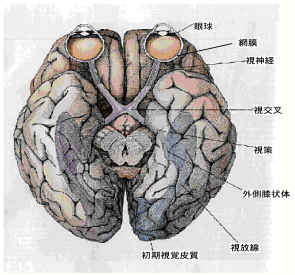
# 色覚と表色系

- 色覚のメカニズムと表色系
- 1931:CIE表色系の基礎
- 1976:均等色空間への発展
- 2002:最先端のCIE表色系
- 色覚・CIE規格・画像工学

# 人間の色覚メカニズムと表色系



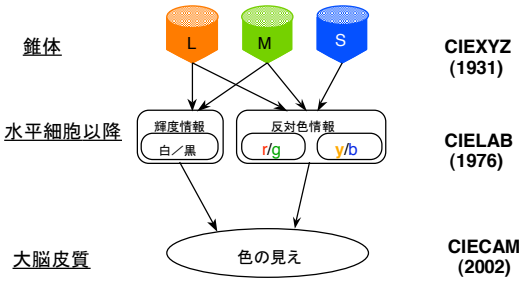

- 眼球:カメラ
- 網膜:知的入力デバイス
  - 超高感度センサー(桿体)とカラーセンサー(錐体)
  - 輝度と色の分離(水平細胞)
  - コントラスト検出(神経節細胞)
- 外側膝状体:M-経路, P-経路
  - M(全体の形状, 動き), P(色, テクスチャー)
- 大脳:V1, V2, V3, V4,下側頭皮質
  - 形, 色, 動き, 奥行きの認識, アピアランス

1931 CIEXYZ

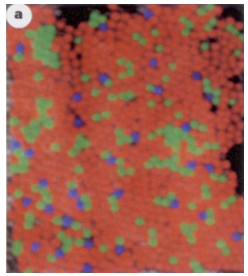
1976 CIELAB

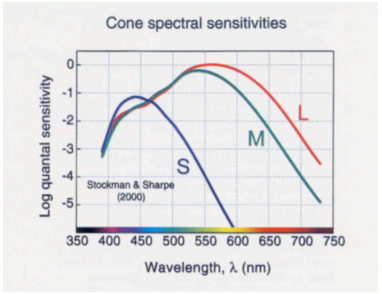
2002 CIECAM

# 色覚モデルとCIE表色系の歩み




# 光受容体—錐体—



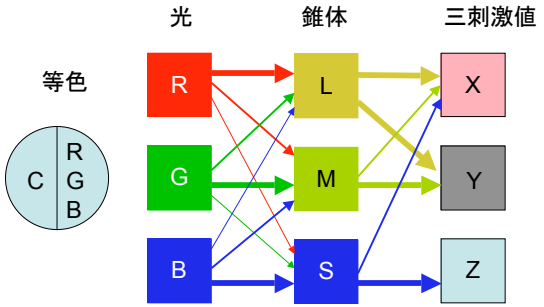




Roorda and Williams, *Nature*, 397, 520-522 (1999)

# Basic Colorimetry
## Gunter Wyszecki (1973)

- *Colorimetry is a tool used to making a prediction on whether two lights of different spectral power distributions will match in color for certain given conditions of observation.*
- *The prediction is made by determining the tristimulus values of the two visual stimuli.*
- *If the tristimulus values of a stimulus are identical to those of the other stimulus, a color match will be observed by an average observer with normal color vision.*

# 等色と三刺激値



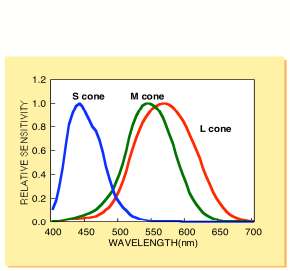

# 基礎となる表色系

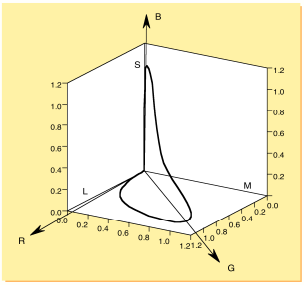
- **LMS (錐体刺激値)**
- **RGB (光の三刺激値)**
- **XYZ (三刺激値)**

全て光の量である。

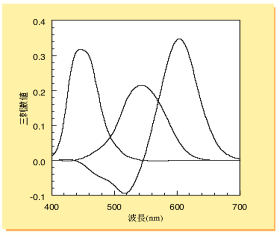
物理量（放射量）に線形な尺度。

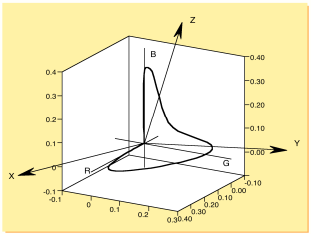
# LMS
# (生理学的色空間)



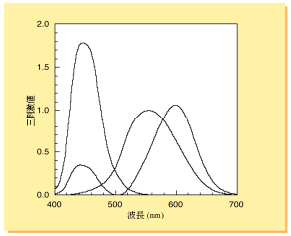



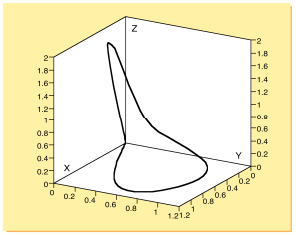
## RGB
## (物理的色空間)



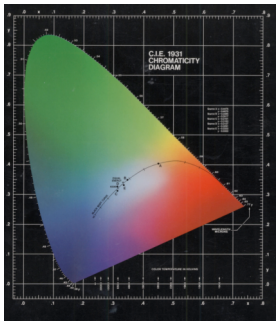

## XYZ
## (数学的色空間)




## CIE1931XYZ表色系の
## (x, y)色度座標と(x, y)色度図

- $x = X/(X+Y+Z)$
- $y = Y/(X+Y+Z)$
- $z = Z/(X+Y+Z)$
- $x+y+z = 1$
- $X = xY/y$
- $Z = (1-x-y)Y/y$
- $Y$, $(x, y)$




## Advanced Colorimetry
### Gunter Wyszecki (1973)

- ***Colorimetry is its broader sense includes methods of assessing the appearance of color stimuli presented to the observer in complicated surroundings as they may in occur in everyday life.***
- ***This is considered the ultimate goal of colorimetry, but because of its enormous complexity, this goal is far from being reached.***

# 表色系の発展

- 均等色空間, CIE1976L*a*b*
- 色の見えモデル, CIECAM02

# CIELAB(CIE1976L*a*b*)

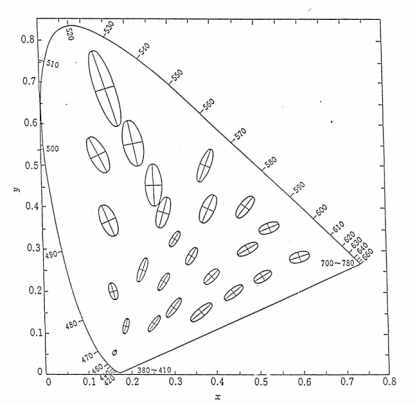
$$L^* = 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16$$

$$a^* = 500\left\{\left(\frac{X}{X_n}\right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}}\right\}$$

$$b^* = 200\left\{\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right\}$$

- 色順応
  - 照明が変化しても白い物は白い
- 非線形
  - 物理量から知覚量へ
- 反対色性
  - 輝度と色の分離

# MacAdamの楕円



# 輝度と主観的明るさ・明度

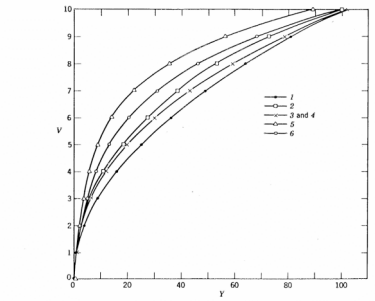
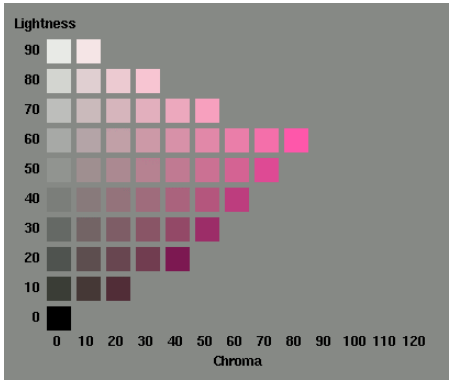
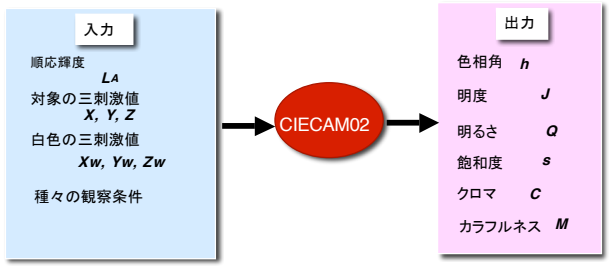



Fig. 2(6.3). Relationship between lightness-scale value $V$ and luminance factor $Y$ plotted in accordance with different formulae [see Table 1(6.3)]. 1: Priest, Gibson, and McNicholas (1920); 2: Munsell, Sloan, and Godlove (1933); Godlove (1933); 3: Newhall, Nickerson and Judd (1943) (also known as the *Munsell Renotation-Value Scale*); 4: CIE (1976) lightness scale (plotting $V = L^*/10$); 5: Foss (1944) (gray scale of the *Color Harmony Manual*); 6: Richter (1953) (gray scale of the German *DIN Color Chart*; plotting $V = 10 - D$).

## CIELAB色空間(h=0deg)

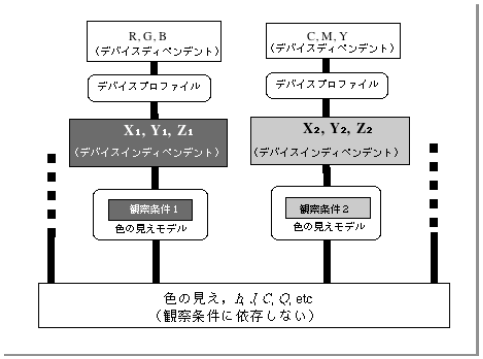



## CIE色の見えモデル (CIECAM02)




## CIECAMの応用

—異なる画像メディアにおける色情報伝達—




## 視覚情報の流れと画像工学への応用

映像情報メディア学会誌, Vol. 54, 1234–1238 (2000)