

Unidad 3

Modelado del Color y la Iluminación

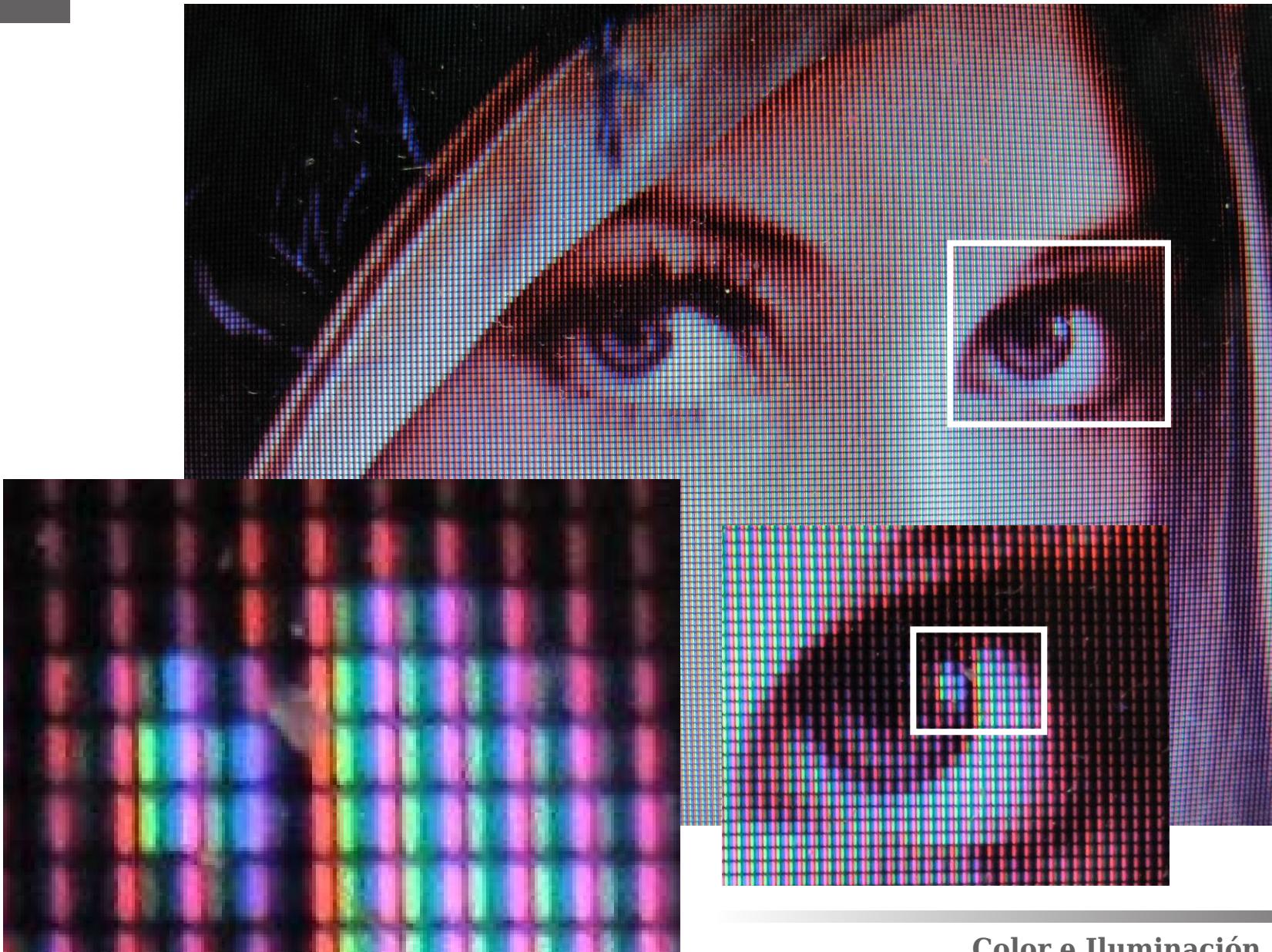


1ra Parte: Color

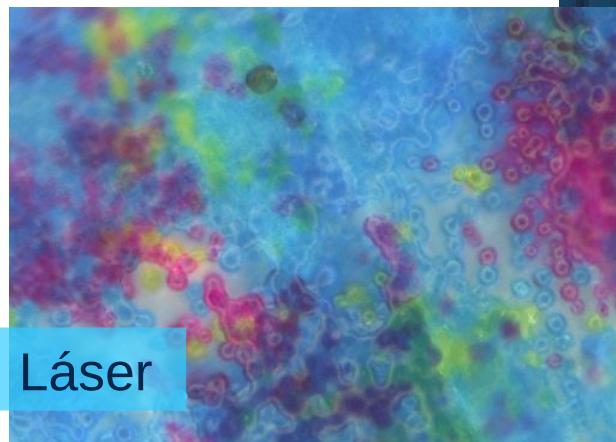
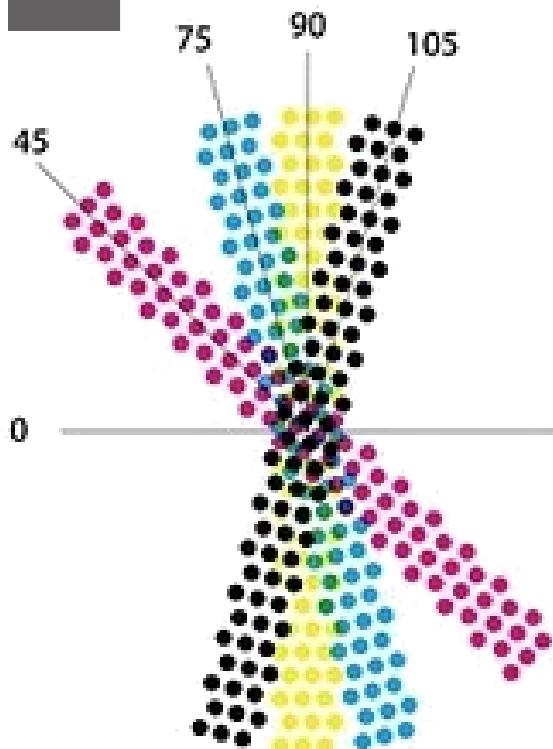


¿Qué es? ¿Cómo se percibe? ¿Cómo se cuantifica el color?

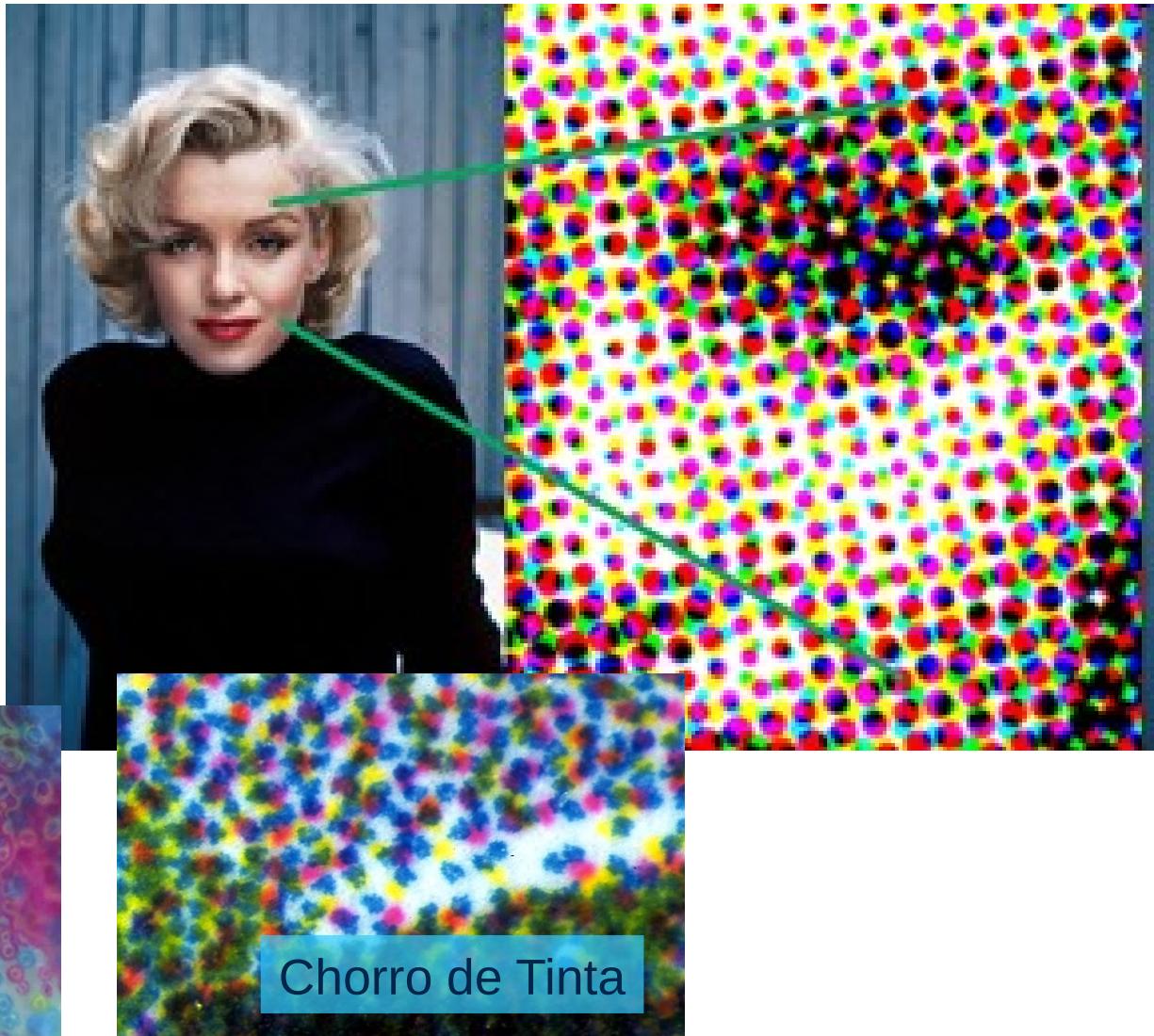
Reproducción: Monitor (RGB)



Reproducción: Impresora (CMY[K])



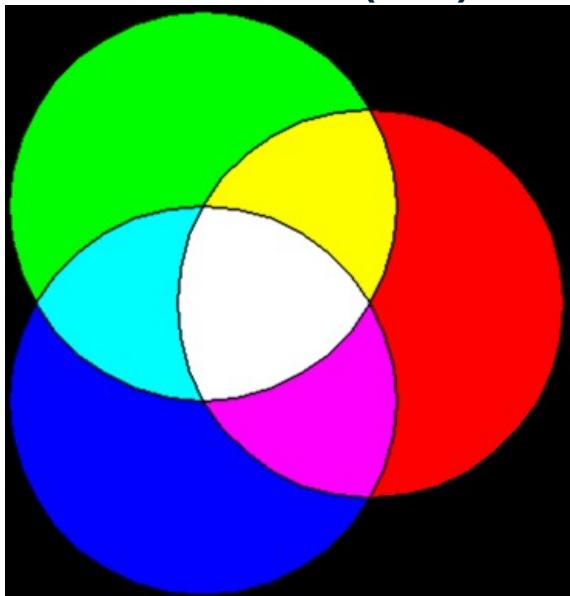
Láser



Chorro de Tinta

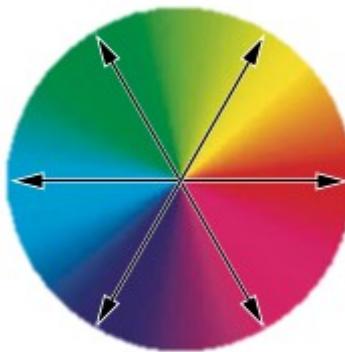
Reproducción: Colores Aditivos y Sustractivos

Colores Aditivos (RGB)

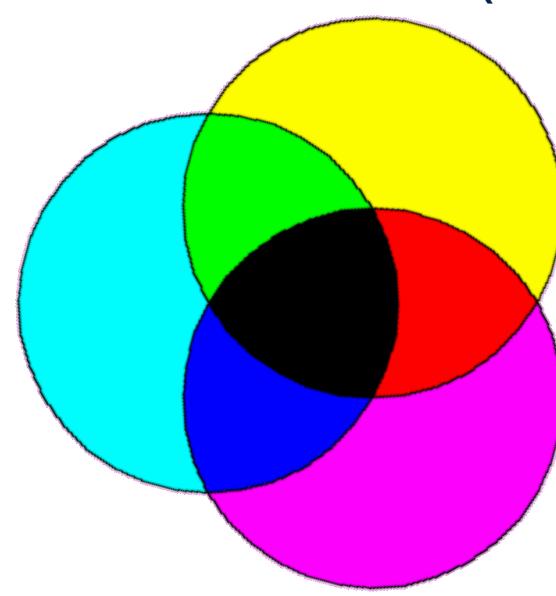


Agregan color (emisores, monitor)

Colores Sustractivos (CMY)



Complementarios



Quitan color (tintas, impresora)

$C = 1-R$ La tinta cian (celeste) absorbe el color rojo

$M = 1-G$ La tinta magenta (fucsia) absorbe el color verde

$Y = 1-B$ La tinta amarilla absorbe el color azul

Los tres colores R,G,B, al máximo emiten todo lo posible $\Rightarrow R+G+B = \text{blanco}$

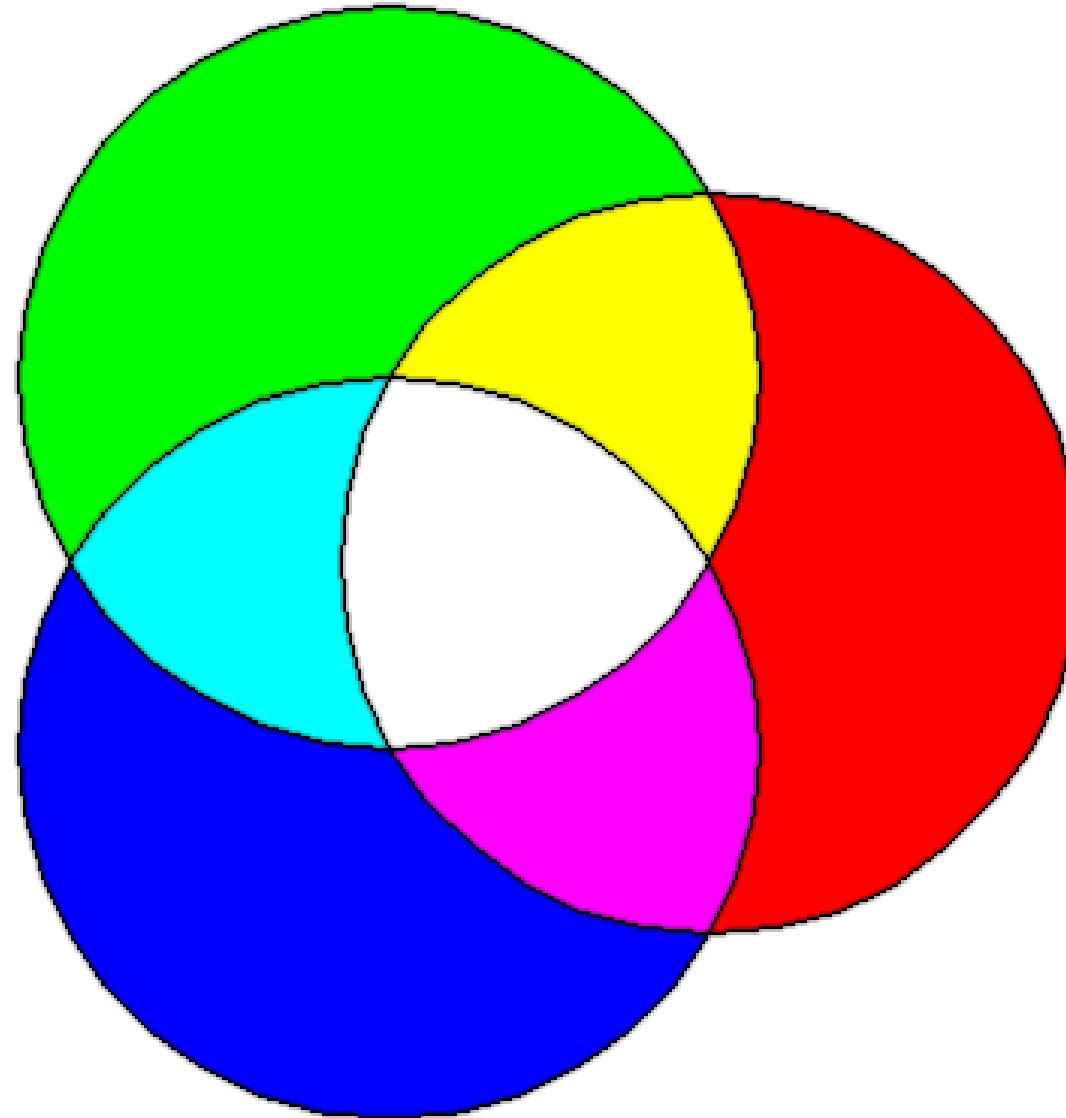
Las tres tintas C,M,Y, al máximo, absorben todo el color $\Rightarrow C+M+Y = \text{negro}$

Las impresoras usan tinta negra más económica $K=\min(C,M,Y)$

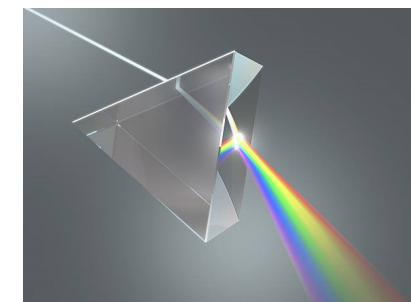
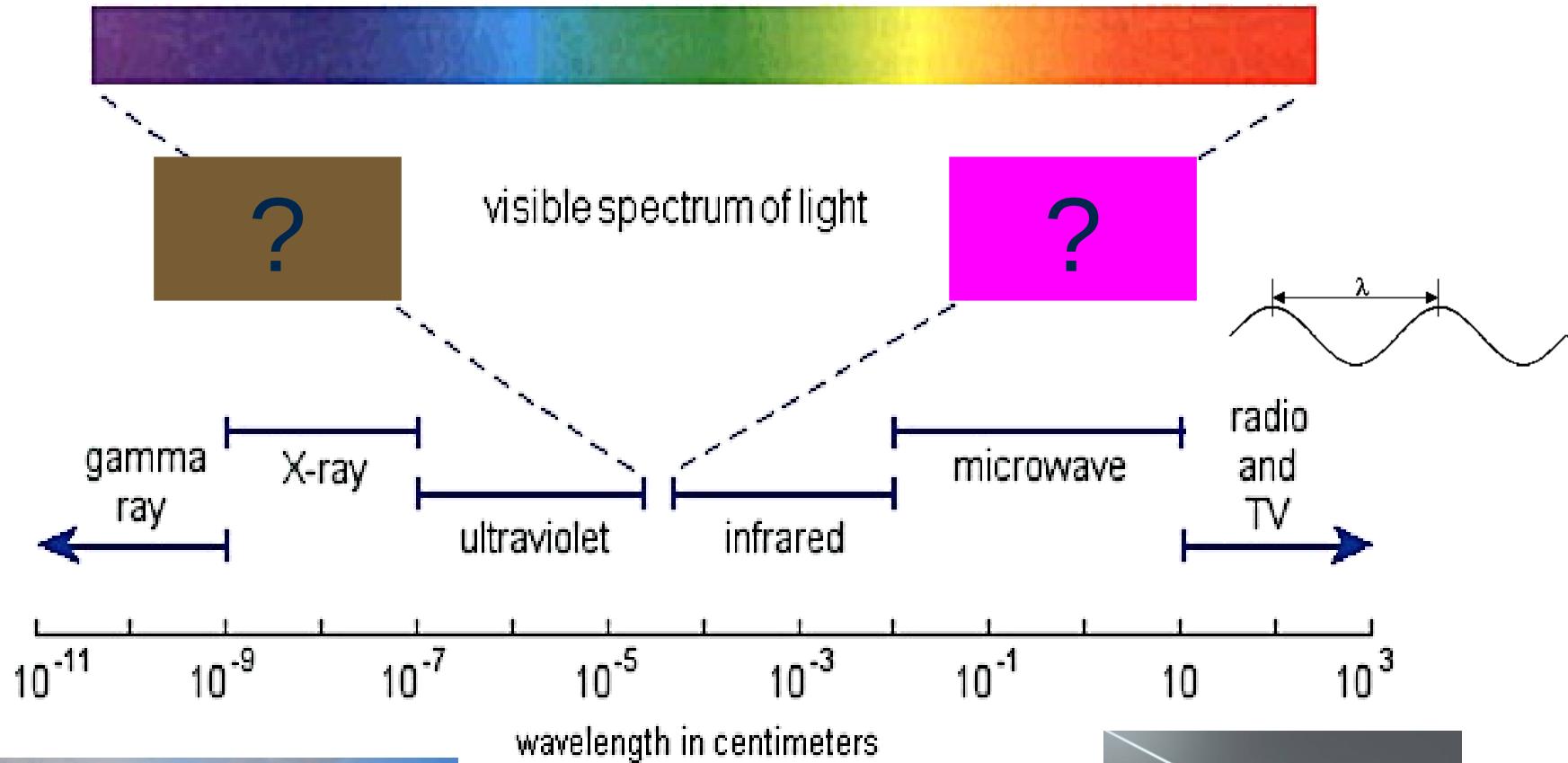
Reproducción: Impresora (CMY[K])



Definición



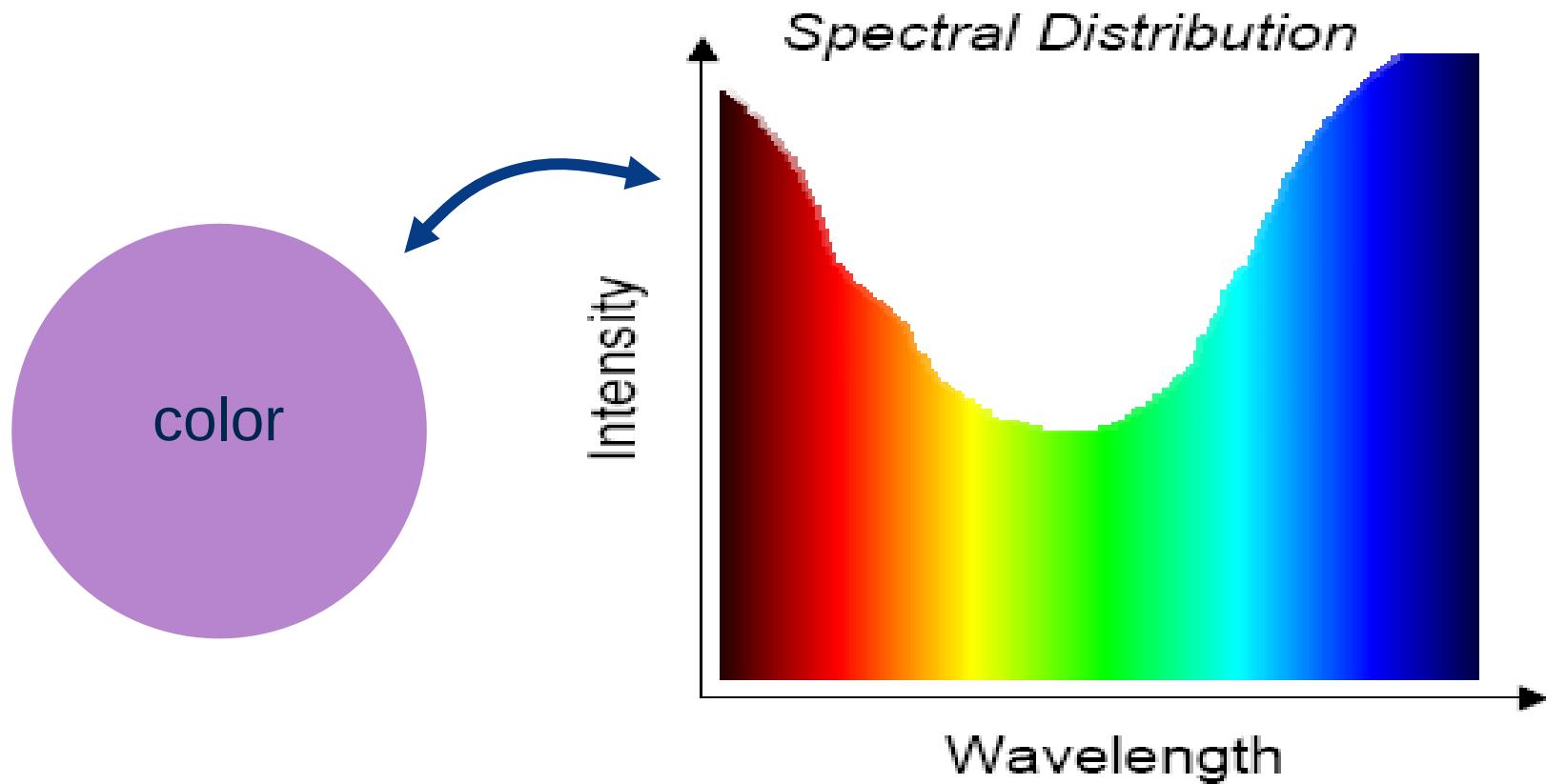
Física del Color



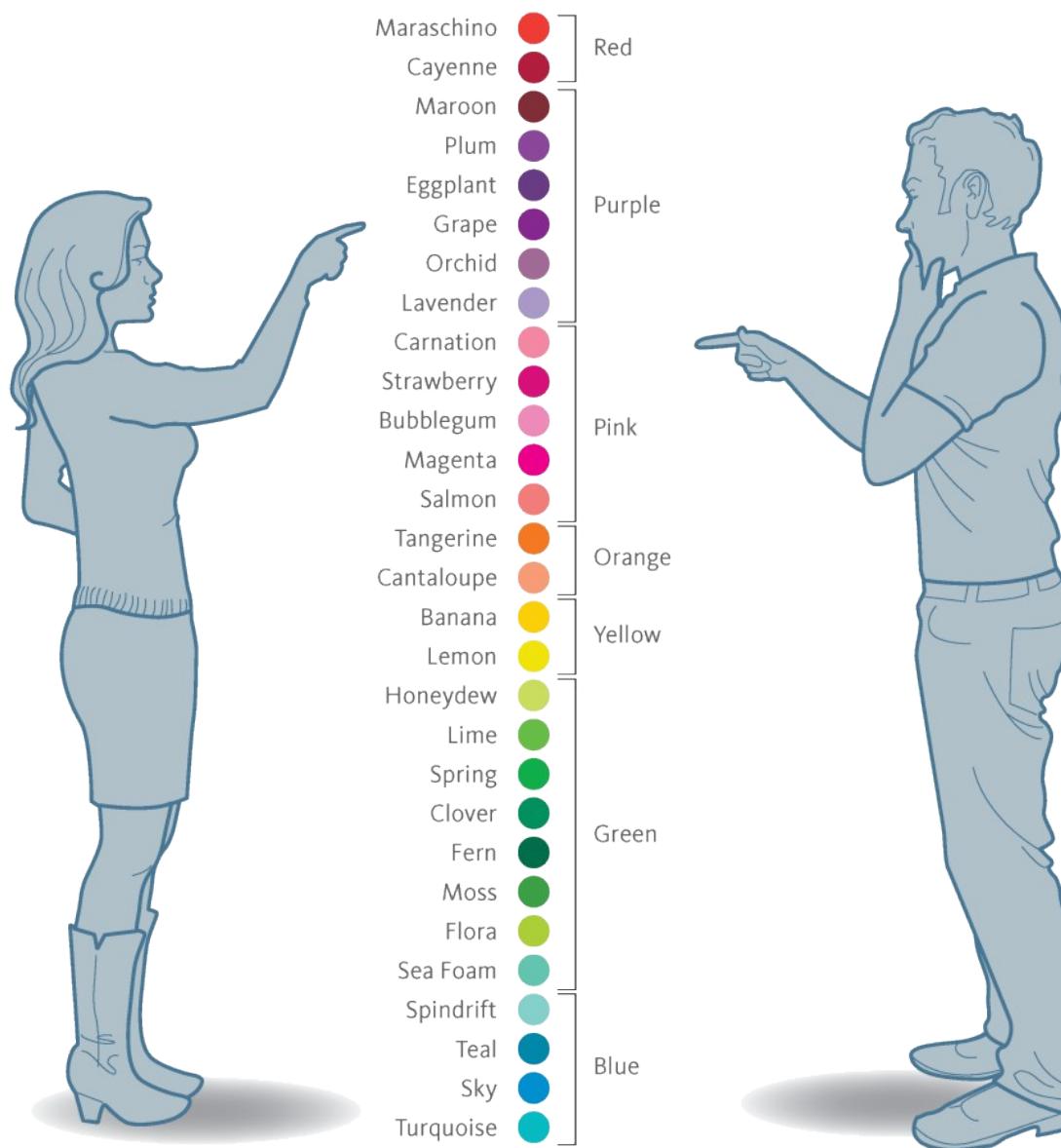
Definición Física de Color

Un color es una distribución o espectro de longitudes de onda electromagnéticas visibles.

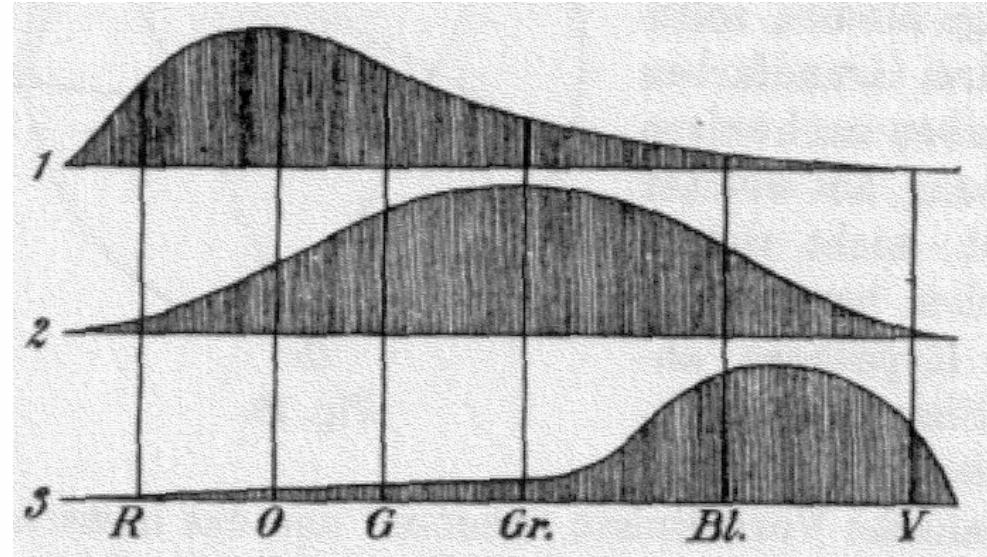
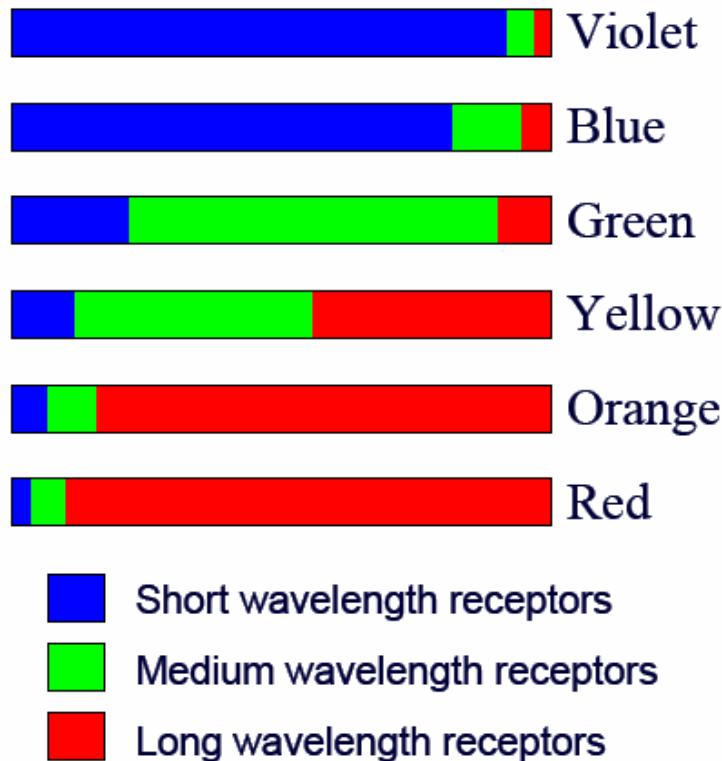
Es una función $I(\lambda)$, no un valor.



Fisiología del Color (color percibido)

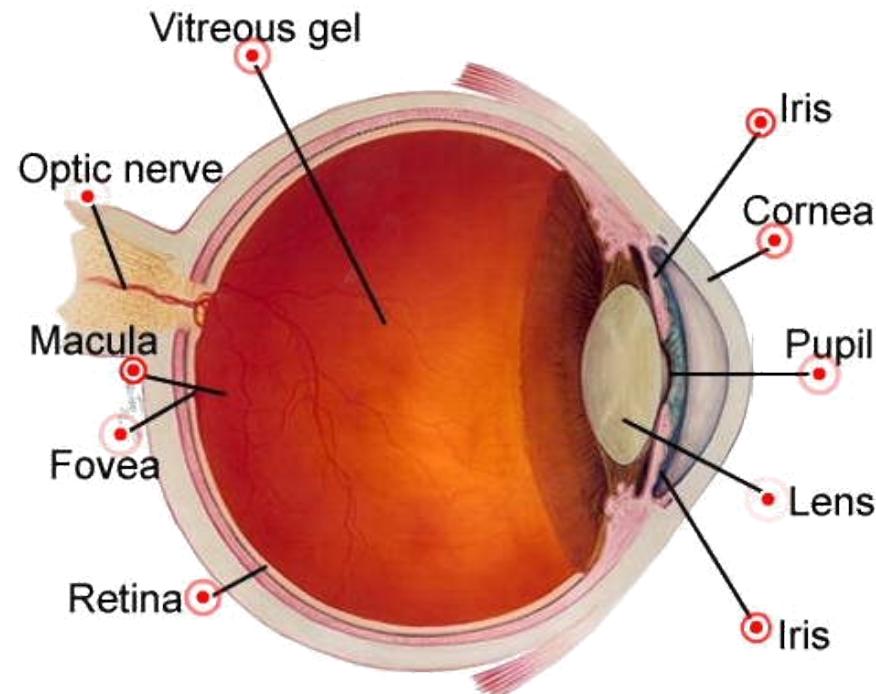
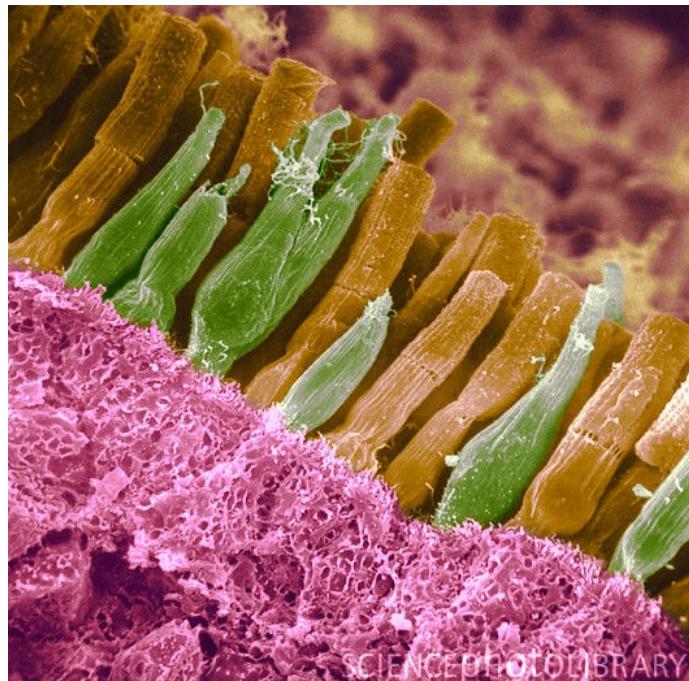
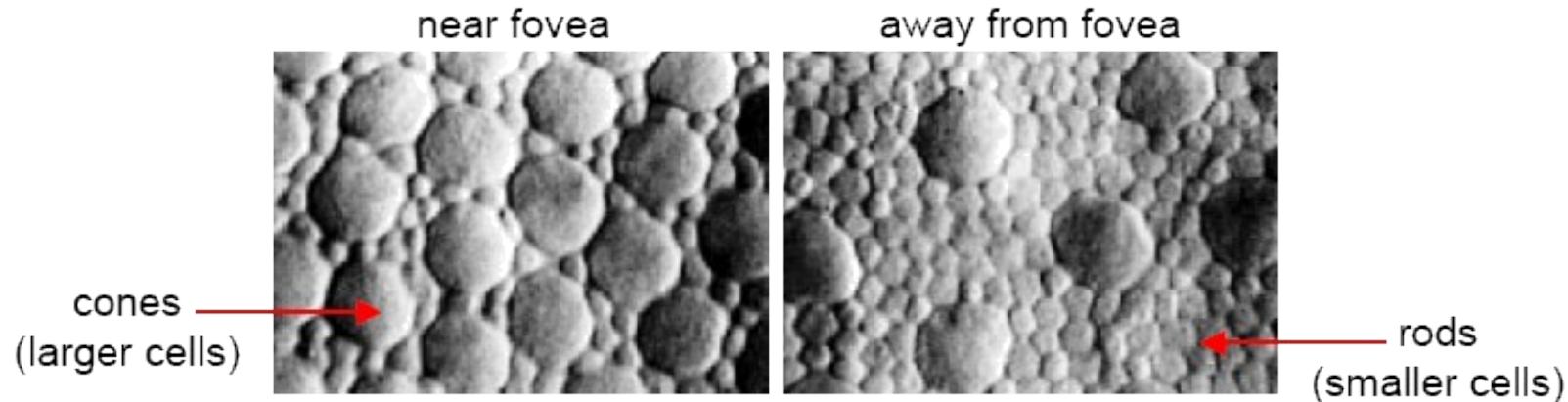


Teoría Tricromática: Young - Helmholtz

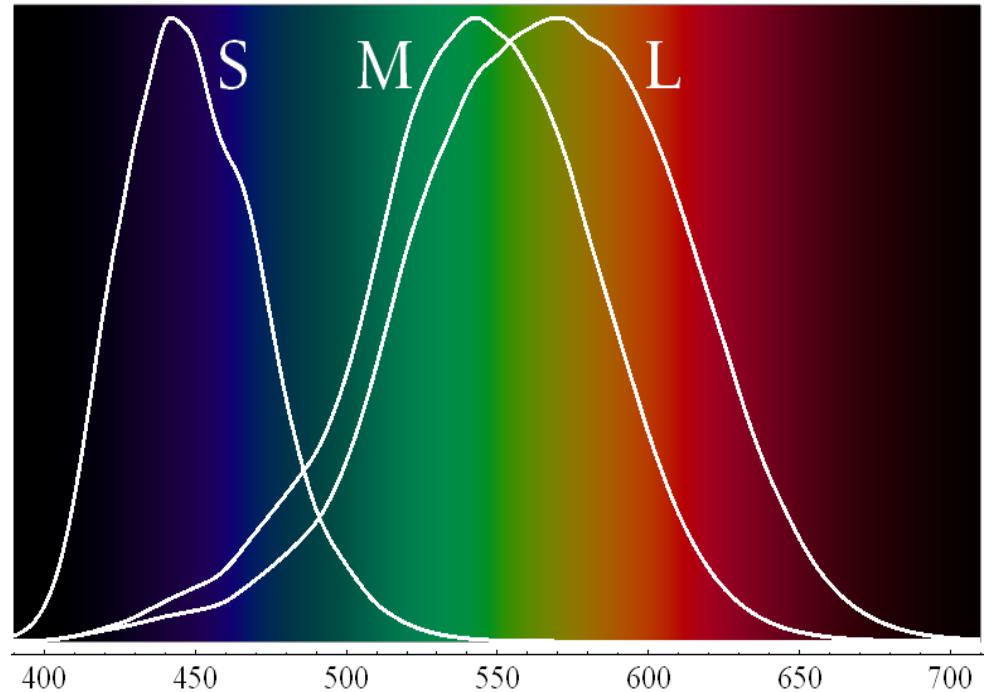
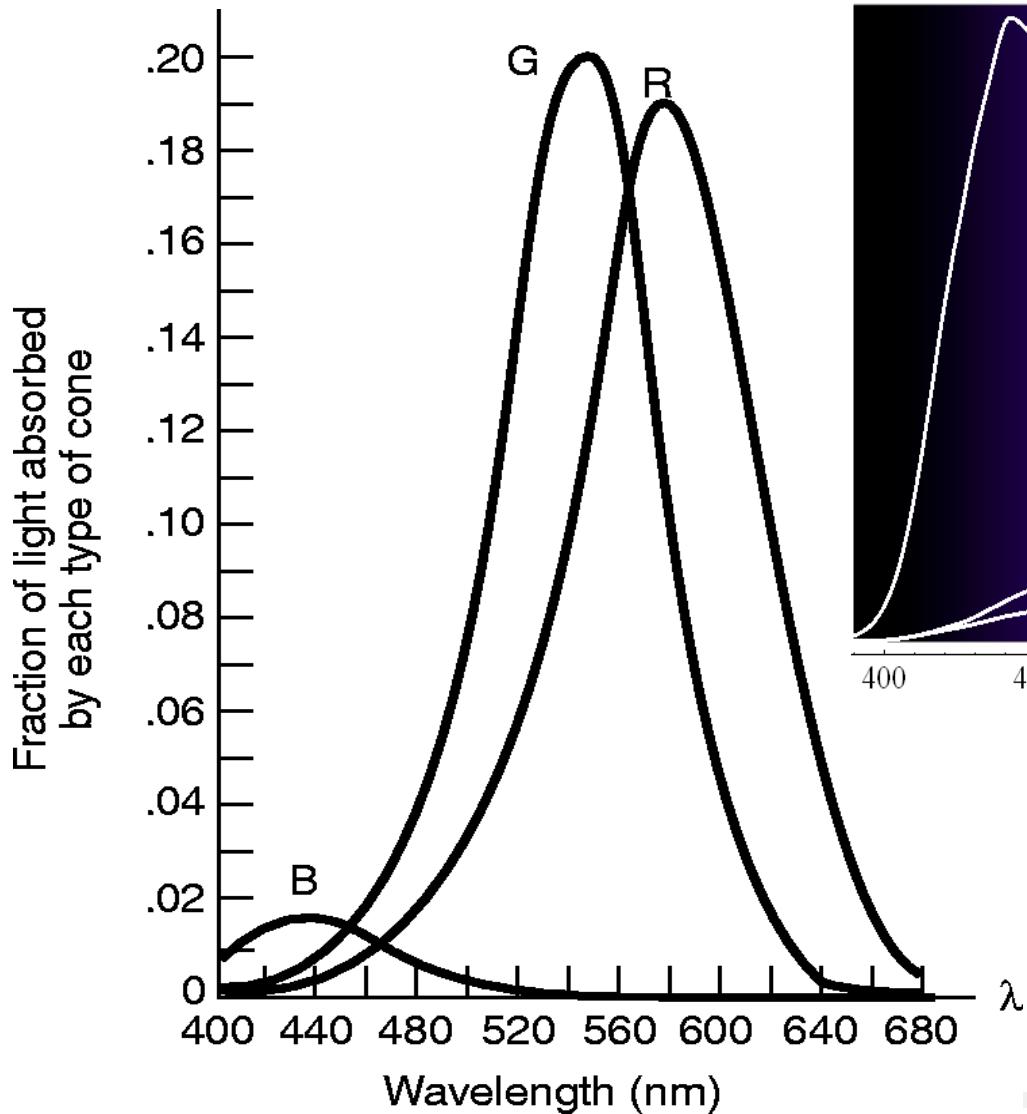


Los colores se perciben de acuerdo a las respuestas relativas de tres tipos de receptores.

Fisiología del Ojo Humano: Conos y Bastones



Tres Tipos Especializados de Conos

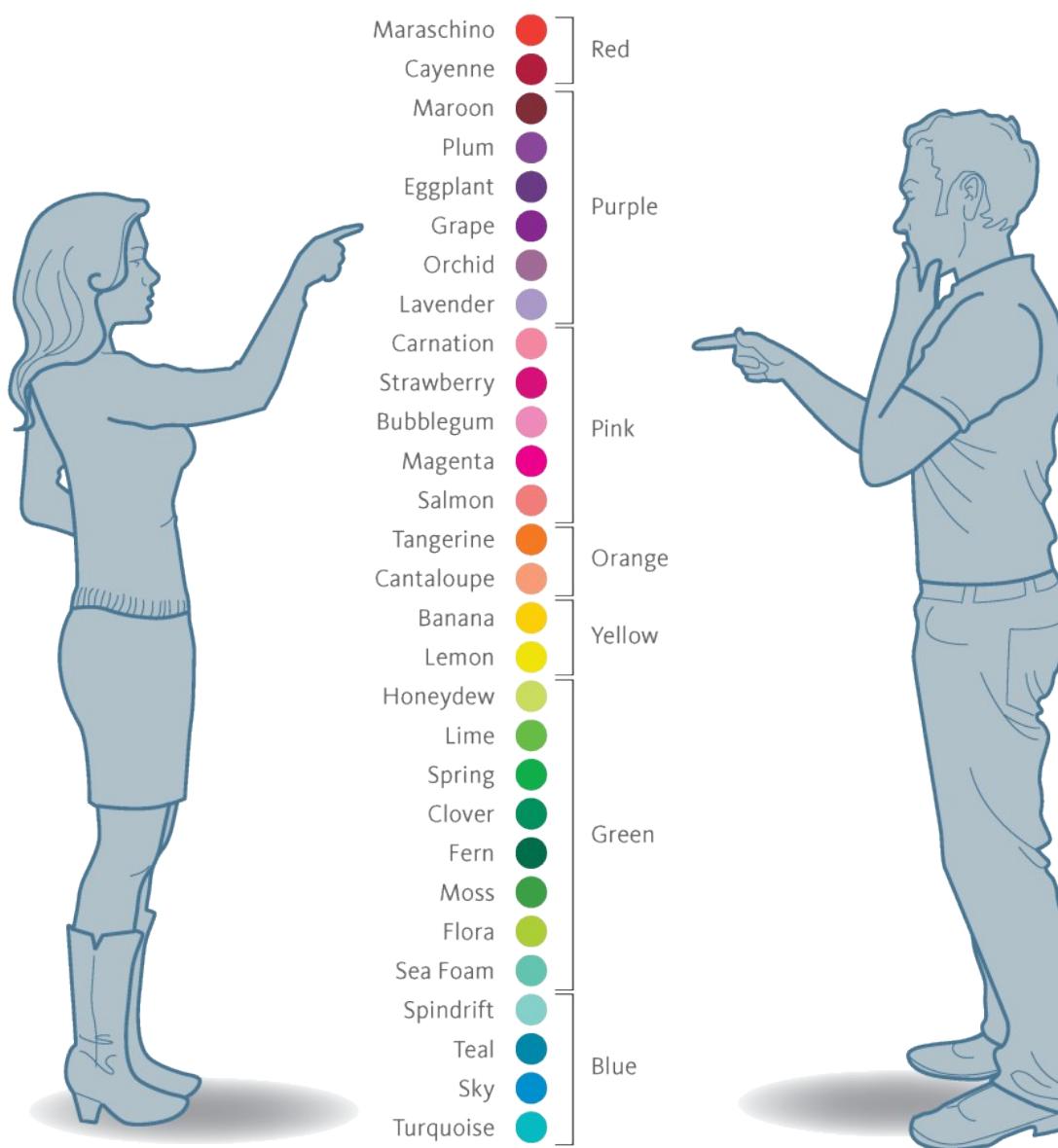


$$I_R = \int I_i A_R d\lambda$$

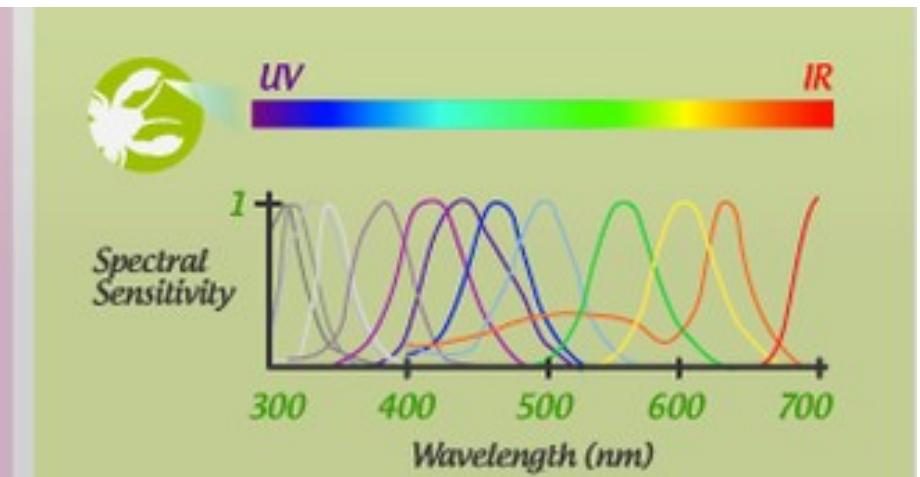
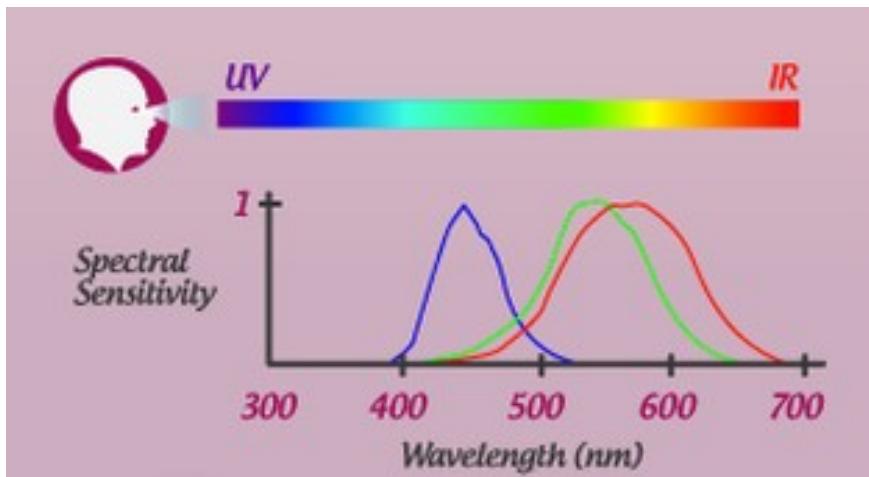
$$I_G = \int I_i A_G d\lambda$$

$$I_B = \int I_i A_B d\lambda$$

Opsinas Codificadas en el Cromosoma X



Humano vs. Mantis Shrimp

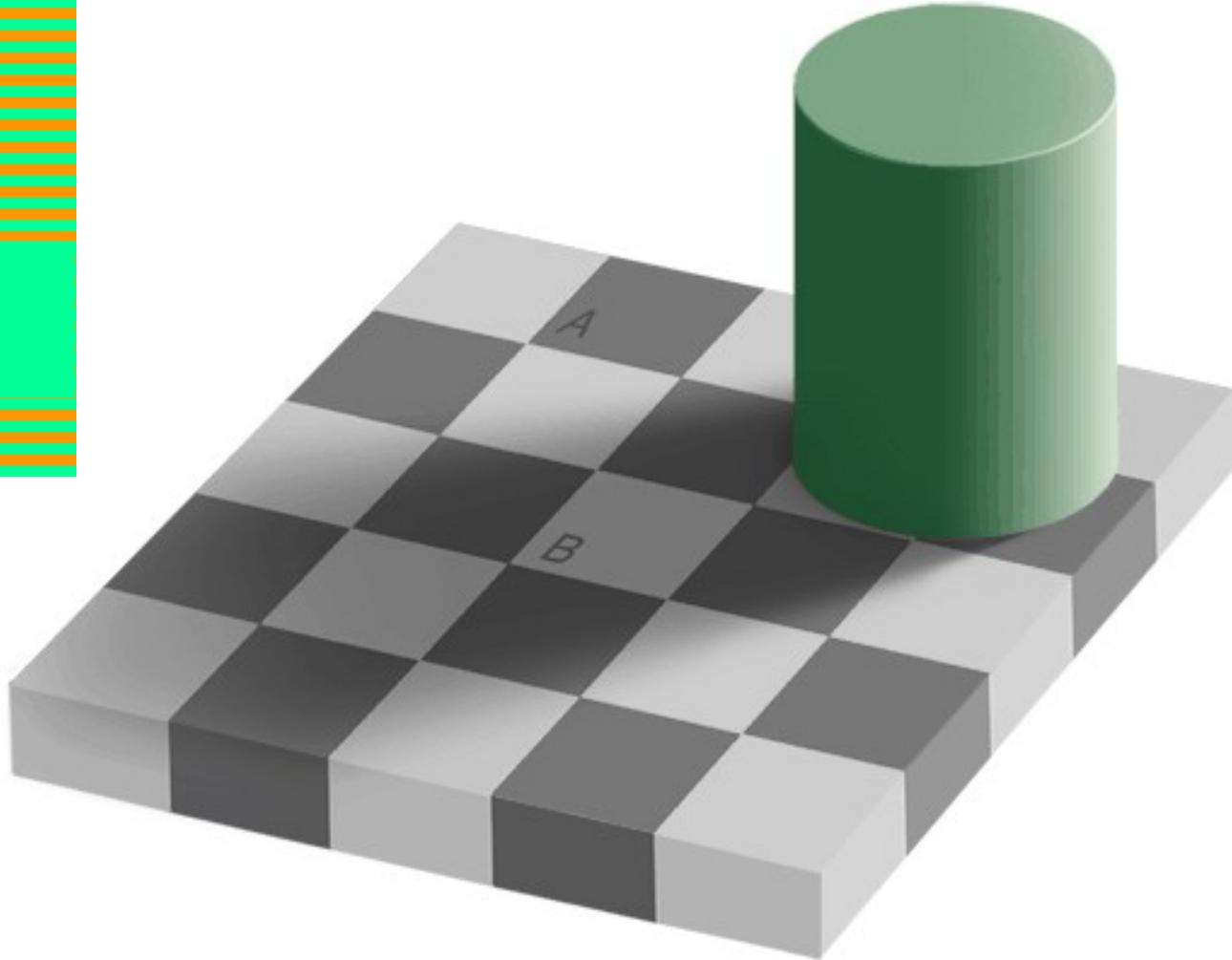
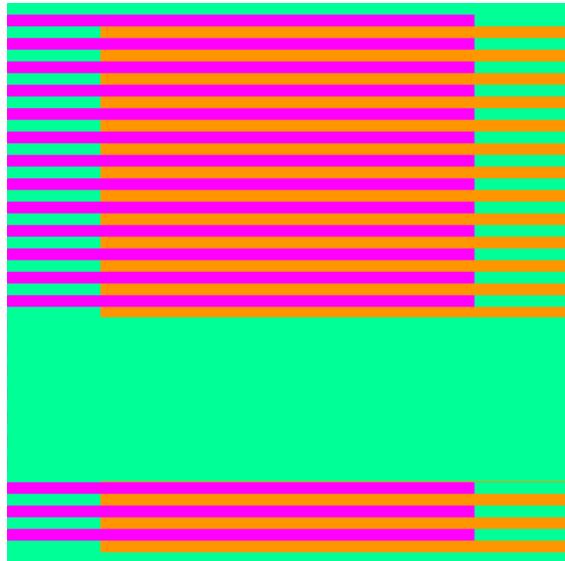


Humano vs. Mantis Shrimp



©Dentist Chef 2013

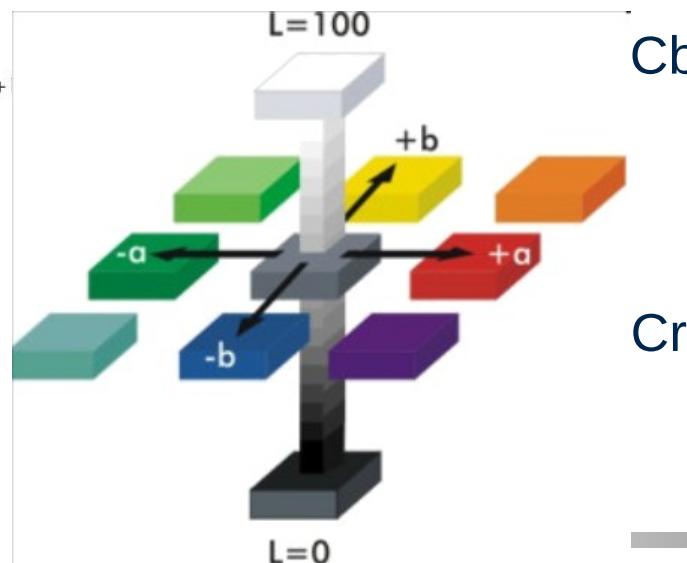
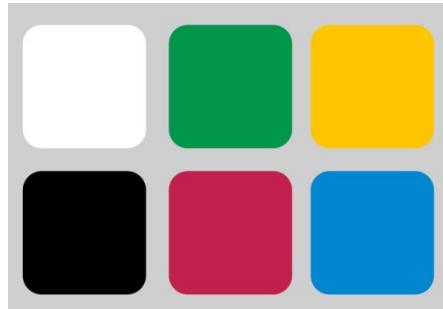
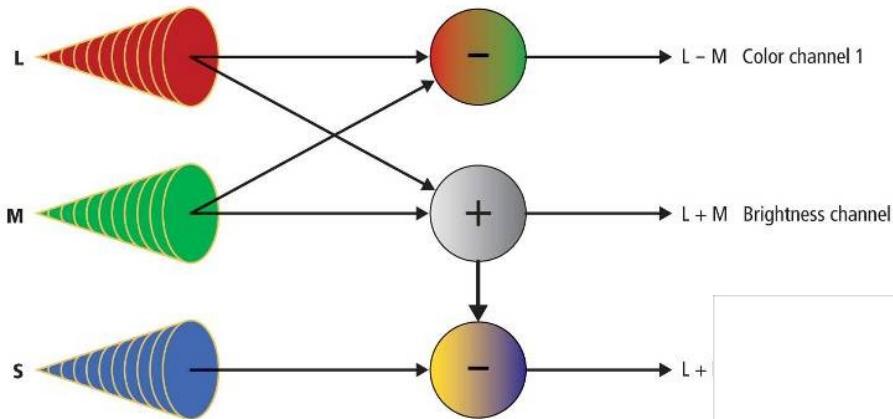
Eso No Es Todo





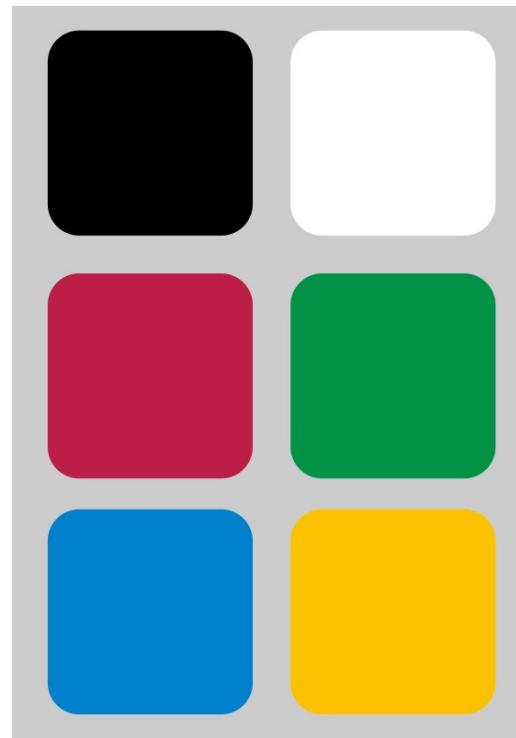
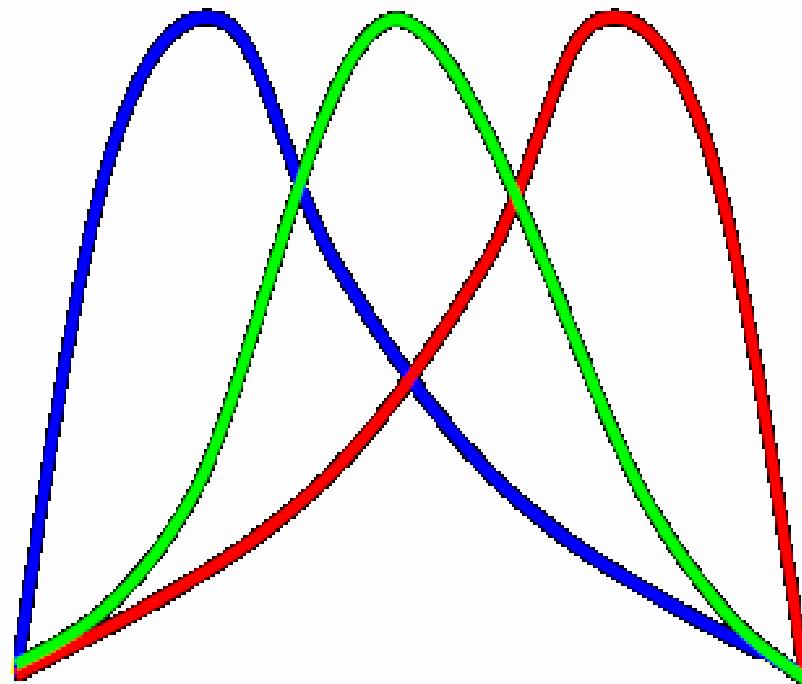
Teoría de Opuestos: Goethe - Hering

- ¿Alguien vió un rojo verdoso o un azul amarillento?
- ¿Cómo se explican los contrastes y las afterimages con la teoría tricromática?



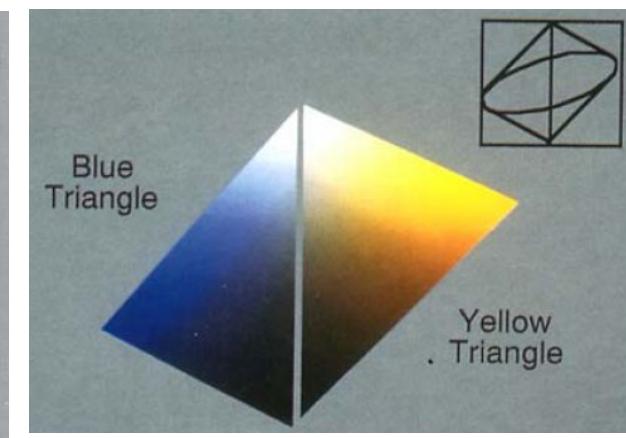
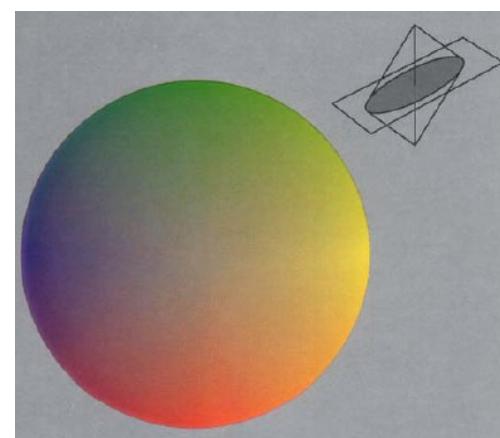
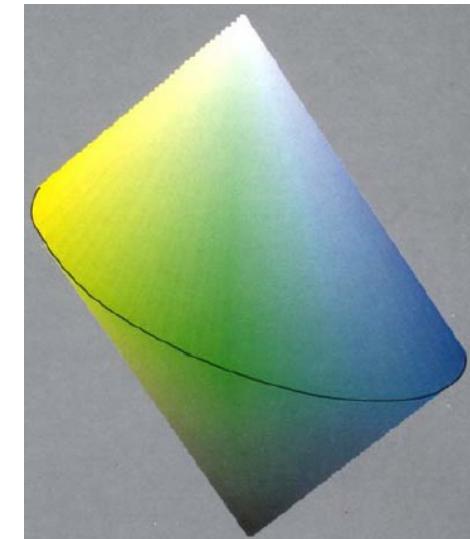
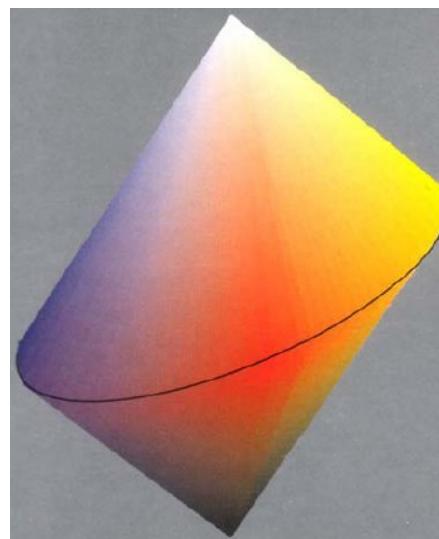
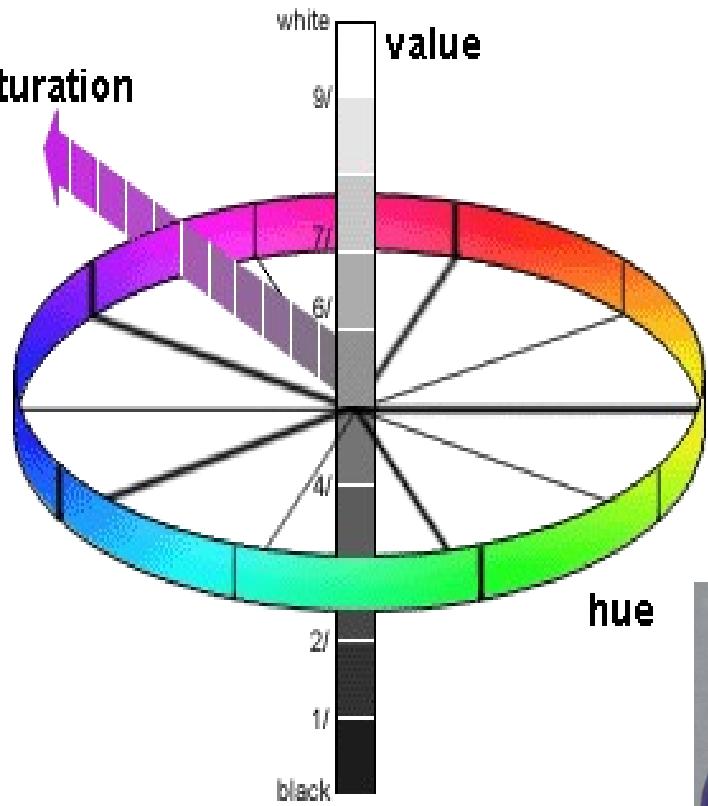
Teoría Dual

Los colores son percibidos de acuerdo a las respuestas relativas de los tres tipos de receptores. Pero se procesan tanto las contribuciones individuales como las sumas y las diferencias. Y de todos modos, eso no es todo...



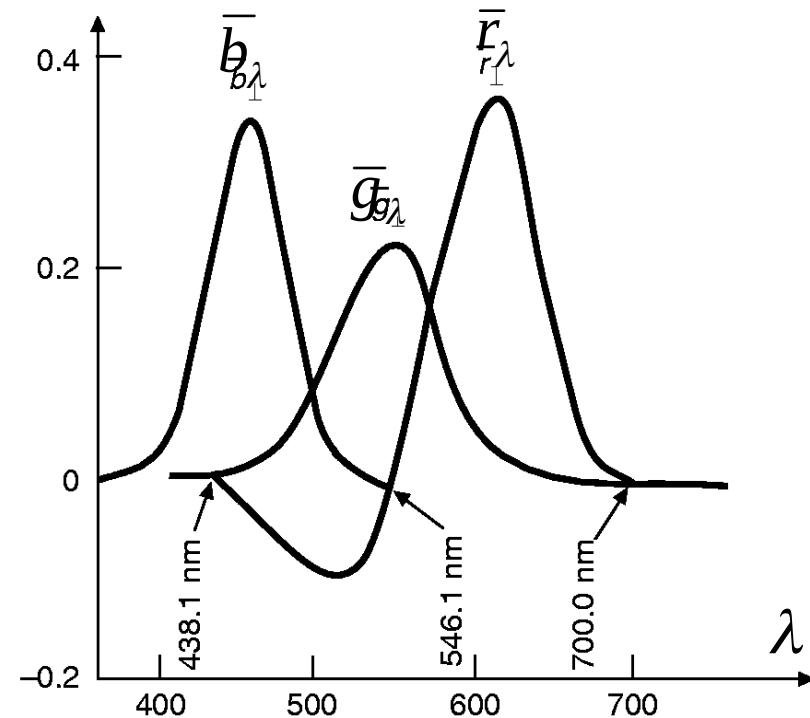
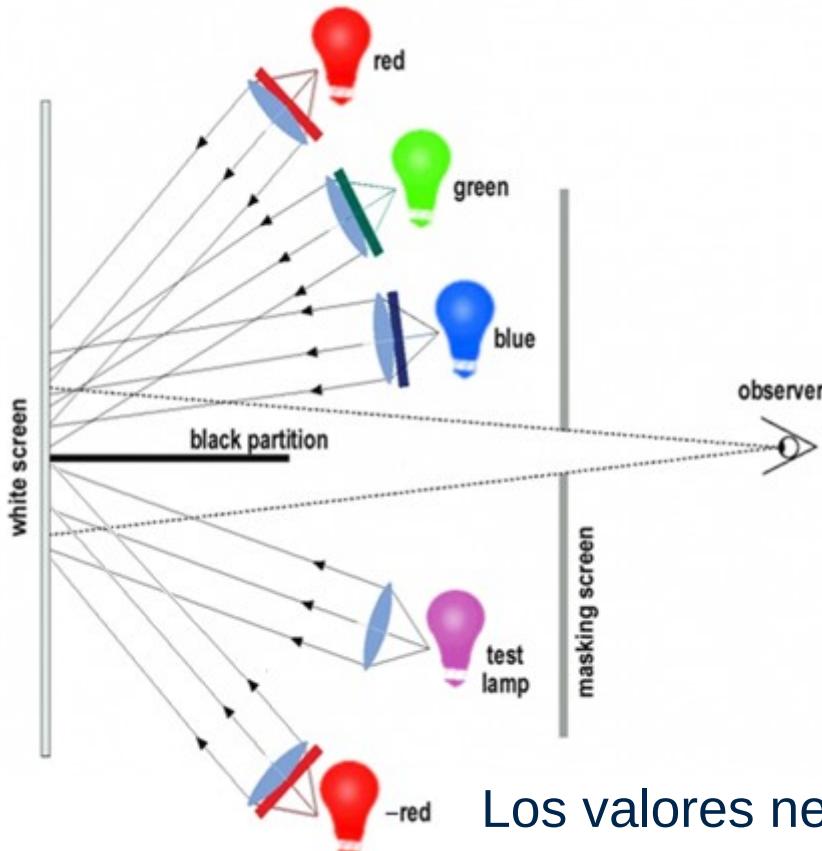
Cuantificación del Color Percibido

saturation



Reproducción del Color

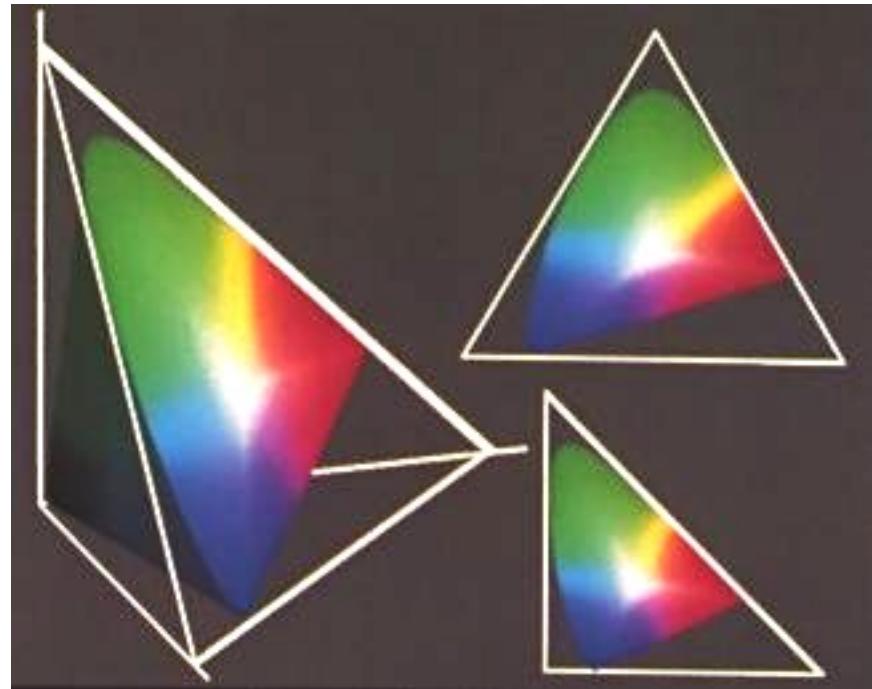
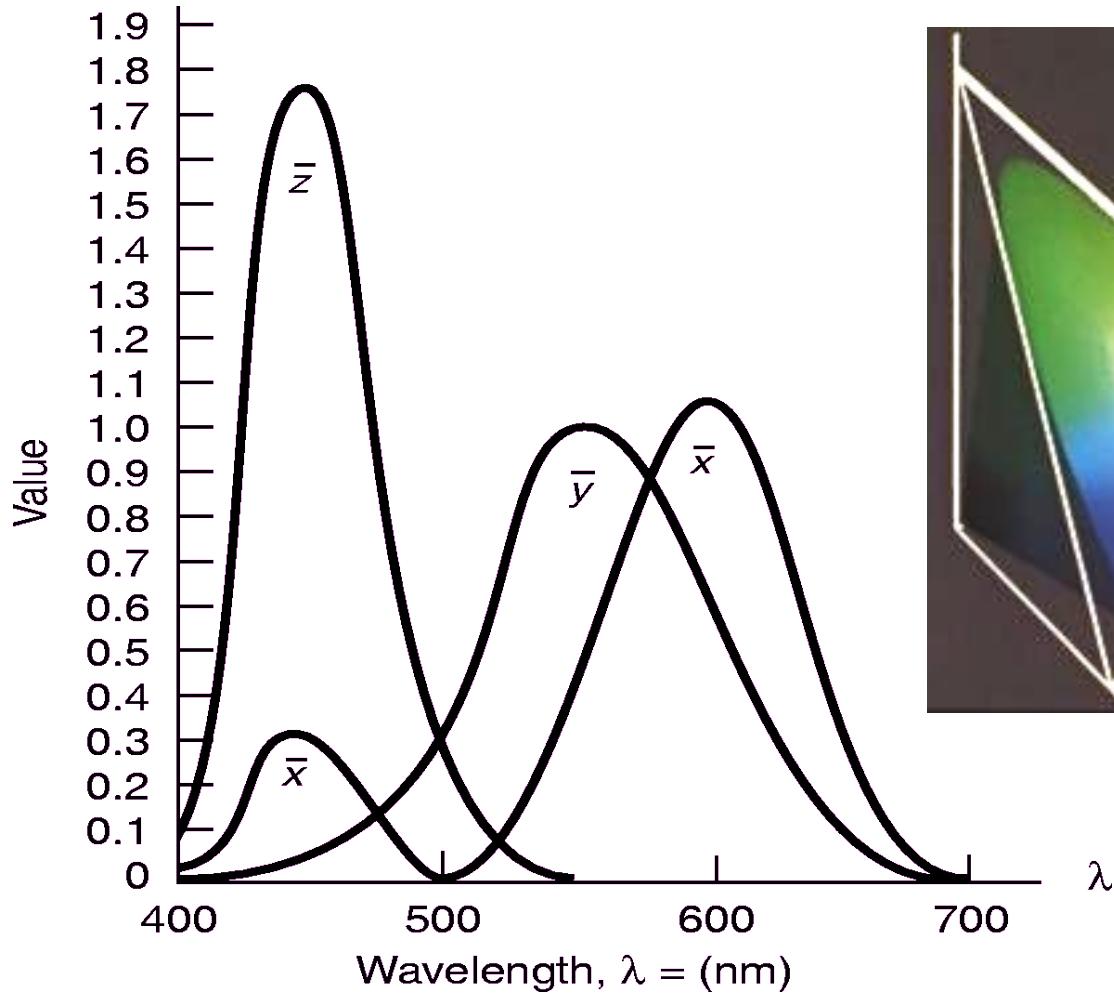
Wright and Guild ~1930: Comparación visual entre un color de referencia y uno generado mediante tres luces (RGB)



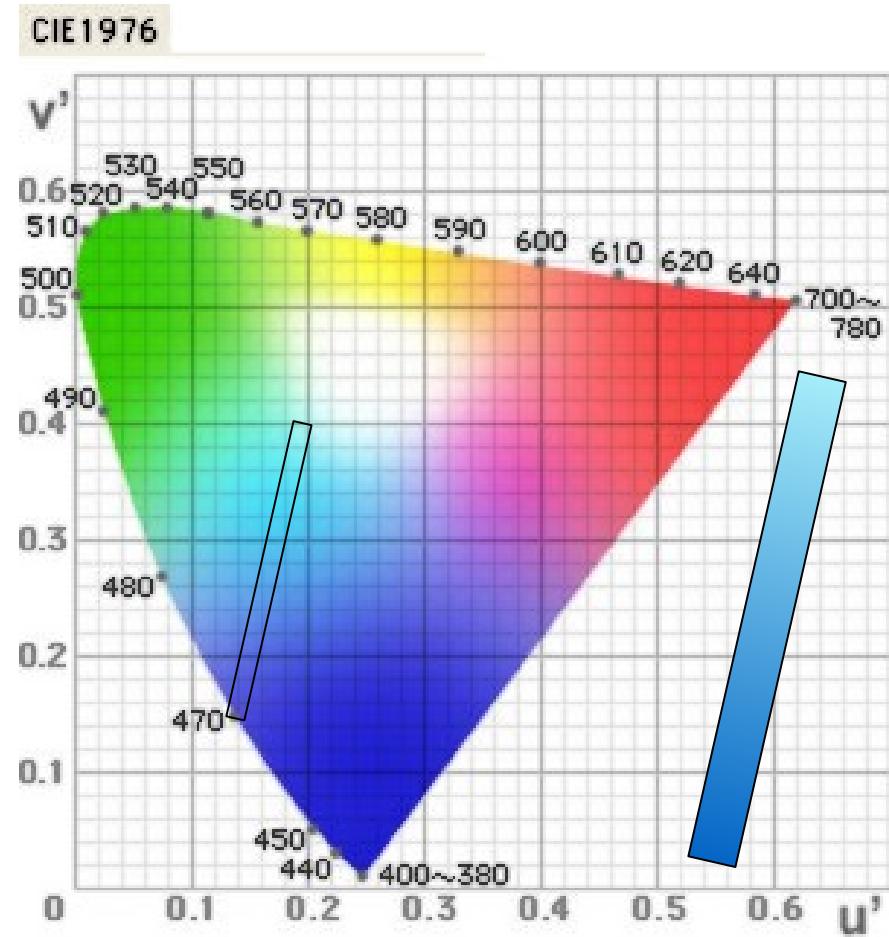
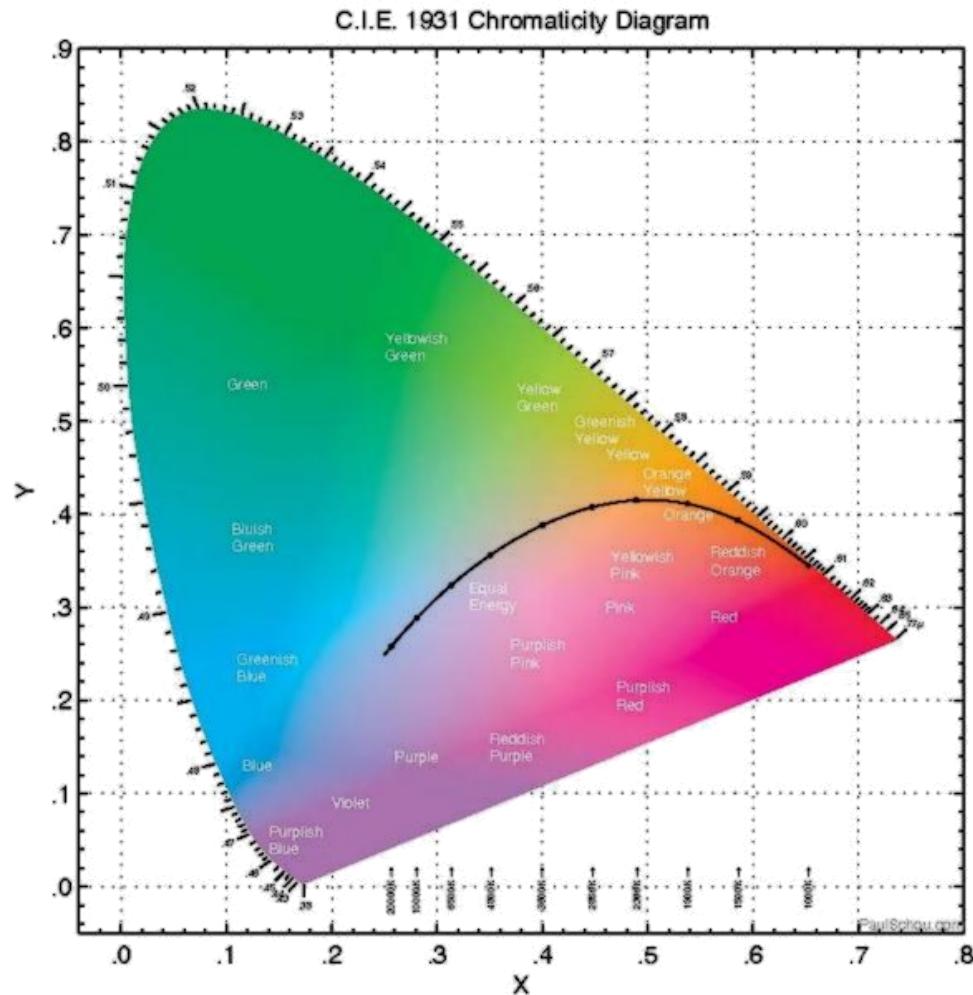
Los valores negativos del rojo significan que no se puede reproducir ese color, a menos que se agregue luz roja al campo de referencia

Commission Internationale de l'Éclairage (CIE)

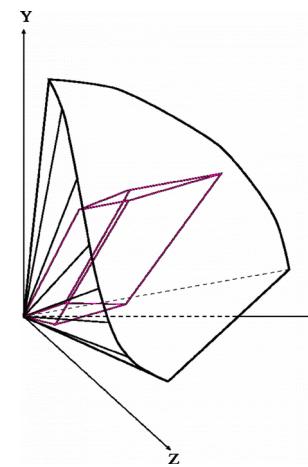
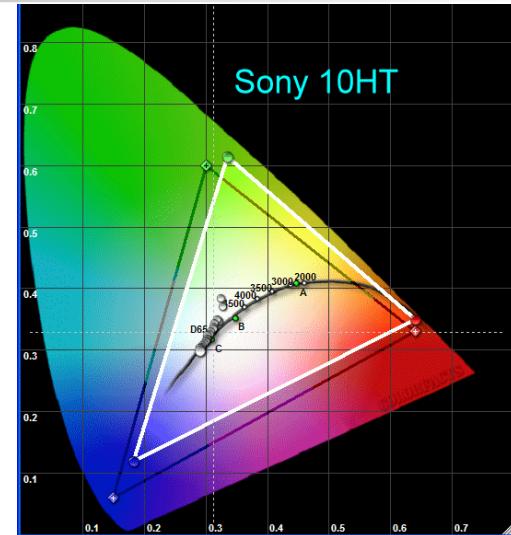
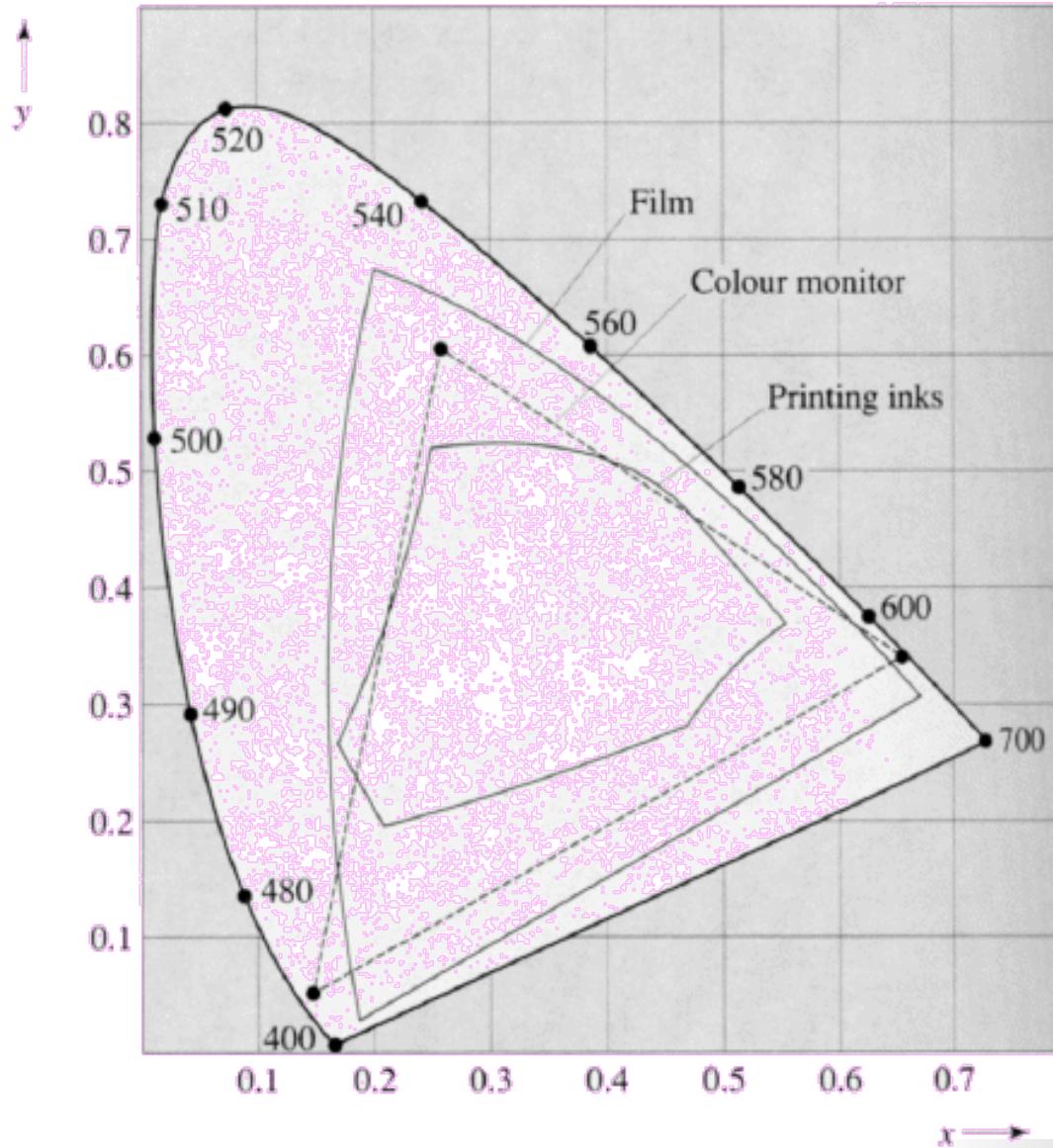
CIE 1931: Standard Colorimetric Observer



Commission Internationale de l'Éclairage (CIE)

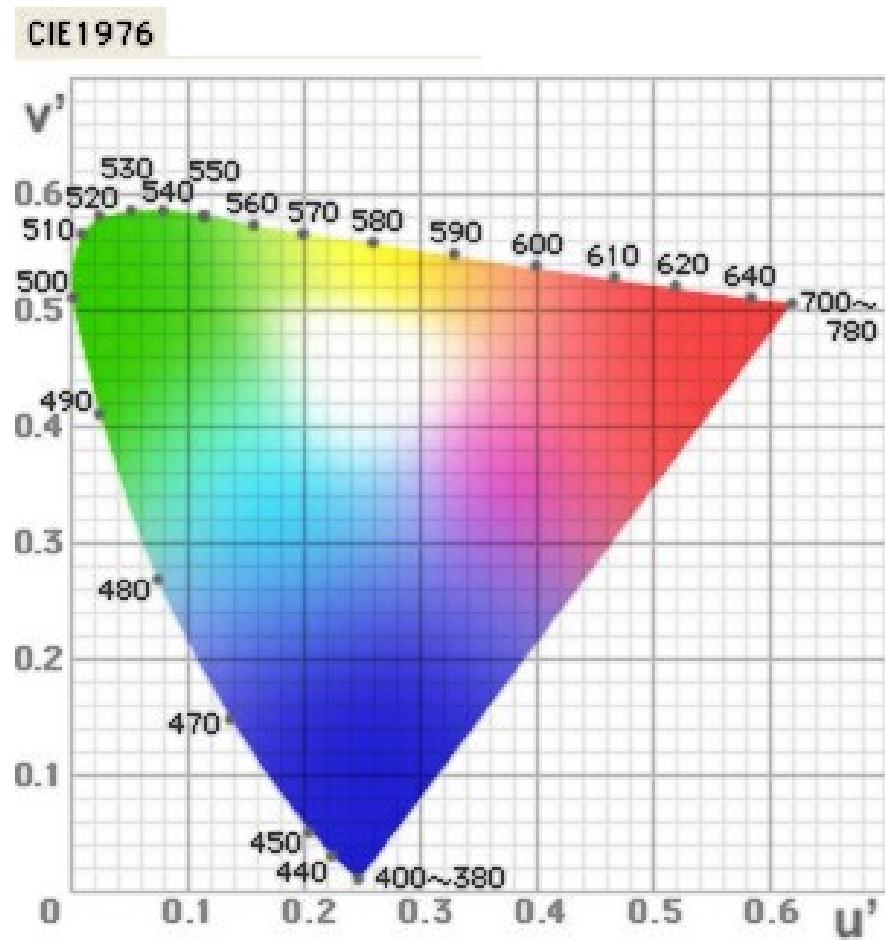
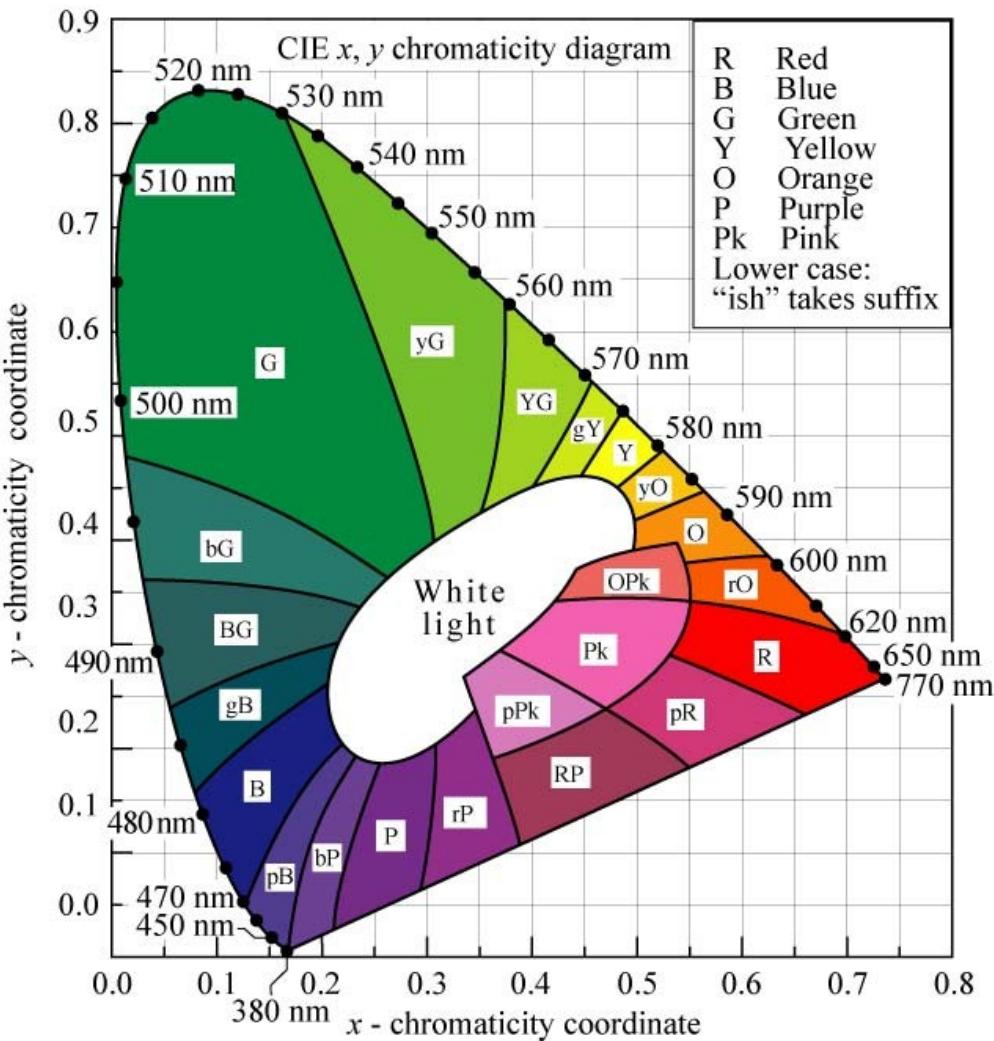


Gamut

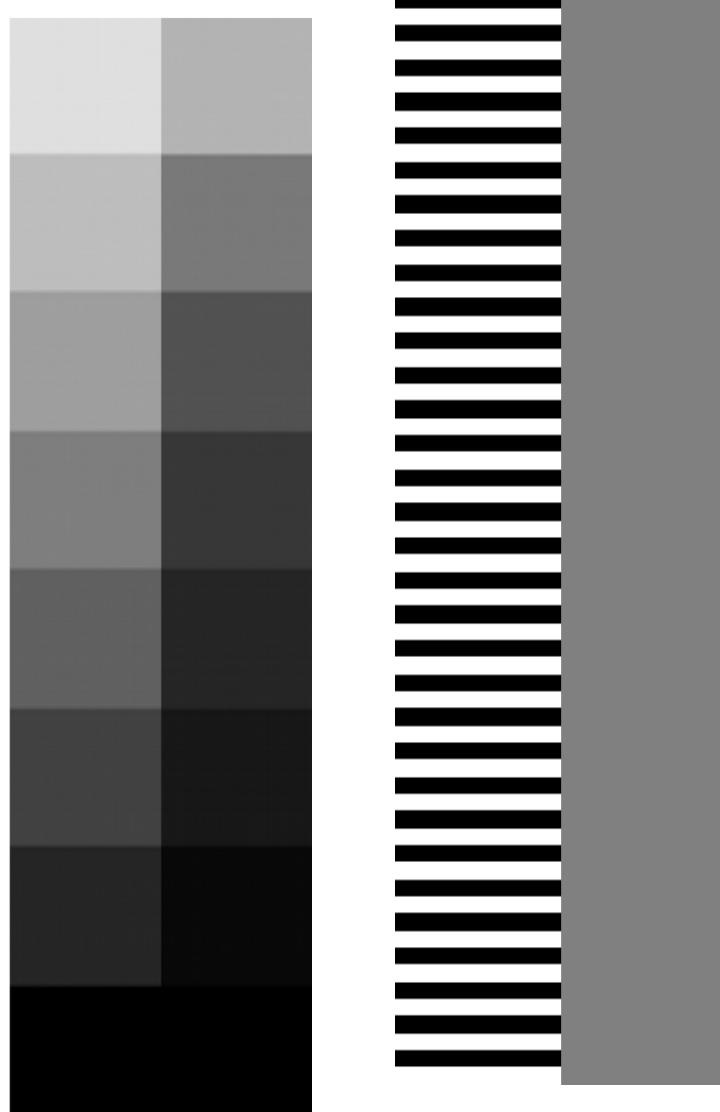
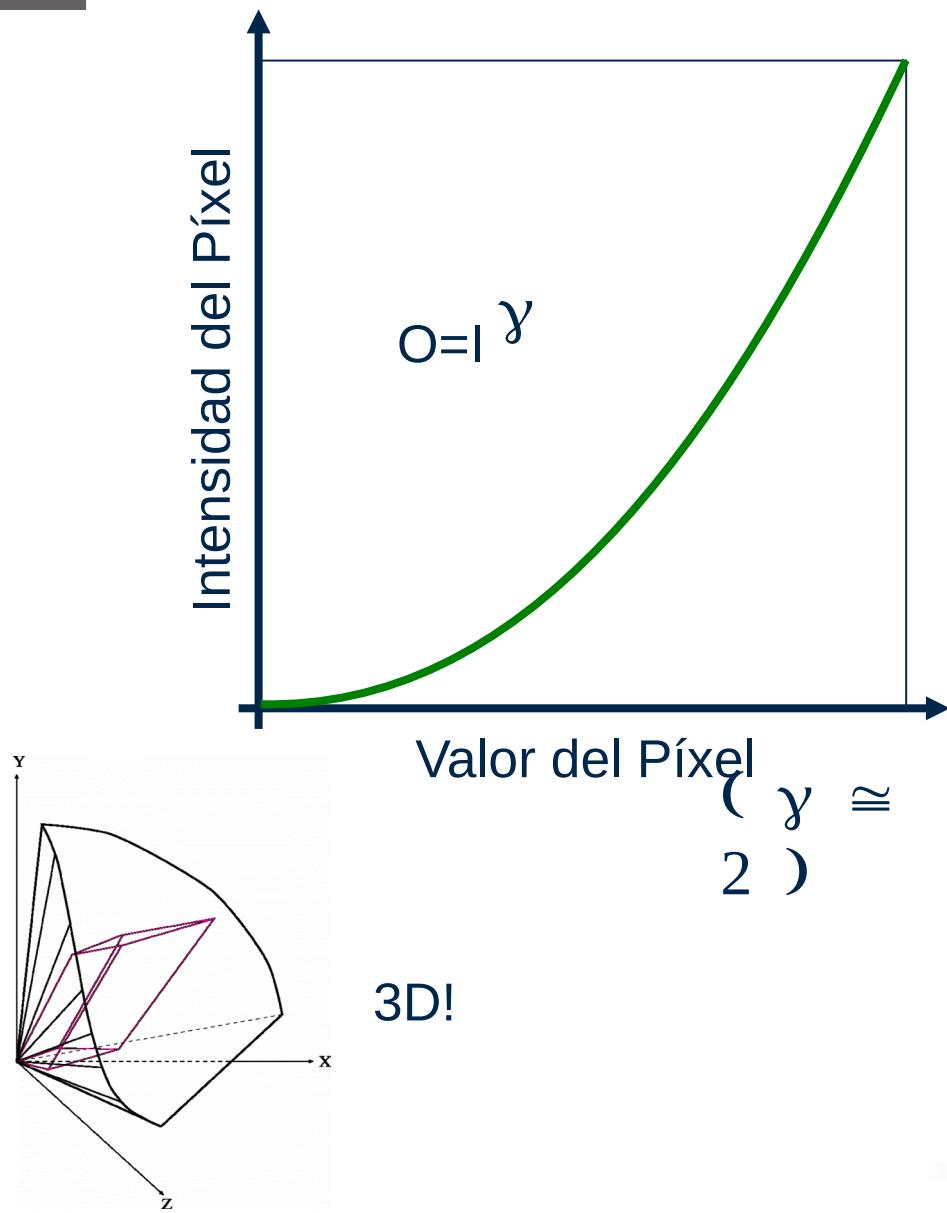


$$I \sim 0.3R + 0.6G + 0.1B$$

Commission Internationale de l'Éclairage (CIE)



Corrección Gamma



Color RGBA

El **color** (RGB o RGBA) se asigna **por cada vértice** de cada primitiva.

La **A** se refiere al canal adicional **alpha**:

- Puede considerarse como “nivel de opacidad”
- En la etapa de Blending se mezcla con el color “anterior”

$$\text{Usualmente: } \mathbf{R} = \mathbf{A}_s \mathbf{S} + (1-\mathbf{A}_s) \mathbf{D}$$

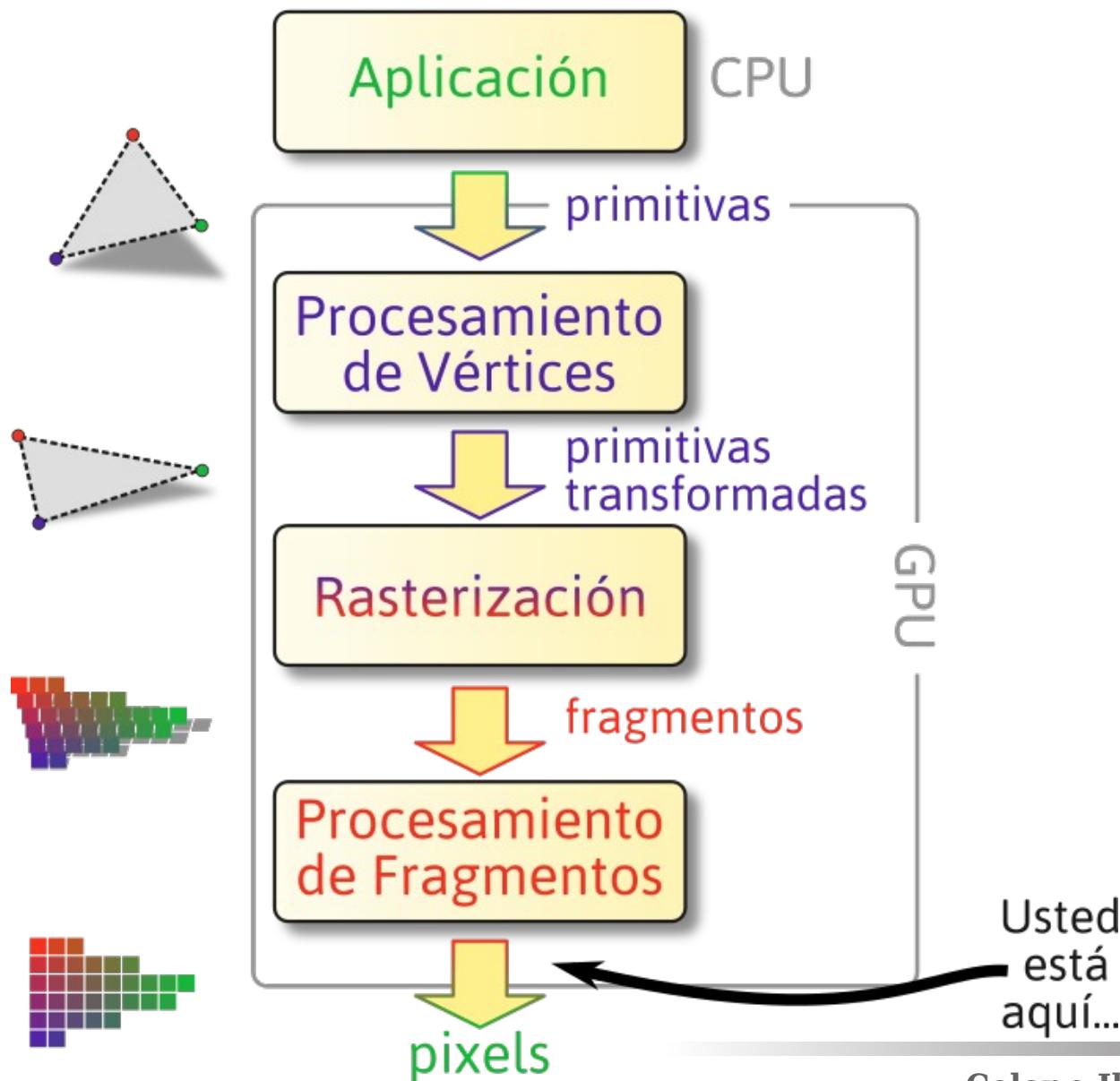
R resultado, color final que se escribirá en el color-buffer

S (source) es cada uno de los valores R, G o B del fragmento entrante

D (destination) corresponde a la derecha al píxel almacenado en el color buffer en esa posición.

As es el alpha del fragmento entrante, que se utiliza aquí como nivel de opacidad.

Merging/Blending

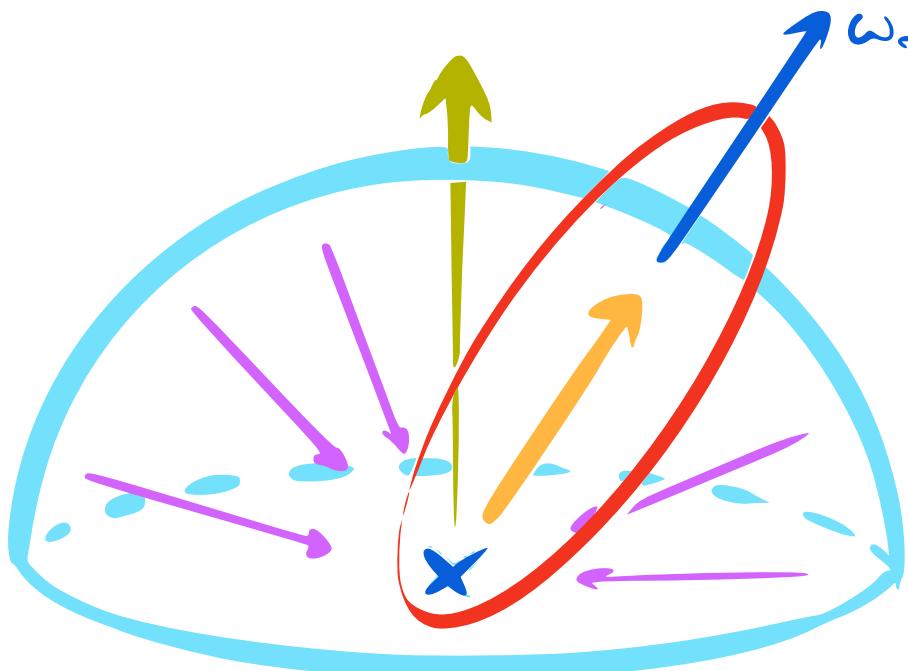


2da Parte: Iluminación y Sombreado en CG



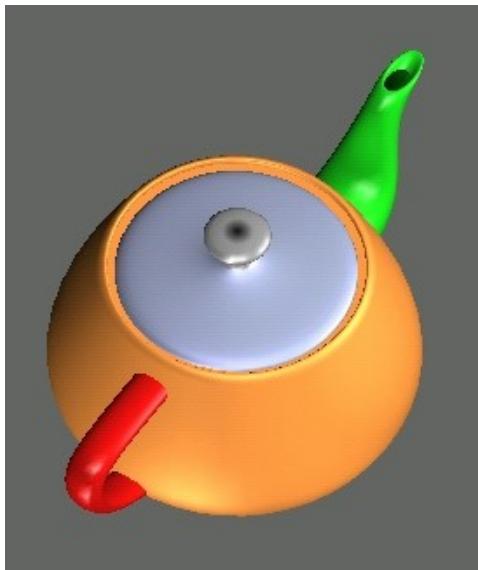
Como interactúan los materiales con la luz

La Ecuación del Rendering



$$L_o(\mathbf{x}, \omega_o) = L_e(\mathbf{x}, \omega_o) + \underbrace{\int_{\Omega} L_i(\mathbf{x}, \omega_i) \cdot f_r(\mathbf{x}, \omega_i \rightarrow \omega_o) \cdot \cos\theta_i d\omega_i}_{L_r(\mathbf{x}, \omega_o)}$$

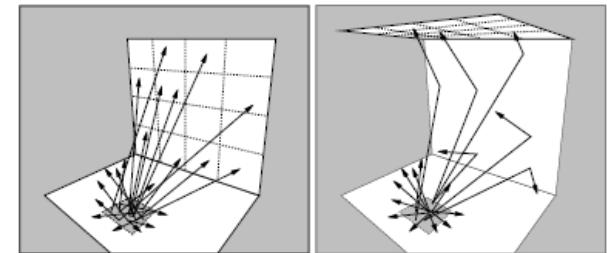
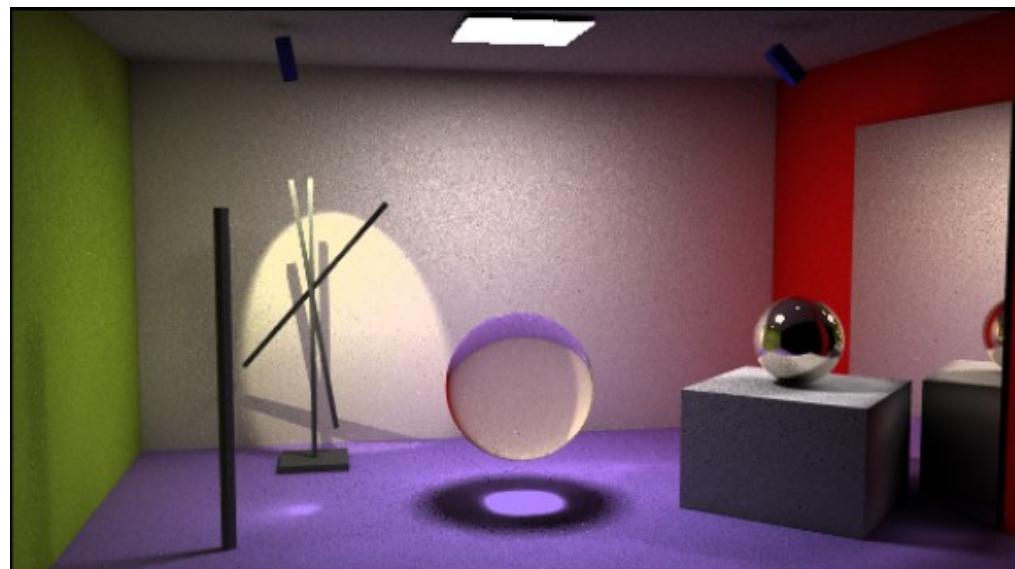
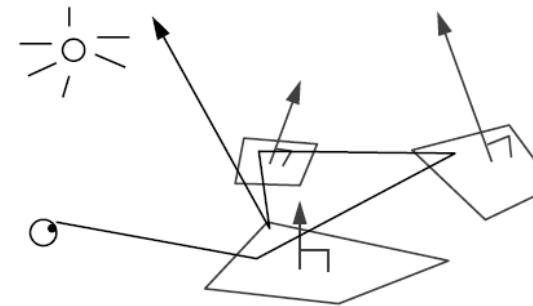
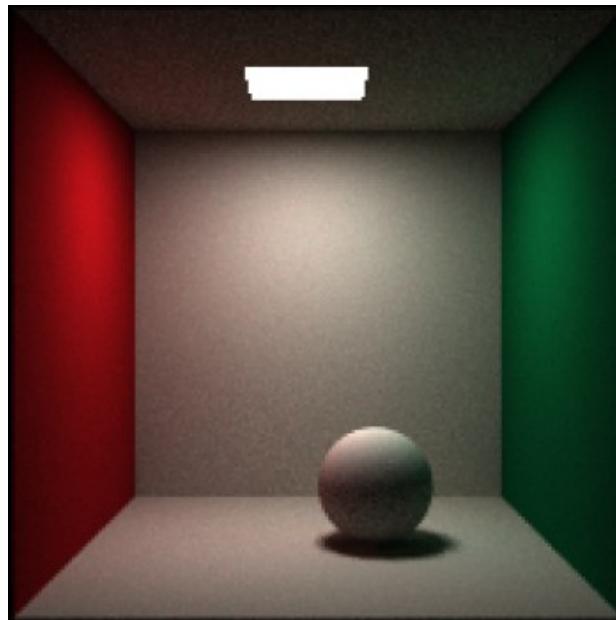
Iluminación Local vs. Global



Iluminación local: depende del material, la luz ambiente, el ángulo de incidencia de la luz y el ángulo con el eje visual

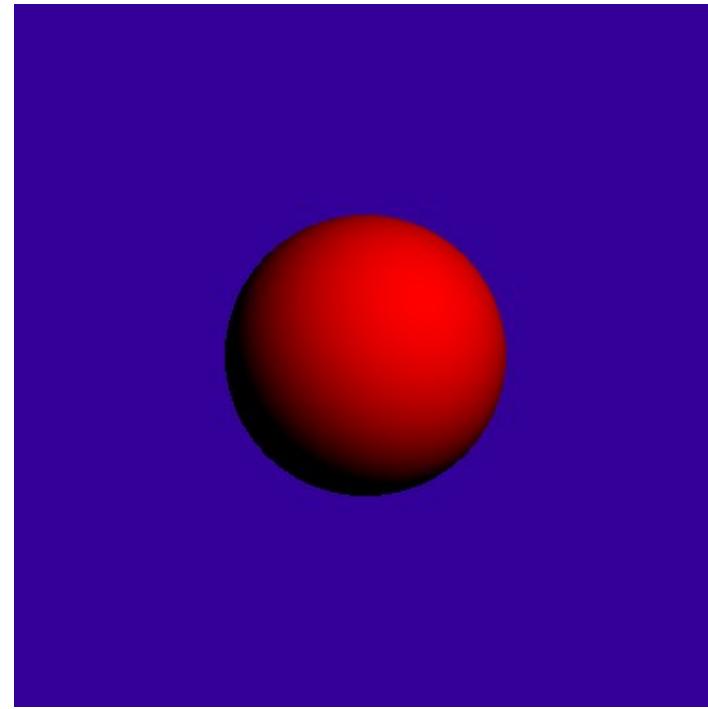
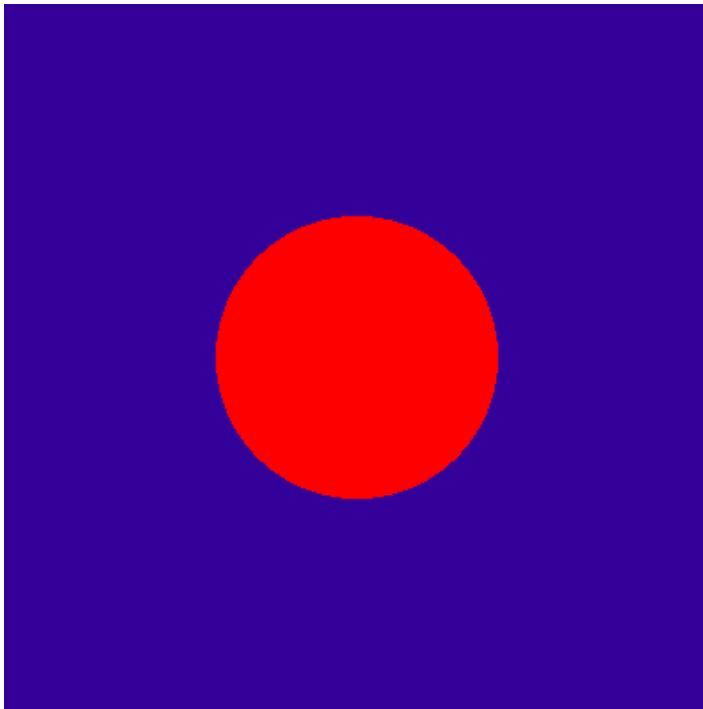
Iluminación Global: considera además la luz reflejada por los otros objetos y un ambiente mas complejo.

Modelos Avanzados de Iluminación



Ray Tracing
Radiance
Radiosity
Photon Map
.....

Sombreado

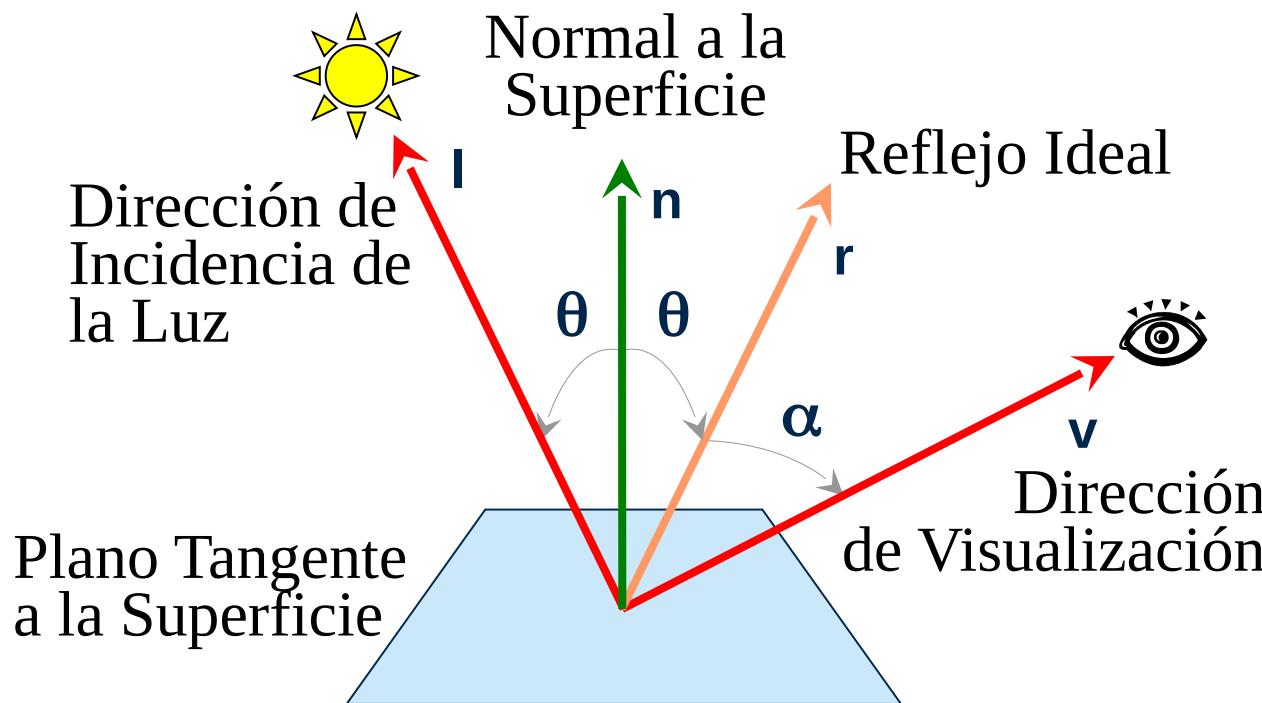


Analizaremos el sombreado debido a la forma del objeto en relación con el ojo y las fuentes de luz.

(No confundir sombreado con proyección de sombras)

Bidirectional Reflectance Distribution Function

Proporción de luz que refleja una superficie en función del ángulo de incidencia y el ángulo de visión



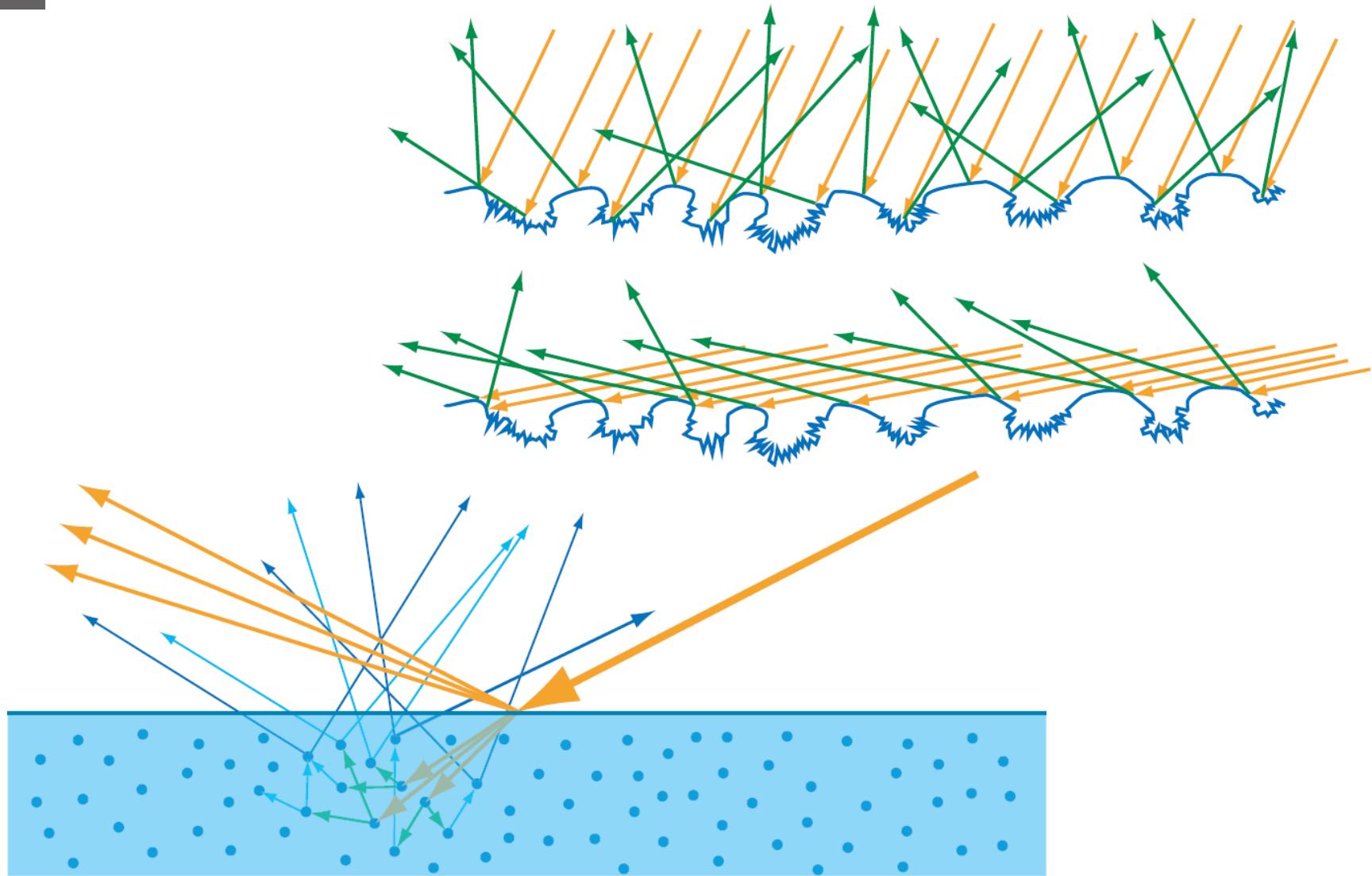
Notas:

La superficie no es necesariamente plana pero es suave: tiene un plano tangente.

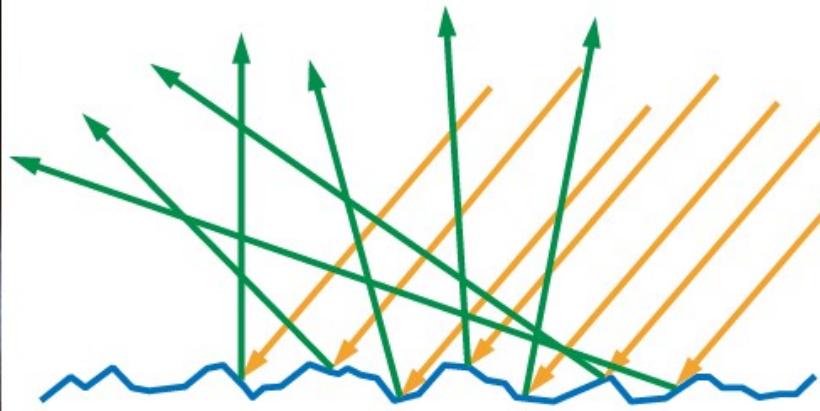
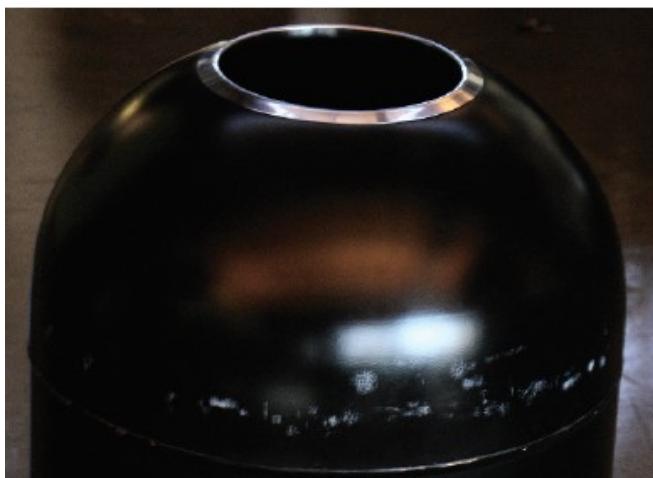
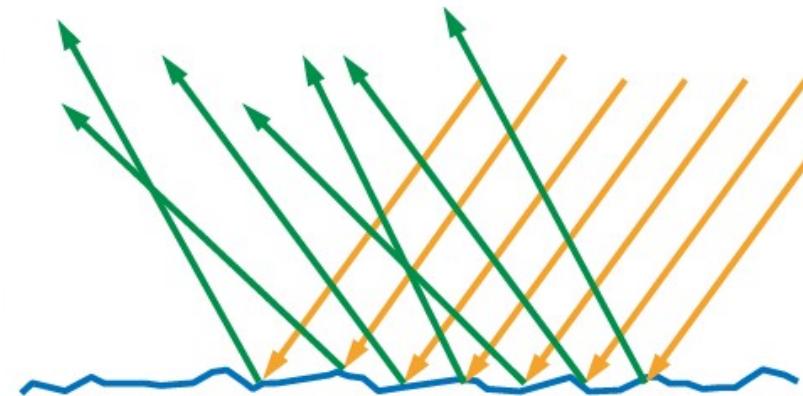
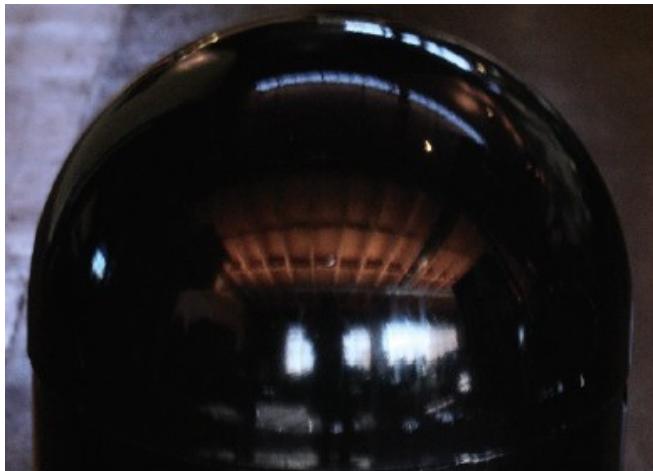
Los vectores **I** **n** y **r** están en el mismo plano, el vector **v** puede que no.

El ángulo de visión α se mide respecto al rayo reflejado.

Modelos NPR vs. Fenomenológicos

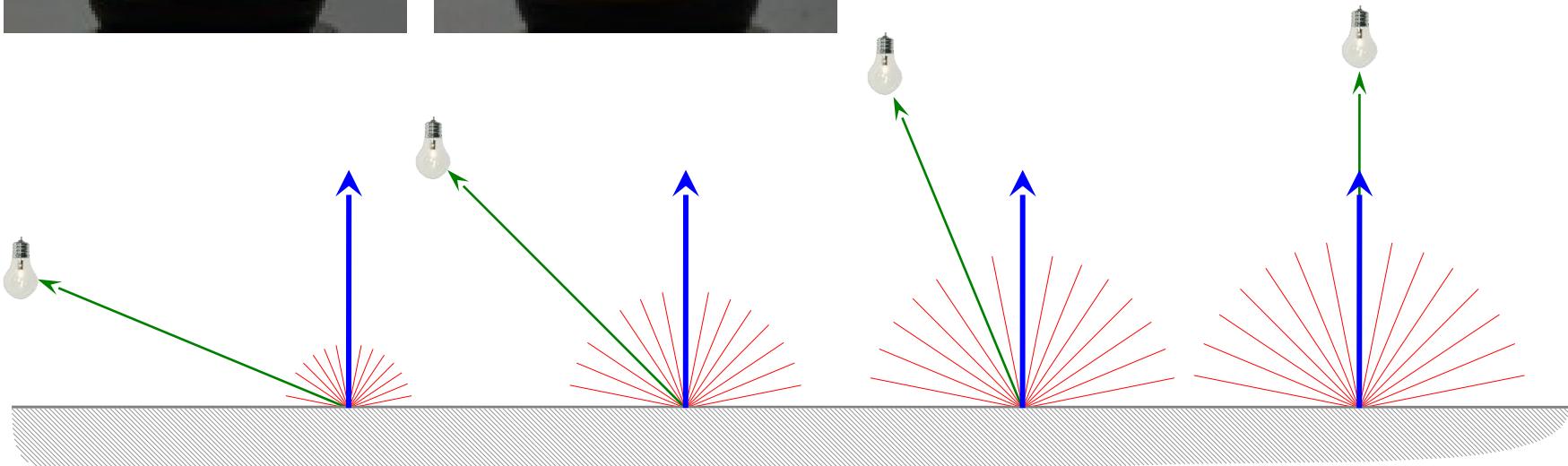
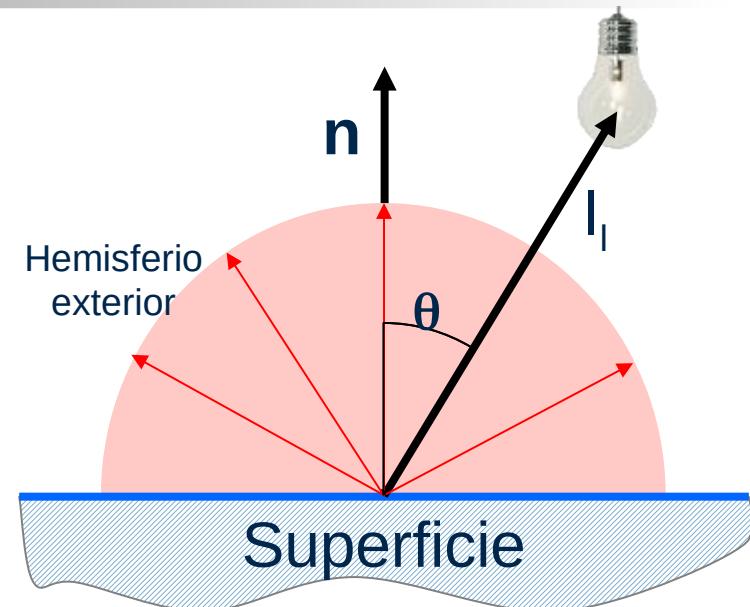
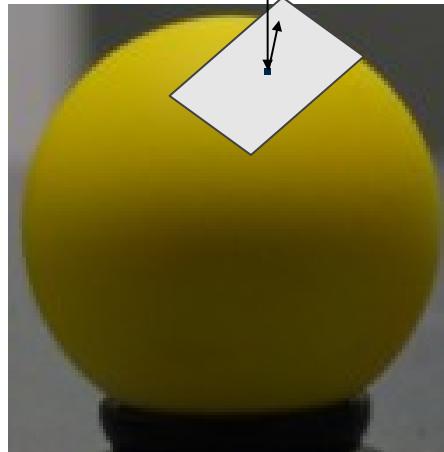


Modelos NPR vs. Fenomenológicos

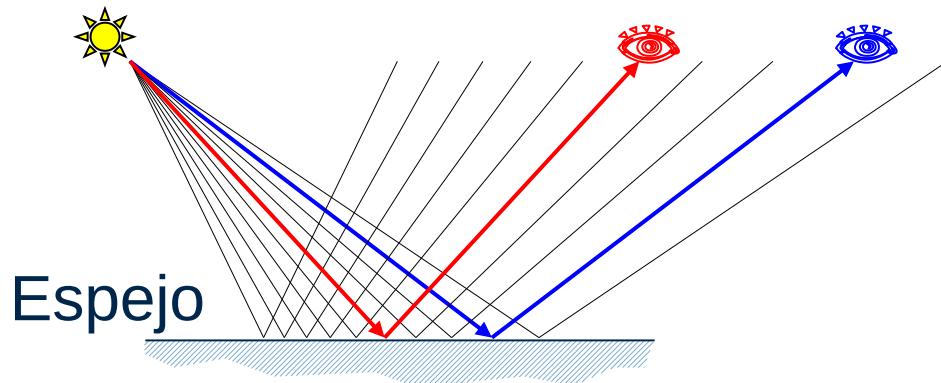
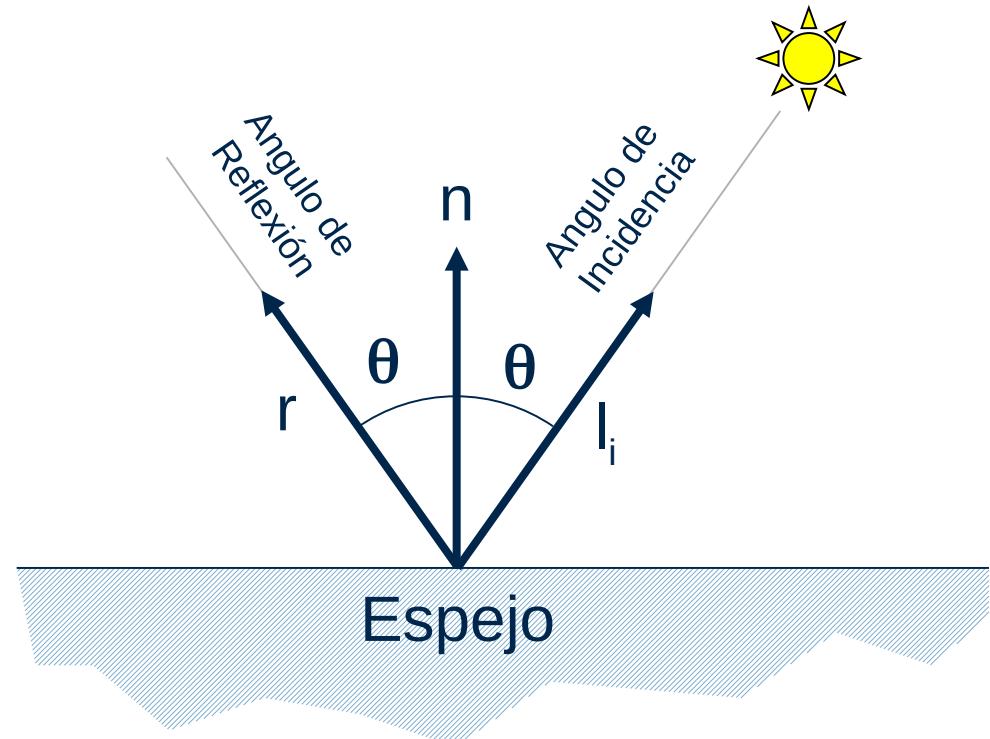


Reflexión Difusa Lambertiana Ideal

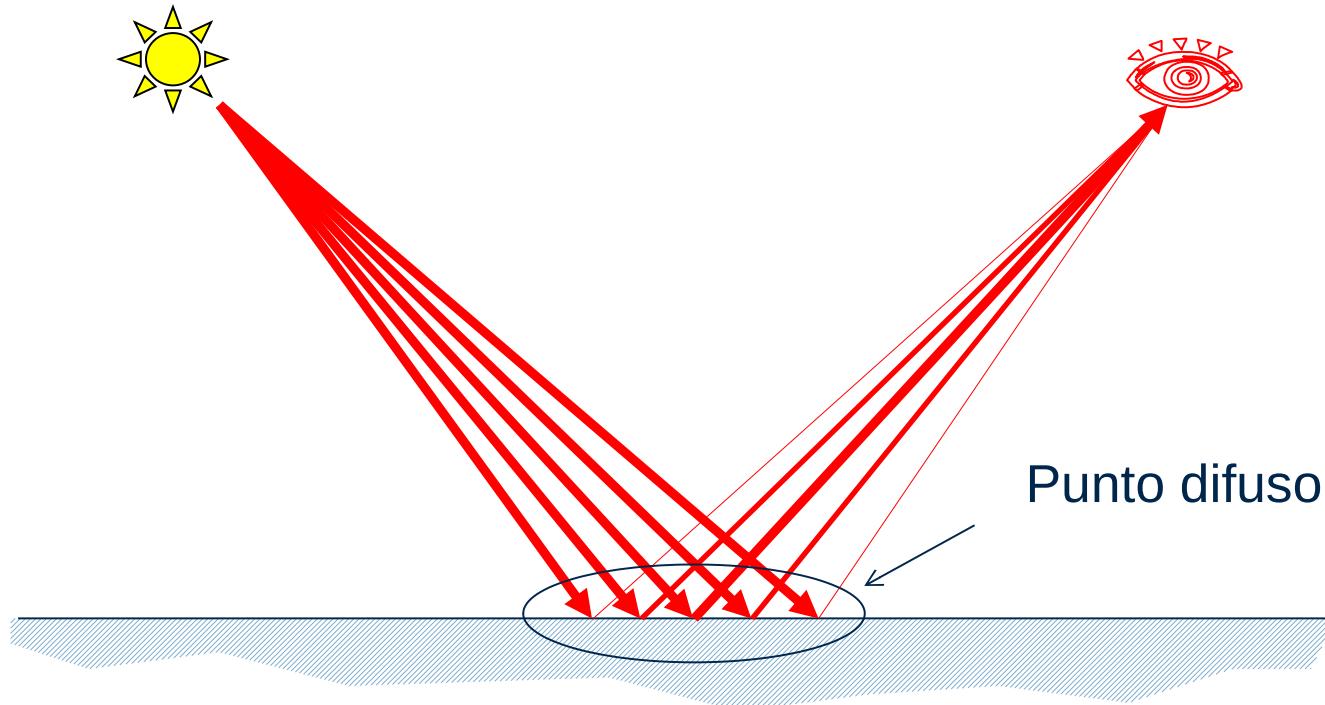
$$I_d = K_d I_i \cos(\theta)$$



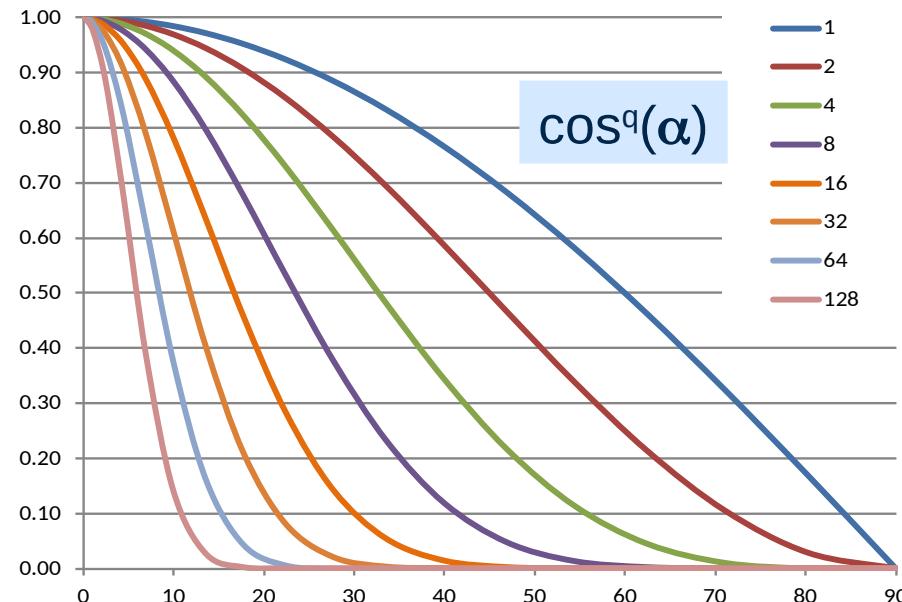
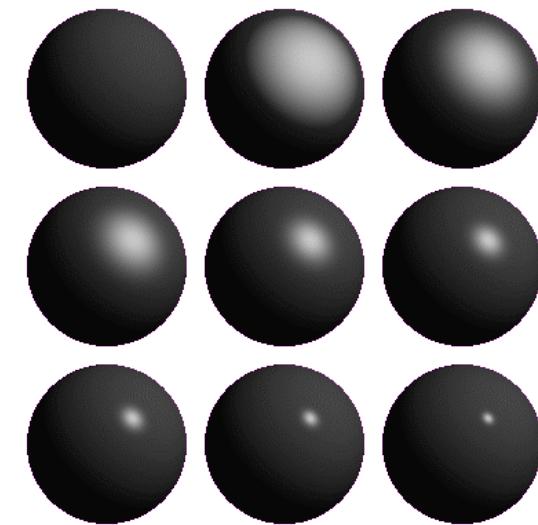
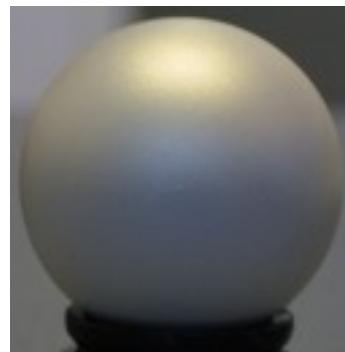
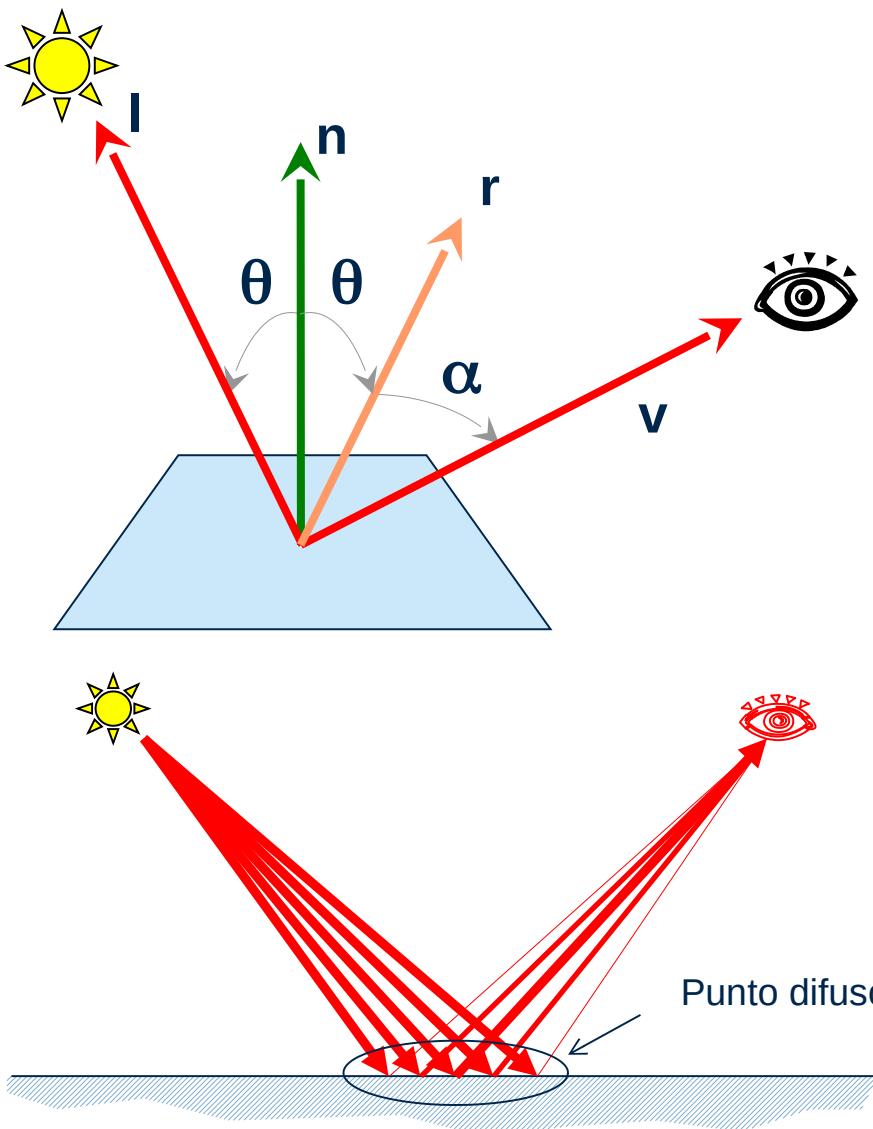
Reflexión Especular Ideal



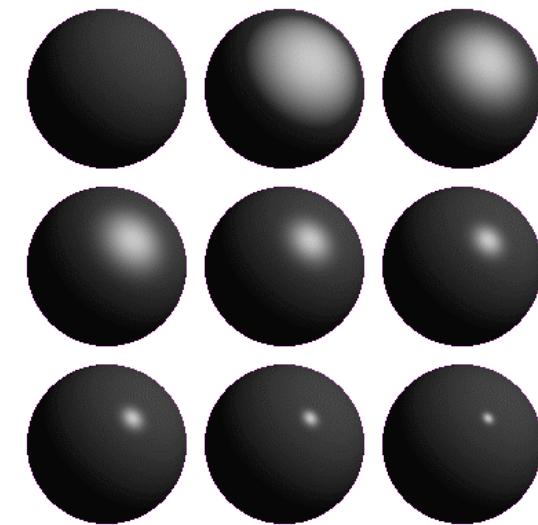
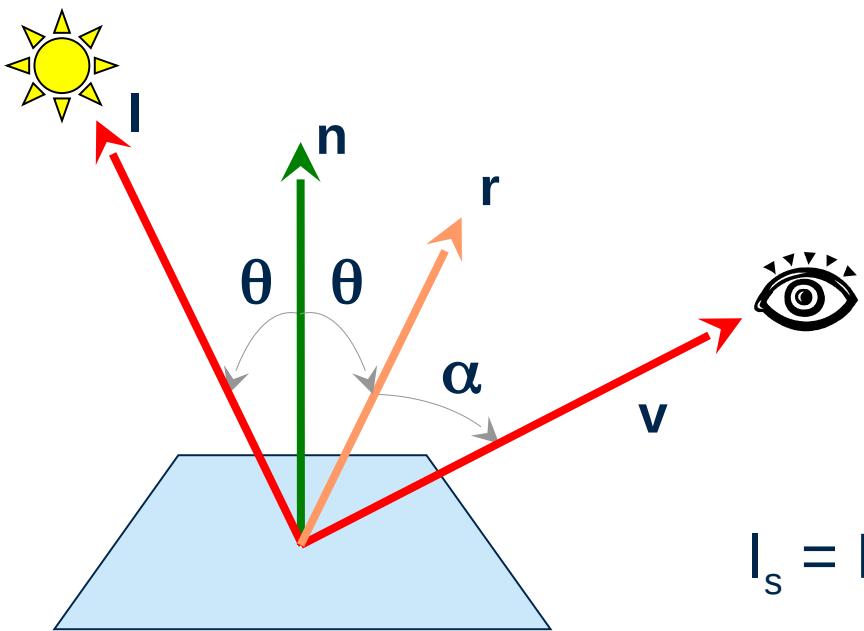
Reflexión Especular No Ideal



Reflexión Especular No Ideal (Phong, 1973)

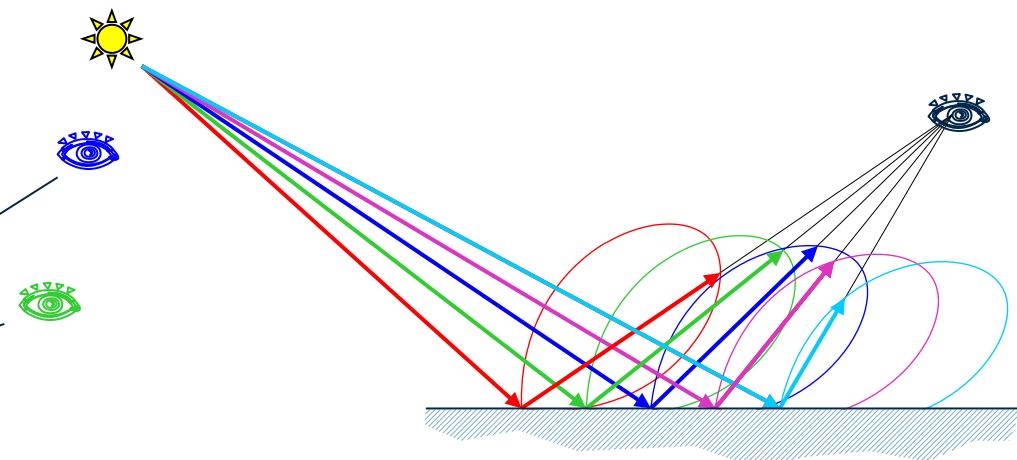
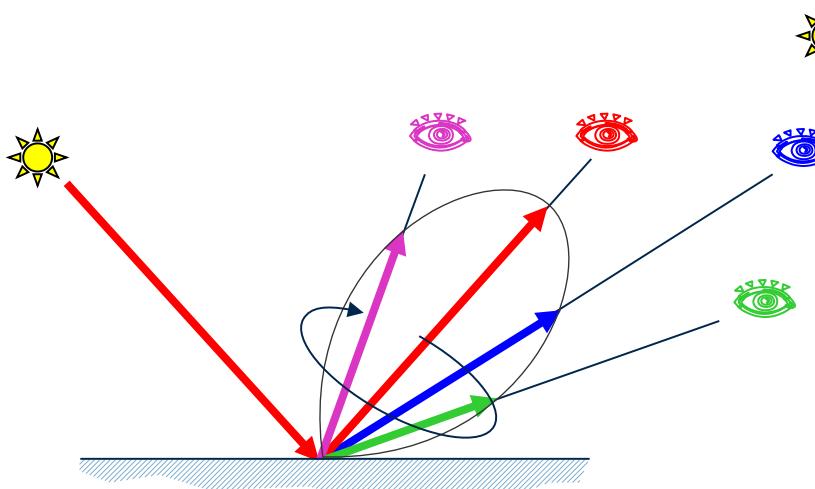


Reflexión Especular No Ideal (Phong, 1973)



$$I_s = K_s I_i \cos^q(\alpha)$$

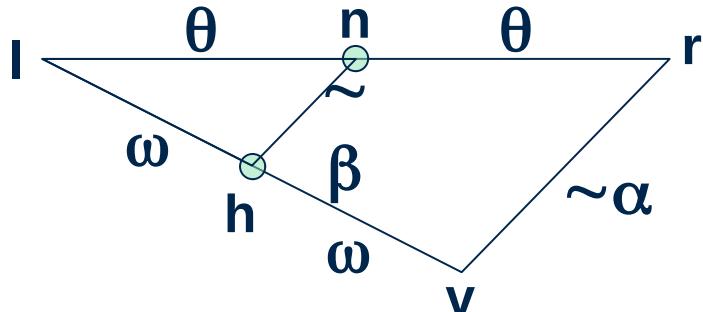
$$\cos(\alpha) = v.r$$



Reflexión No Ideal (Phong 1973 - Blinn 1977)

$$I_s = K_s I_i \cos^q(\beta)$$

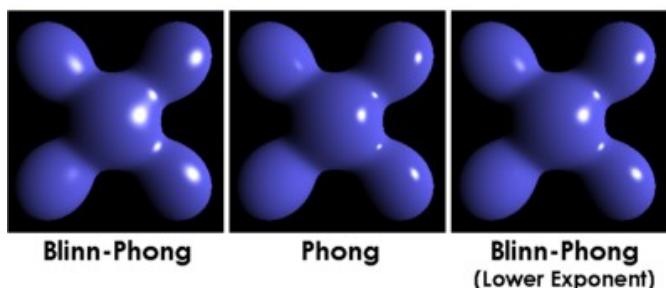
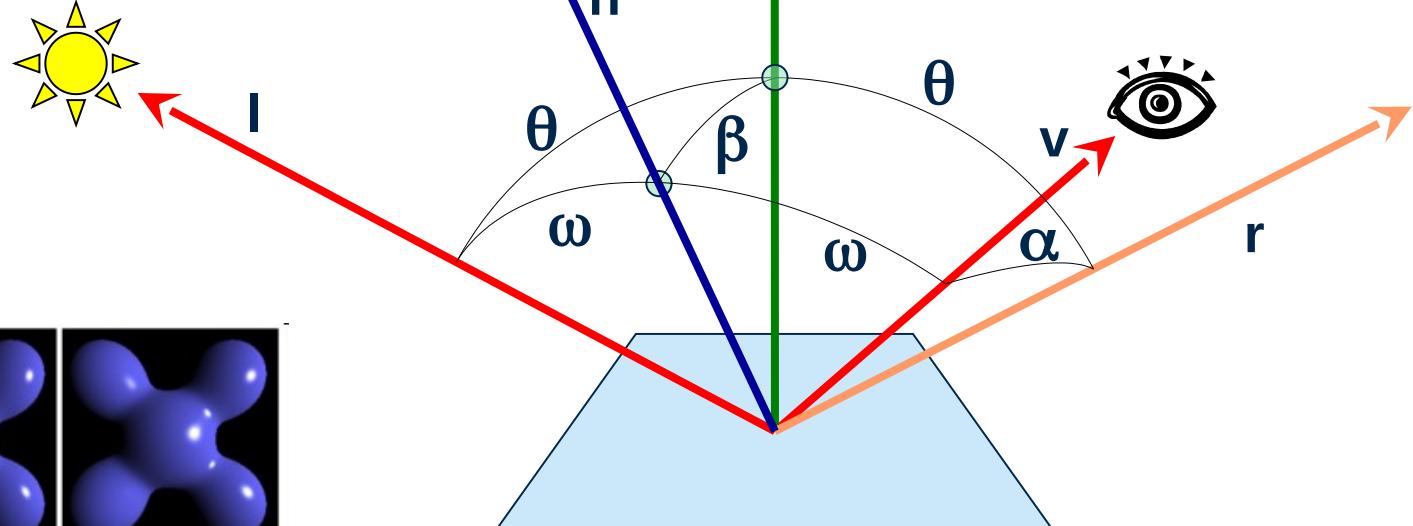
$$\cos(\beta) = \mathbf{n} \cdot \mathbf{h}$$



$$\mathbf{h} = (\mathbf{l} + \mathbf{v}) / |\mathbf{l} + \mathbf{v}|$$

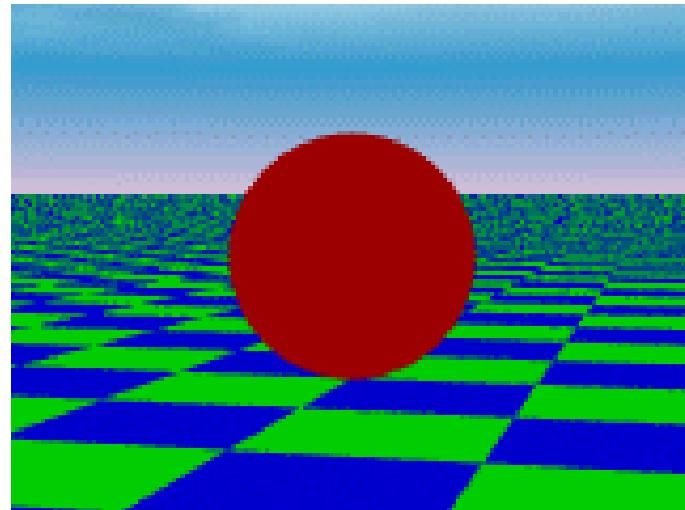
$$\beta \sim \alpha/2$$

$$I_s = K_s I_i (n \cdot h)^q$$



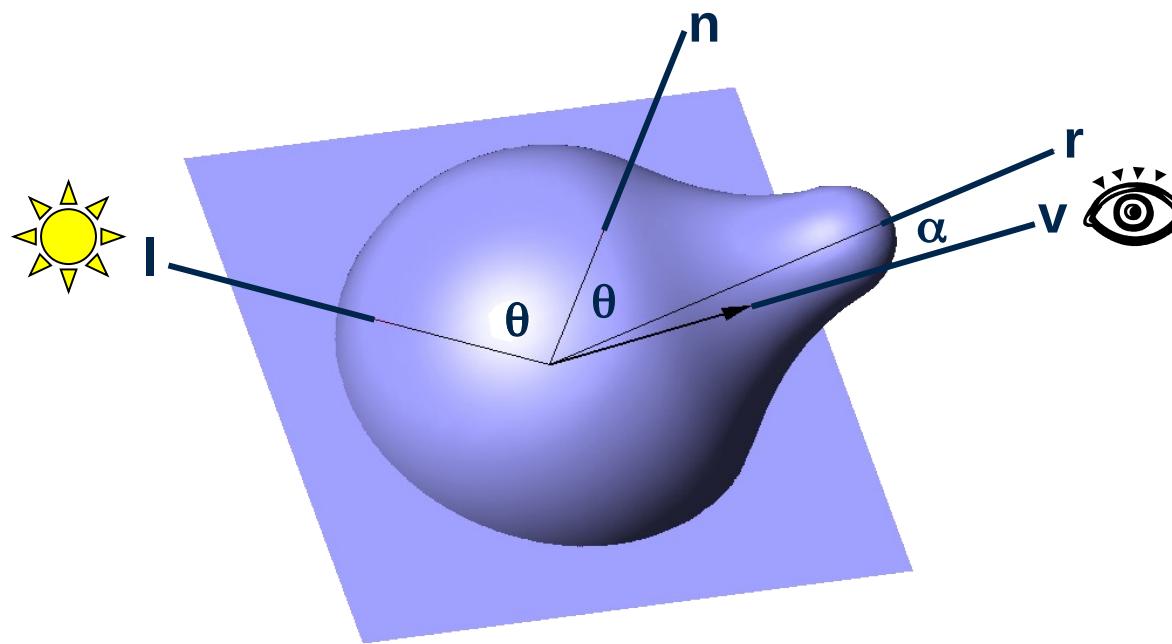
Iluminación Ambiente

$$I_a = I_i K_a$$

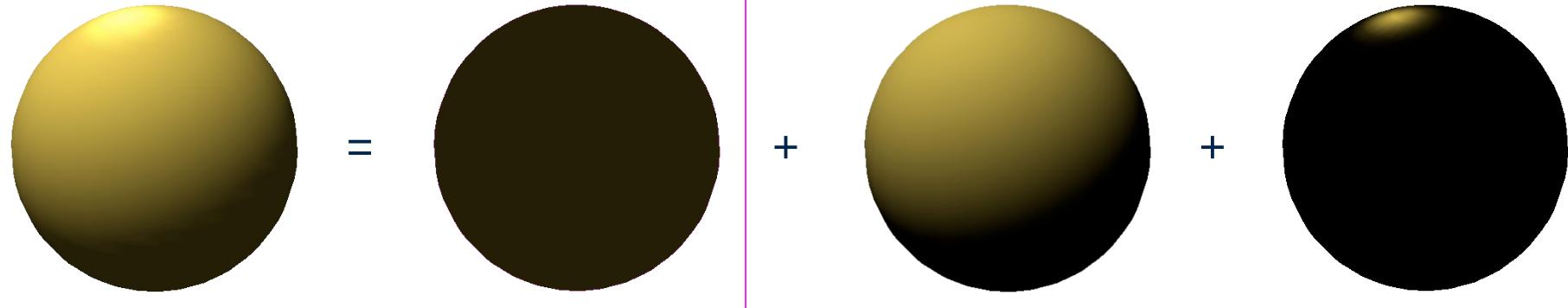


La luz reflejada por todo el entorno se simplifica como luz ambiente. Es independiente de la dirección de las fuentes y la de visualización.

Modelo de Phong (Bui Tong Phong, 1973)



$$I_r = I_i (K_a + K_d \cos(\theta) + K_s \cos^q(\alpha))$$

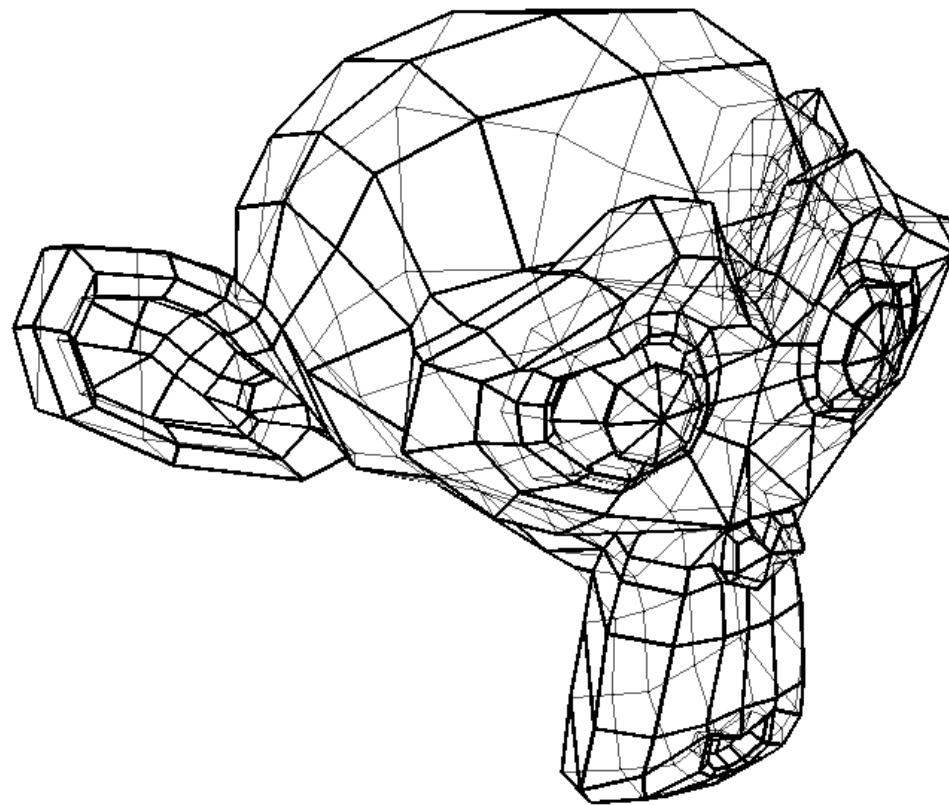


Implementación en OpenGL

$$I_r = K_a I_{ag} + K_e + \sum_j [K_a I_{aj} + K_d I_{dj} \cos(\theta) + K_s I_{sj} \cos^q(\beta)]$$

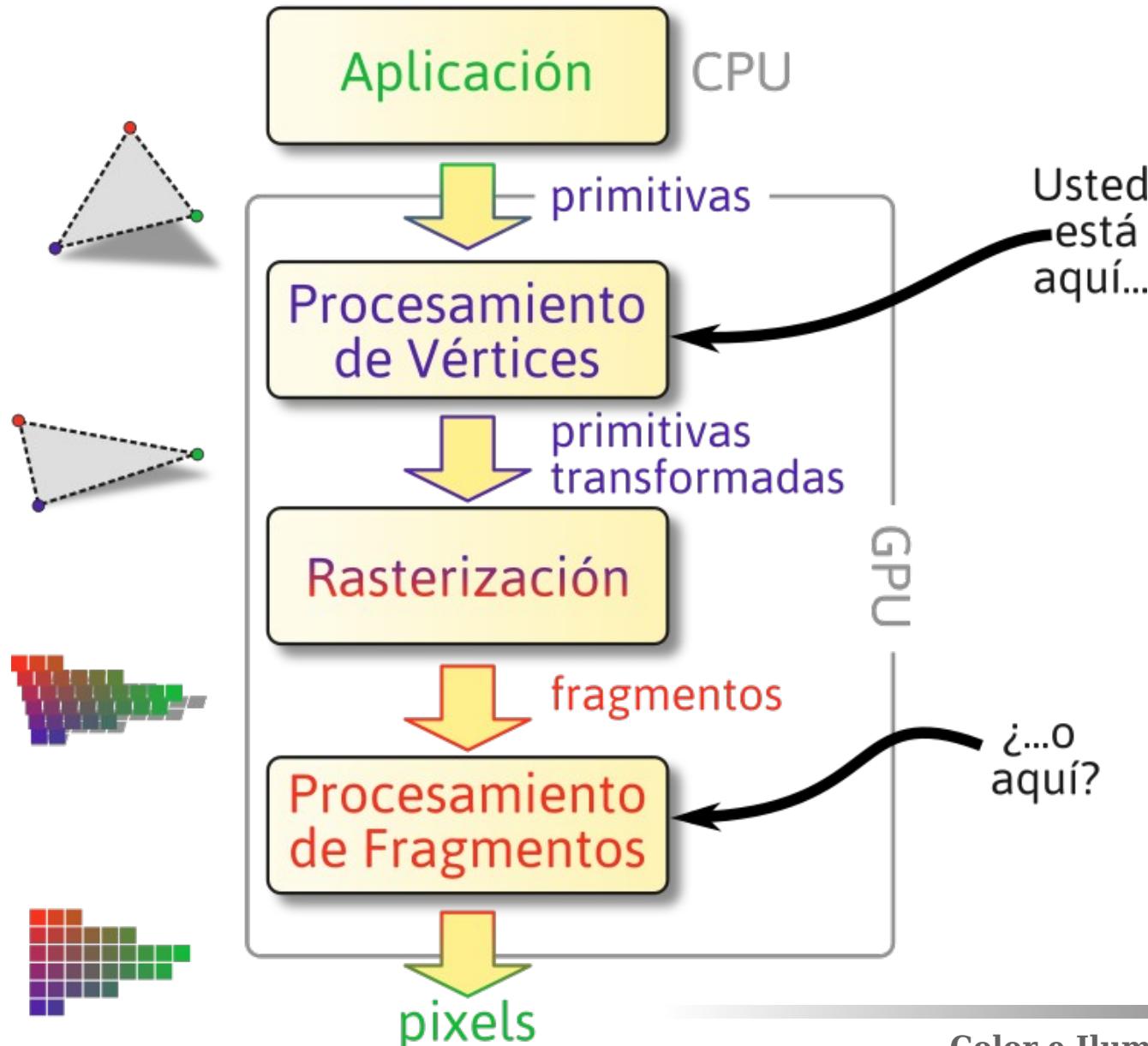


Interpolación del Sombreado



¿Dónde y Cuándo se aplica la BRDF?

Iluminación en el Pipeline



Interpolación del Sombreado: Flat



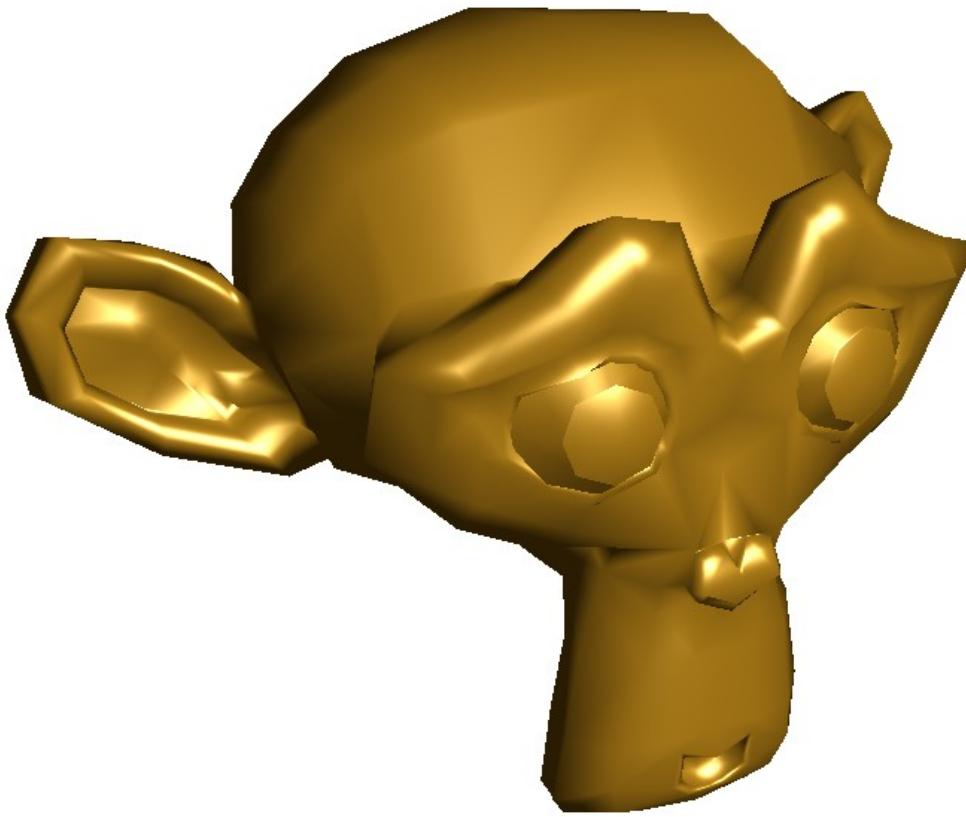
- Se **calcula** iluminación en un vértice por primitiva
- Se usa el **mismo color** resultante para toda la primitiva

Interpolación del Sombreado: Gouraud



- Se **calcula** iluminación en cada **vértice**
- Se **interpola** el **color** para cada fragmento.

Interpolación del Sombreado:Phong



- Se interpolan las **normales** para cada fragmento
- Se **calcula** iluminación en cada **fragmento**

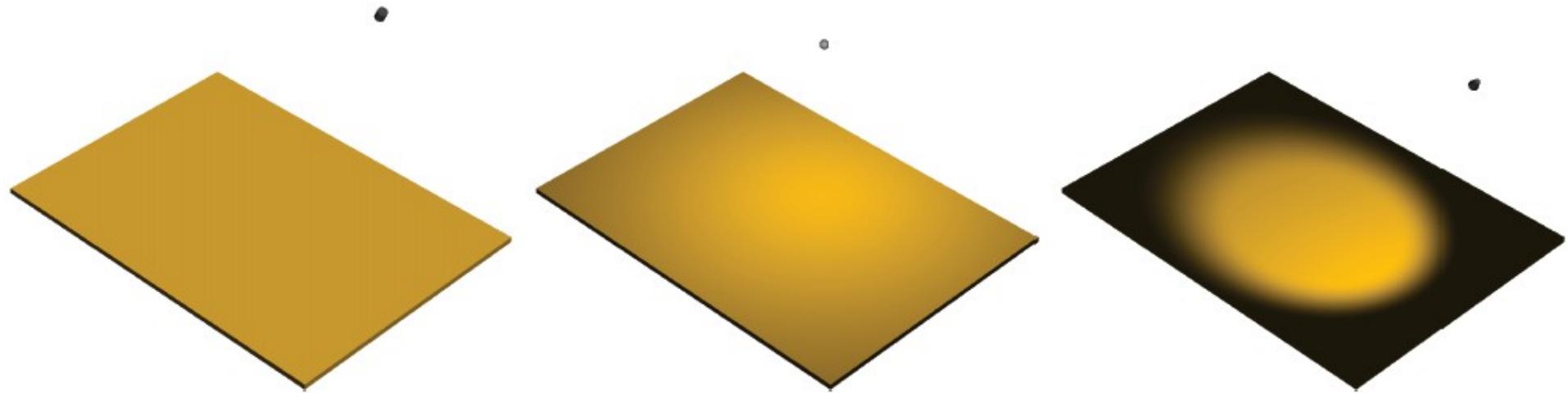
Simulación de Materiales

Material	GL_AMBIENT	GL_DIFFUSE	GL_SPECULAR	GL_SHININESS
Brass	0.329412 0.223529 0.027451 1	0.780392 0.568627 0.113725 1	0.992157 0.941176 0.807843 1	27.8974
Bronze	0.2125 0.1275 0.054 1	0.714 0.4284 0.18144 1	0.393548 0.271906 0.166721 1	25.6
Polished Bronze	0.25 0.148 0.06475 1	0.4 0.2368 0.1036 1	0.774597 0.458561 0.200621 1	76.8
Chrome	0.25 0.25 0.25 1	0.4 0.4 0.4 1	0.774597 0.774597 0.774597 1	76.8
Copper	0.19125 0.0735 0.0225 1	0.7038 0.27048 0.0828 1	0.256777 0.137622 0.086014 1	12.8
Polished Copper	0.2295 0.08825 0.0275 1	0.5508 0.2118 0.066 1	0.580594 0.223257 0.0695701 1	51.2

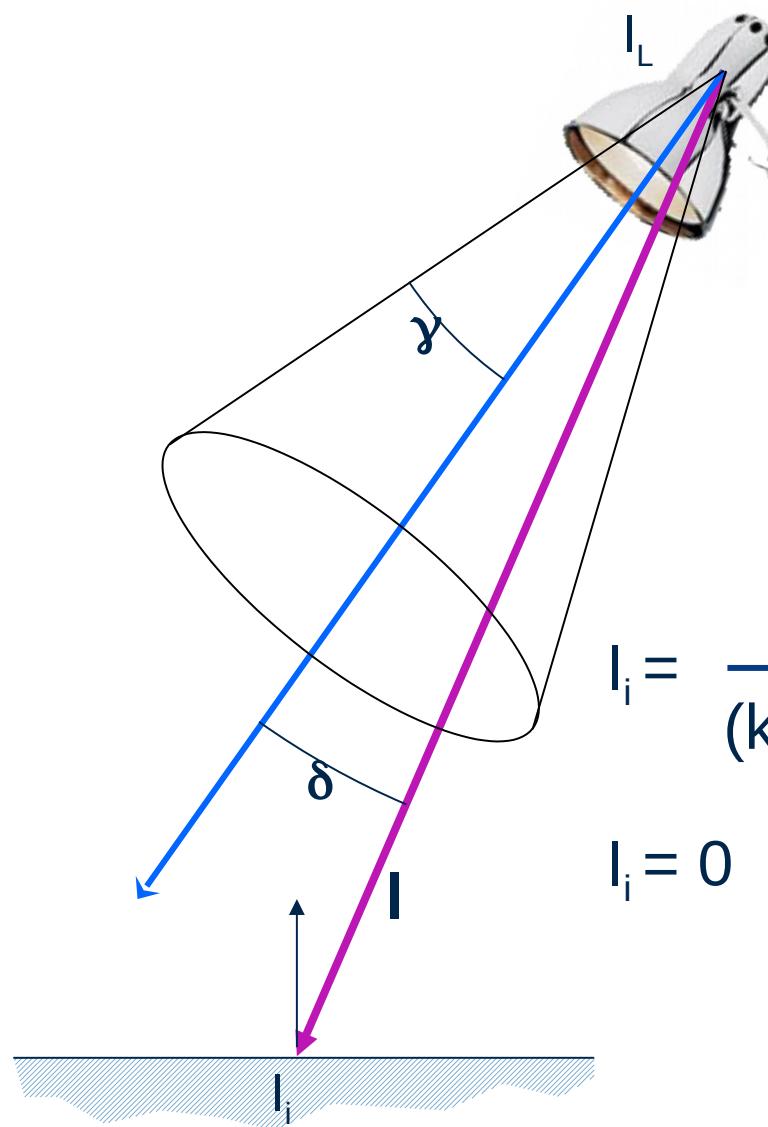
Material	GL_AMBIENT	GL_DIFFUSE	GL_SPECULAR	GL_SHININESS
Gold	0.24725 0.1995 0.0745 1	0.75164 0.60648 0.22648 1	0.628281 0.555802 0.366065 1	51.2
Polished Gold	0.24725 0.2245 0.0645 1	0.34615 0.3143 0.0903 1	0.797357 0.723991 0.208006 1	83.2
Pewter	0.105882 0.058824 0.113725 1	0.427451 0.470588 0.541176 1	0.333333 0.333333 0.521569 1	9.84615
Silver	0.19225 0.19225 0.19225 1	0.50754 0.50754 0.50754 1	0.508273 0.508273 0.508273 1	51.2
Polished Silver	0.23125 0.23125 0.23125 1	0.2775 0.2775 0.2775 1	0.773911 0.773911 0.773911 1	89.6
Emerald	0.0215 0.1745 0.0215 0.55	0.07568 0.61424 0.07568 0.55	0.633 0.727811 0.633 0.55	76.8

Material	GL_AMBIENT	GL_DIFFUSE	GL_SPECULAR	GL_SHININESS
Jade	0.135 0.2225 0.1575 0.95	0.54 0.89 0.63 0.95	0.316228 0.316228 0.316228 0.95	12.8
Obsidian	0.05375 0.05 0.06625 0.82	0.18275 0.17 0.22525 0.82	0.332741 0.328634 0.346435 0.82	38.4
Pearl	0.25 0.20725 0.20725 0.922	1 0.829 0.829 0.922	0.296648 0.296648 0.296648 0.922	11.264
Ruby	0.1745 0.01175 0.01175 0.55	0.61424 0.04136 0.04136 0.55	0.727811 0.626959 0.626959 0.55	76.8
Turquoise	0.1 0.18725 0.1745 0.8	0.396 0.74151 0.69102 0.8	0.297254 0.30829 0.306678 0.8	12.8
Black Plastic	0 0 0 1	0.01 0.01 0.01 1	0.5 0.5 0.5 1	32
Black Rubber	0.02 0.02 0.02 1	0.01 0.01 0.01 1	0.4 0.4 0.4 1	10

Modelo de Luz e Iluminación Recibida



Modelo de Luz e Iluminación Recibida



$$I_i = \frac{I_L \cos^r(\delta)}{(k_0 + k_1 d + k_2 d^2)}$$

$$I_i = 0$$

si $\delta < \gamma$

si $\delta \geq \gamma$

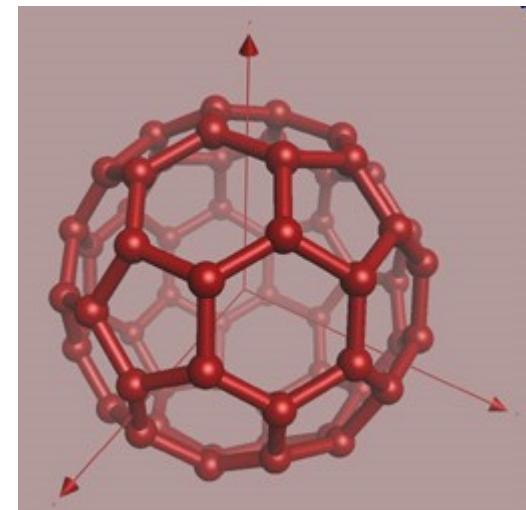
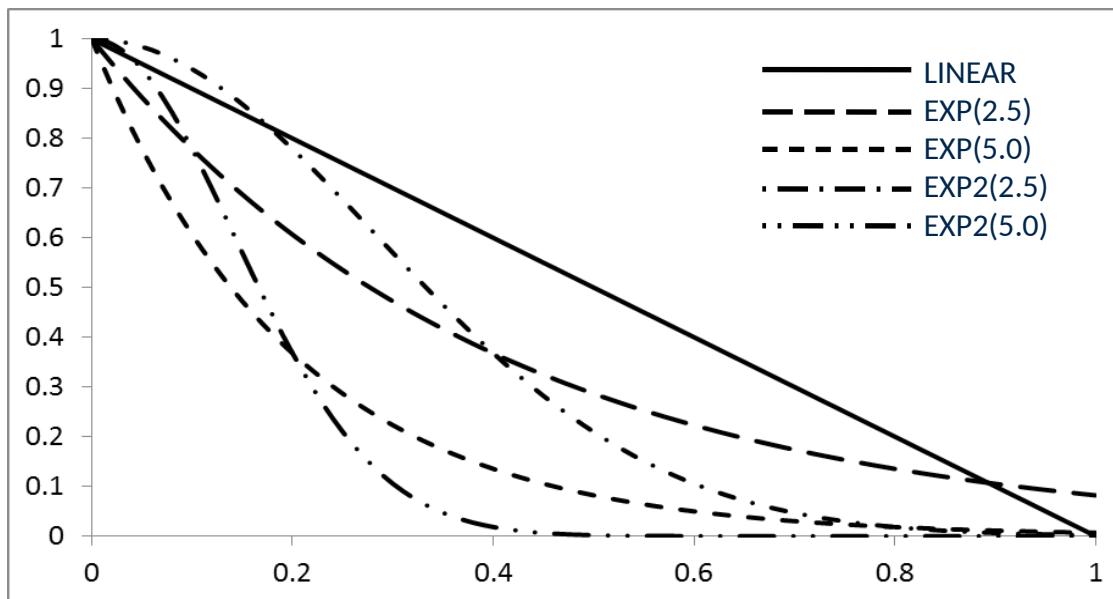
Fog (Niebla)

$$f = e^{-(\text{density} \cdot z)} \quad (\text{GL_EXP})$$

$$f = e^{-(\text{density} \cdot z)^2} \quad (\text{GL_EXP2})$$

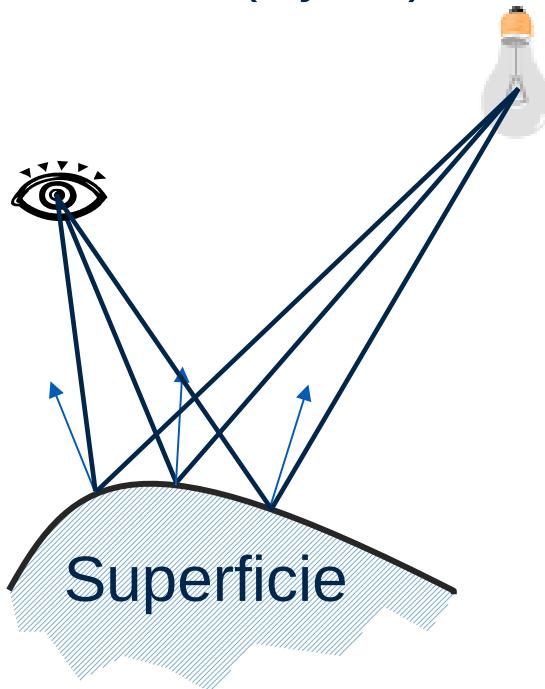
$$f = \frac{\text{end} - z}{\text{end} - \text{start}} \quad (\text{GL_LINEAR})$$

$$C = f(z_s) C_s + (1 - f(z_s)) C_f$$

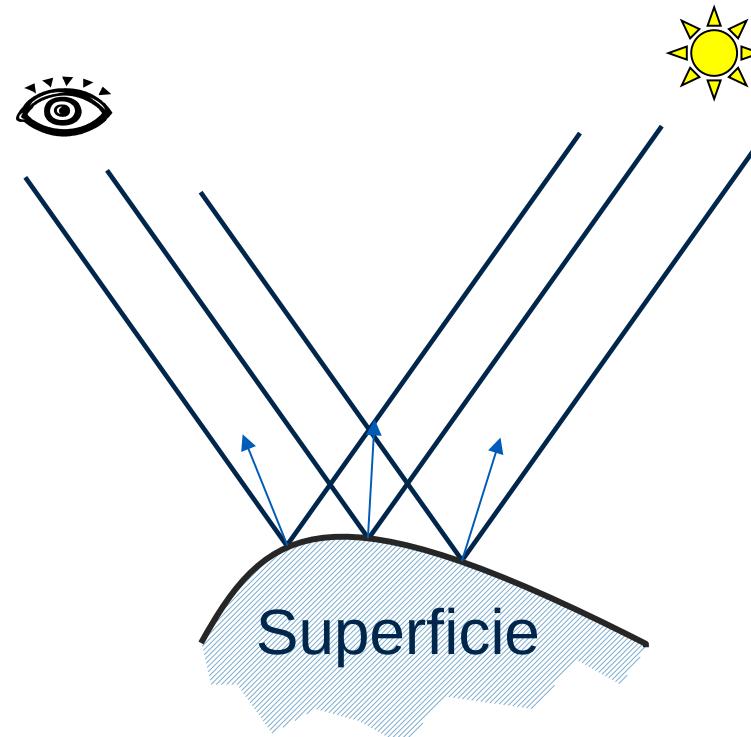


Observador y Luz: Local vs. Infinito

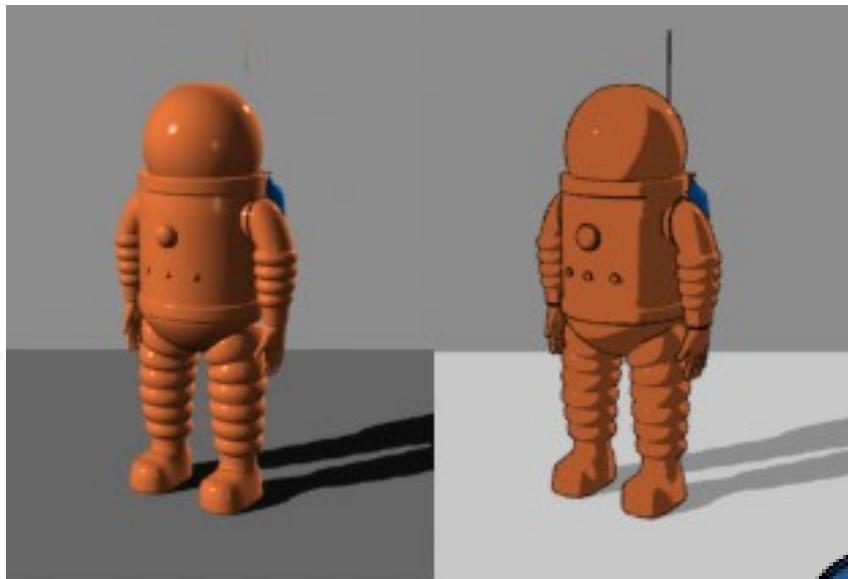
Local viewer TRUE
Luz local ($x,y,z,1$)



Local viewer FALSE
Luz direccional ($x,y,z,0$)
(bisector \mathbf{h} constante)



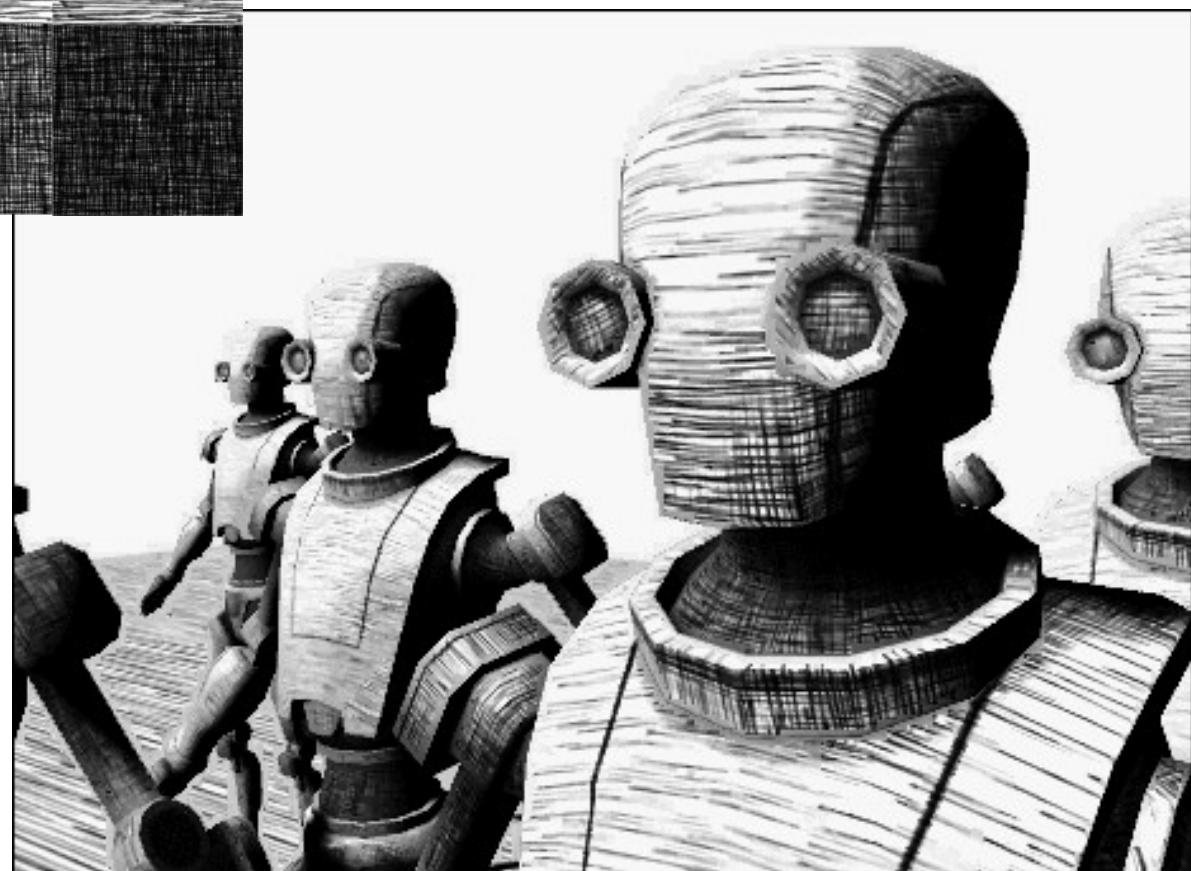
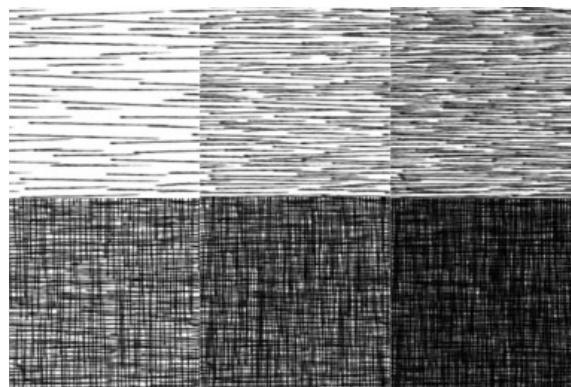
NPR: Toon Shading



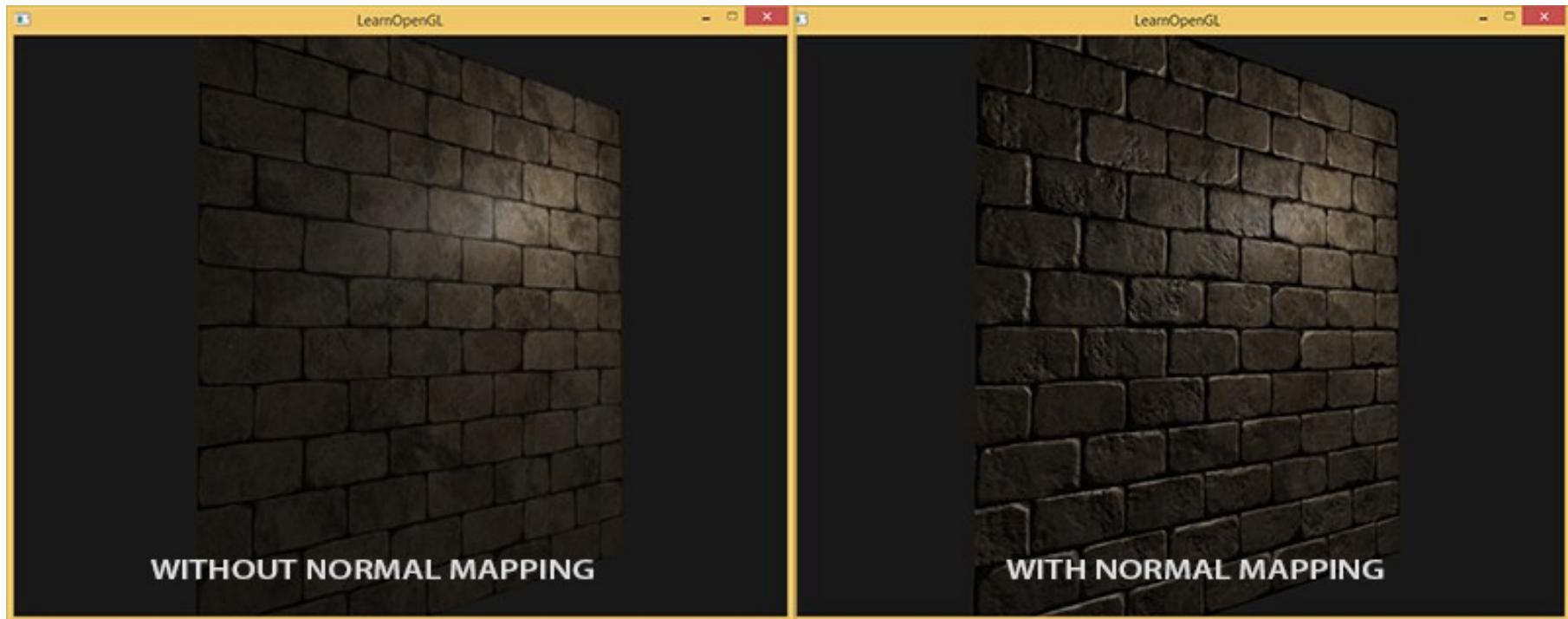
plastic shader

toon shader



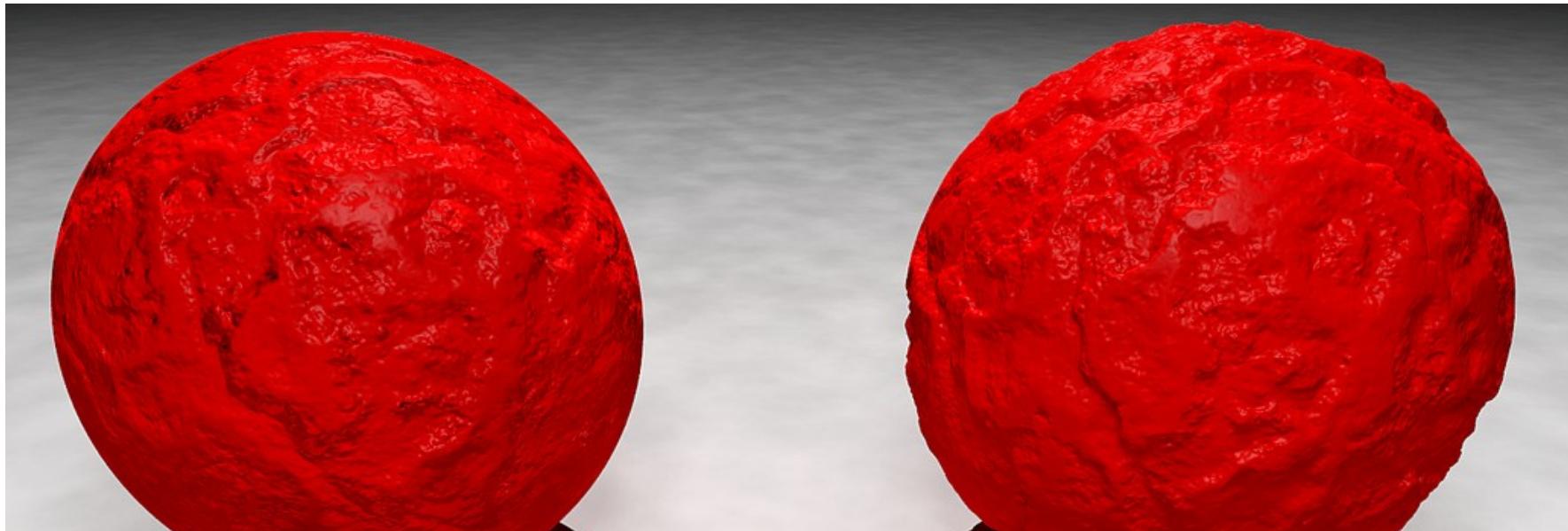
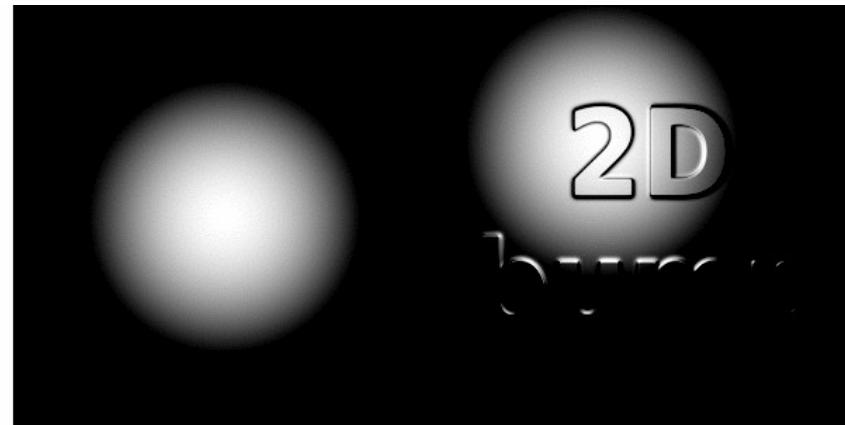


Normal Mapping

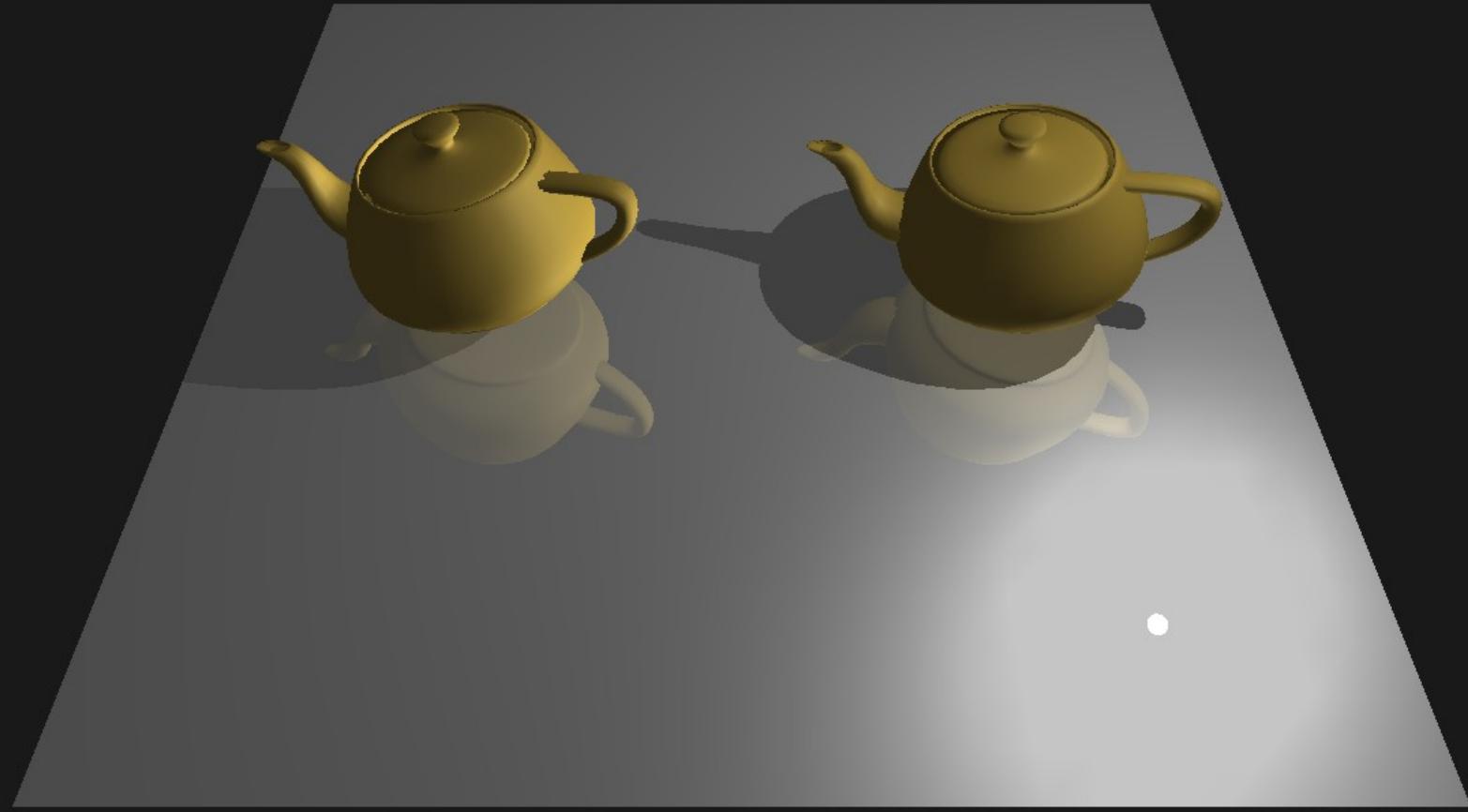


Normal Mapping

**2D
bump**



Próximamente...



Deben Saber...

- Fisiología del ojo:
 - Conos y Bastones en la Retina (función y distribución)
- Color:
 - Aditivos vs. Sustractivos (RGB/CMY/CMYK)
 - Producidos vs. Percibidos (RGB vs. HSV)
 - Diagrama CIE – Gamut
- Iluminación:
 - Concepto de Local vs. Global
 - Modelo de Phong completo (en OpenGL)
 - Modelado de Luz y Niebla
 - Tipos de Sombreado
- Práctica

