for swatch

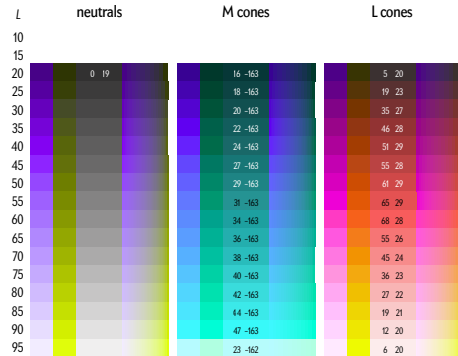
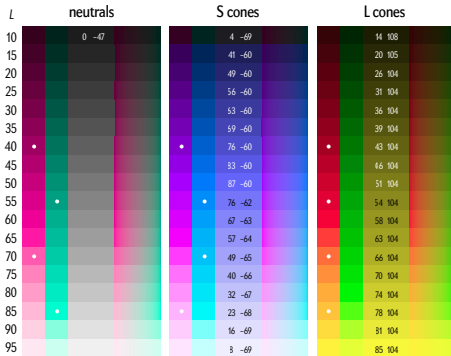
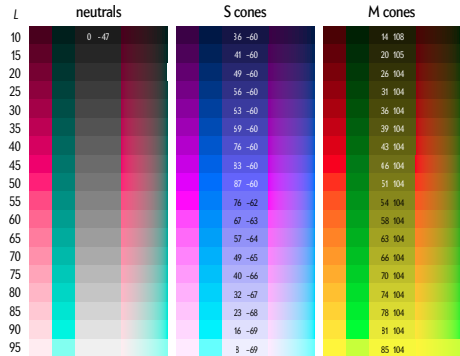
# THE LAST WORD ON COLOR PALETTES FOR COLOR BLINDNESS

<http://mkweb.bcgsc.ca/colorblind>

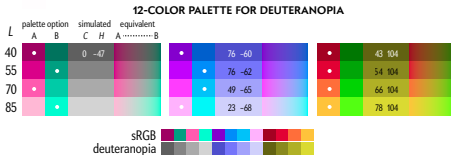
## PROTANOPIA

## DEUTERANOPIA

## TRITANOPIA



For each color blindness type (e.g. deuteranopia) and channel (e.g. S cones), a high-chroma (C) and equal-luminance simulated color ramp (middle swatch) shows the perceived color. Two distinct RGB colors that map to this simulated color are shown to the left of the simulated color and a gradient of all equivalent RGB colors is shown on the right.



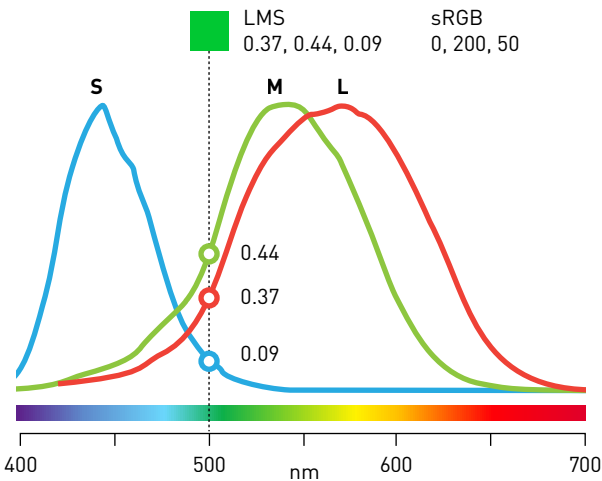
### HOW TO USE

- 1 Pick a color blindness type.
- 2 Pick equally spaced rows from ramps for that type.
- 3 Pick the RGB color from the first or second column.
- 4 The wide swatch in the ramp shows the simulated color.
- 5 The gradient shows all colors that simulate to the same color.



# LMS COLOR SPACE

## NORMAL VISION



Monochromatic light has a unique combination of color receptor stimulation. For example, when the cones are stimulated in a ratio  $(L,M,S) = (0.37, 0.44, 0.09)$ , someone with normal vision will perceive a green color with sRGB = (0, 200, 50).

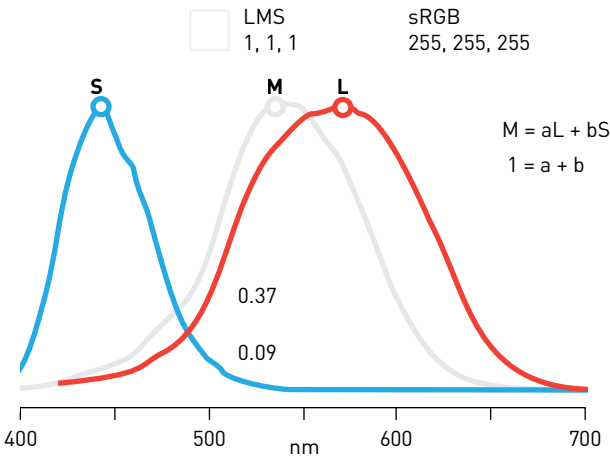
If the M receptors are missing (deuteranopia) it would be intuitive to assume that the M coordinate in this color space is zero. However, if we do this then white with sRGB (255, 255, 255) would be perceived as LMS = (1, 0, 1) which converts to sRGB (255, 0, 255), which is purple. But deuteranopes can distinguish white from purple.



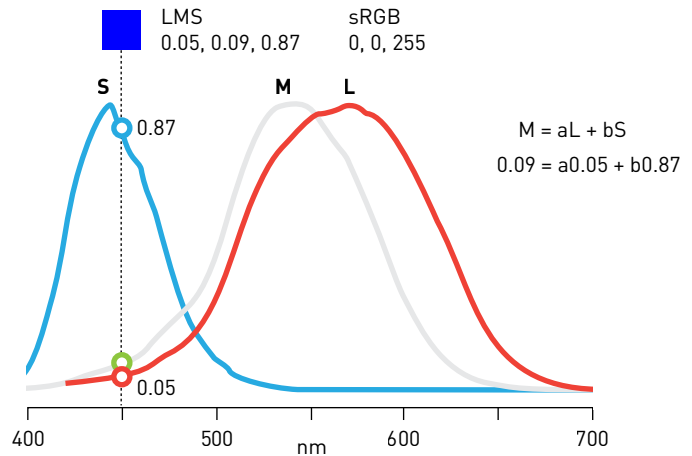
We make the assumption that  $M = aL + bS$ . In other words, the input to M is some combination of L and S. We find the "a" and "b" parameters using two requirements. First, that white has the same LMS coordinate as for normal vision  $LMS = (1, 1, 1)$ .

The second condition is to preserve the appearance of blue, which is far from the range of the M cones. These two requirements impose conditions on the values that "a" and "b" can take and we can solve for them uniquely.

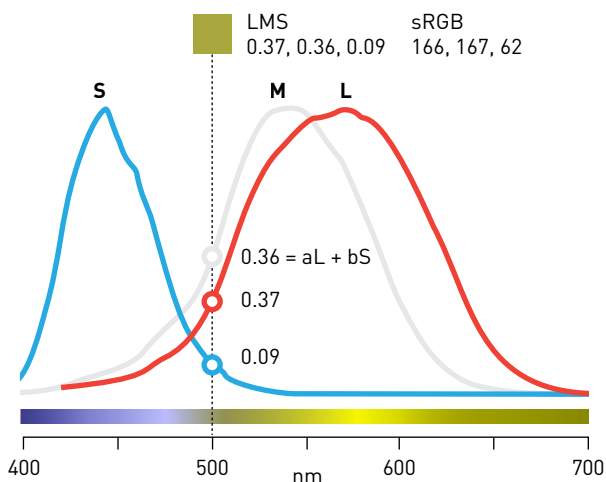
## PRESERVE THE PERCEPTION OF WHITE



## PRESERVE THE PERCEPTION OF BLUE



## DEUTERANOPIA



The equations for a and b are

$$1 = a + b$$

$$0.09 = a*0.05 + b*0.87$$

and solve to

$$a = 0.9513092$$

$$b = 1 - a = 0.04866992$$

Our original green's M coordinate is therefore 0.36 and simulates to sRGB (166, 167, 62).

