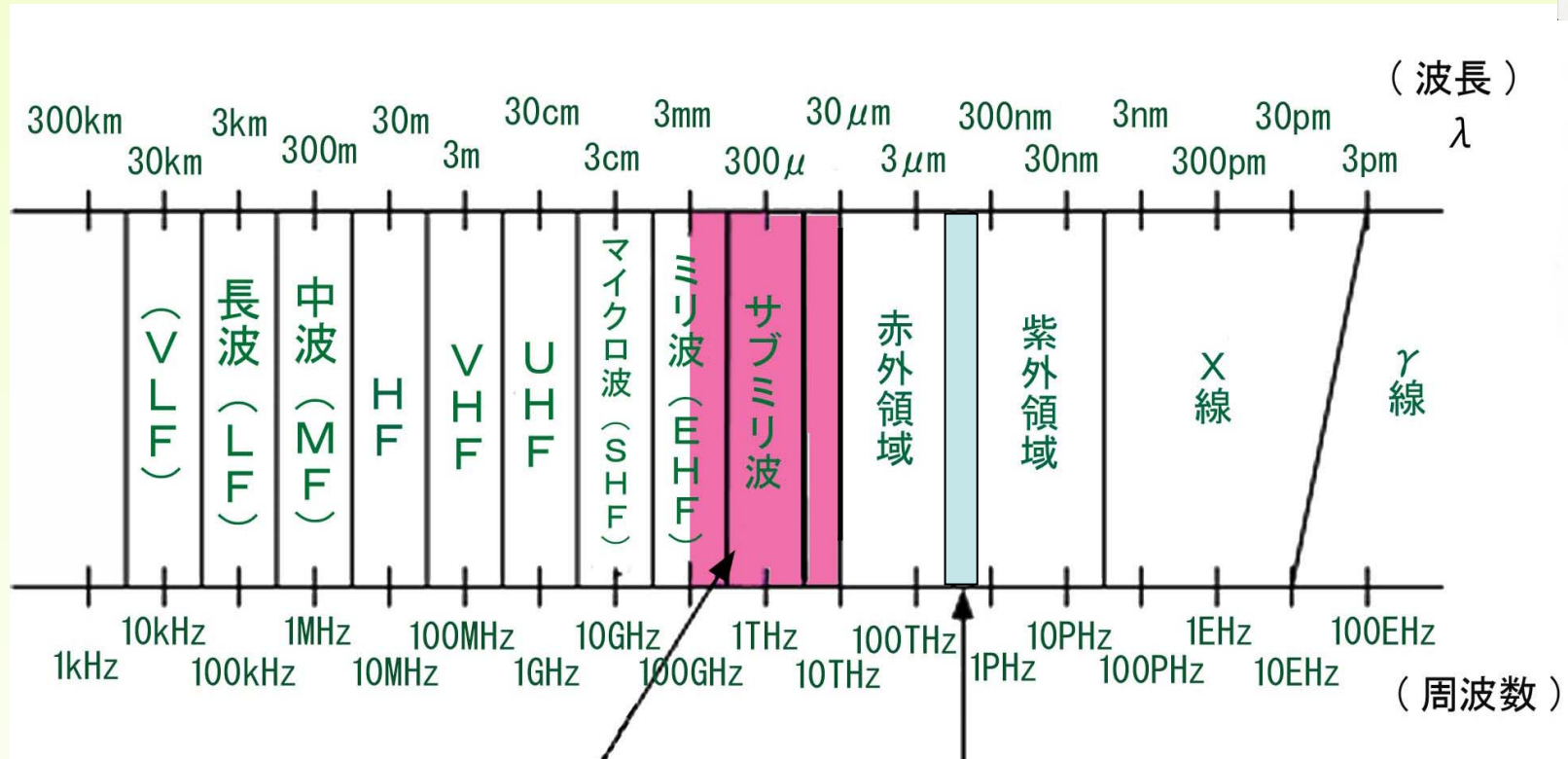


# 生物の光反射特性

授業の目的: 生物がもつ独特の反射特性についての知見を深めると同時にマシンビジョンシステム設計のシミュレーションに関して基礎的な事項を習得する。



# 電磁波の分類



テラヘルツ帯  
(光と電波の中間)

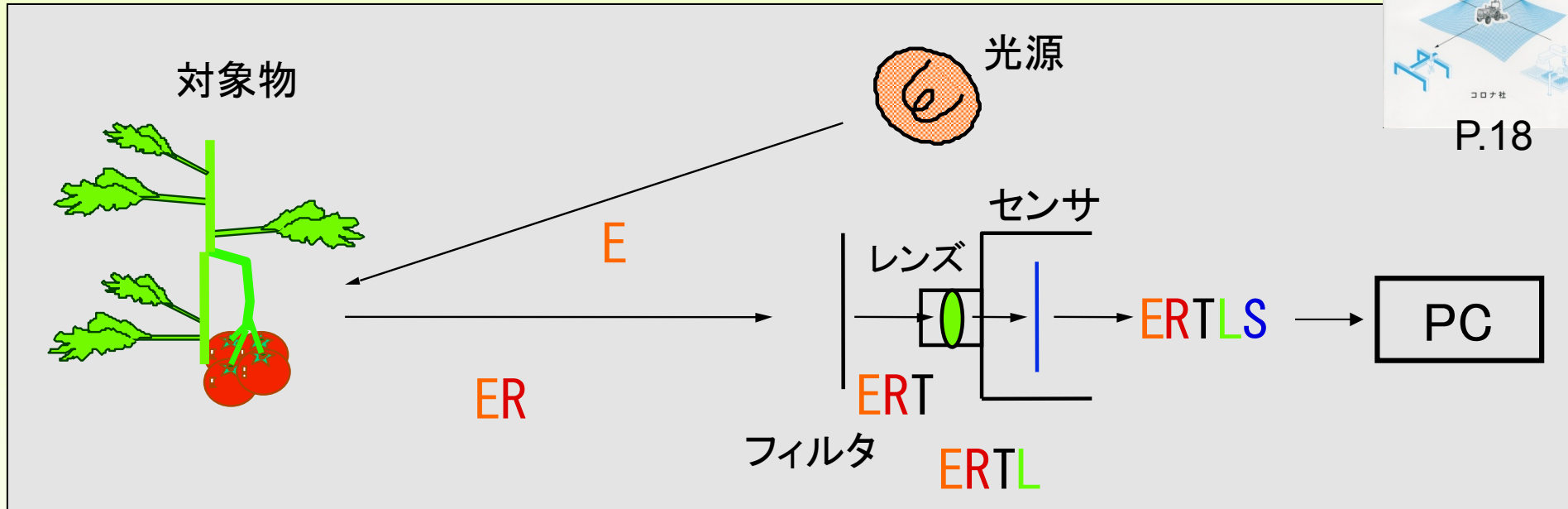
可視領域



# エネルギーの流れ (Energy Flow)



P.18



光源の放射エネルギー :  $E$

対象物  $j$  の反射特性 :  $R_j$

フィルタの透過率 :  $T$

レンズの透過率 :  $L$

撮像素子の感度 :  $S$

対象物  $j$  のセンサの出力 :  $O_j$

フィルタの番号 :  $i$  ( $i=1, 2$ )

対象物 :  $j$  ( $j= a, b$ )

$$\text{対象物aの出力 } O_{ai} = \sum E R_a T_i L S \Delta \lambda$$

$$\text{対象物bの出力 } O_{bi} = \sum E R_b T_i L S \Delta \lambda$$

$$\text{評価関数 } C = \frac{O_{a2} - O_{a1}}{O_{a1} + O_{a2}} - \frac{O_{b2} - O_{b1}}{O_{b1} + O_{b2}}$$

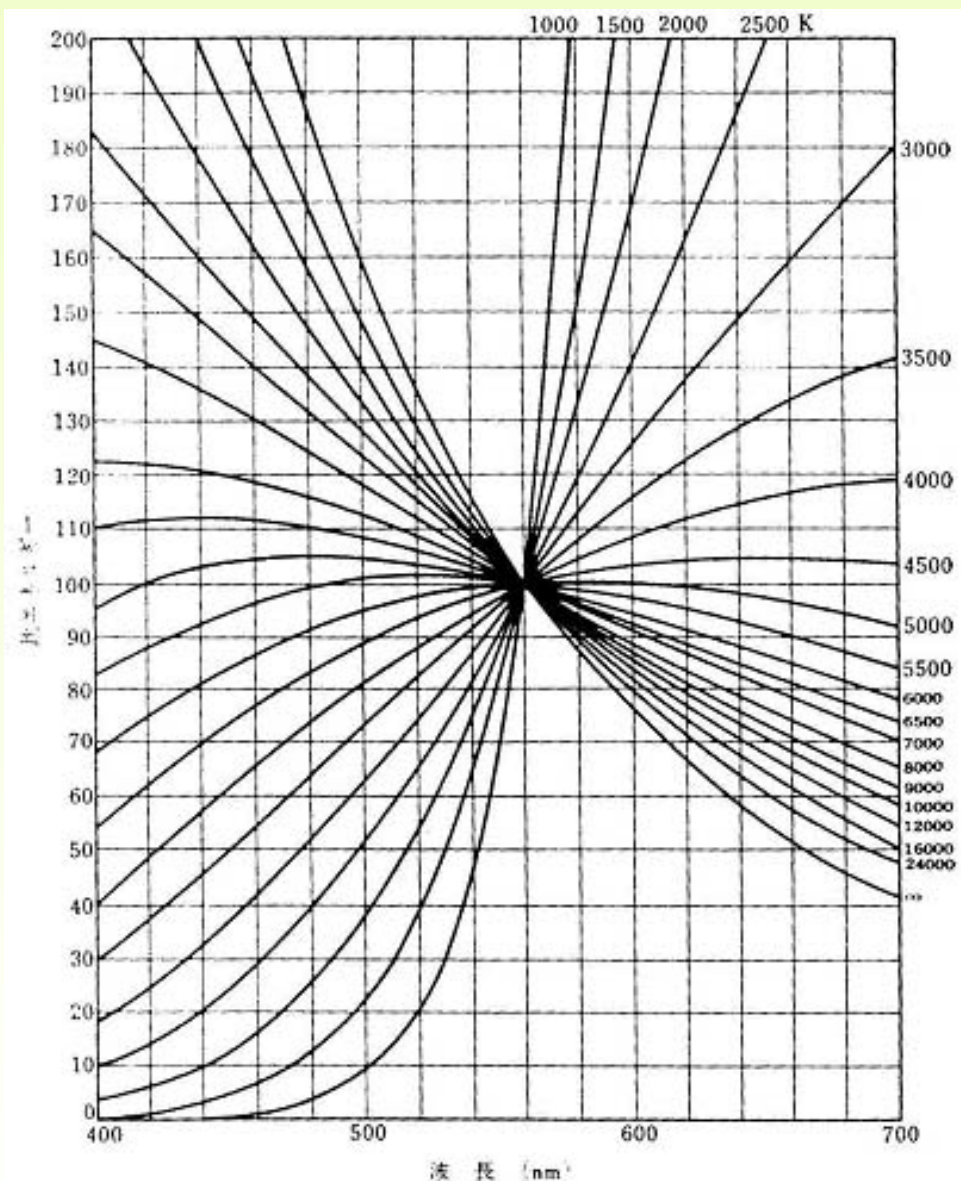
**対象物との最適なインターフェースを構築するには、各要素のモデル化、数式化を図ることが必要**



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# 光源の放射エネルギー (Radiation Energy of Light Source)



黒体の分光分布

光源の種類: 太陽光、ハロゲン、白熱灯  
蛍光灯、LED、HID等

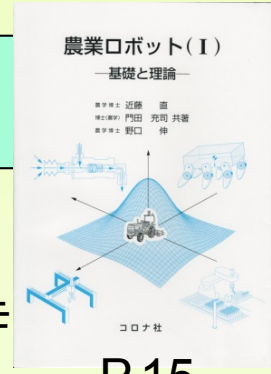
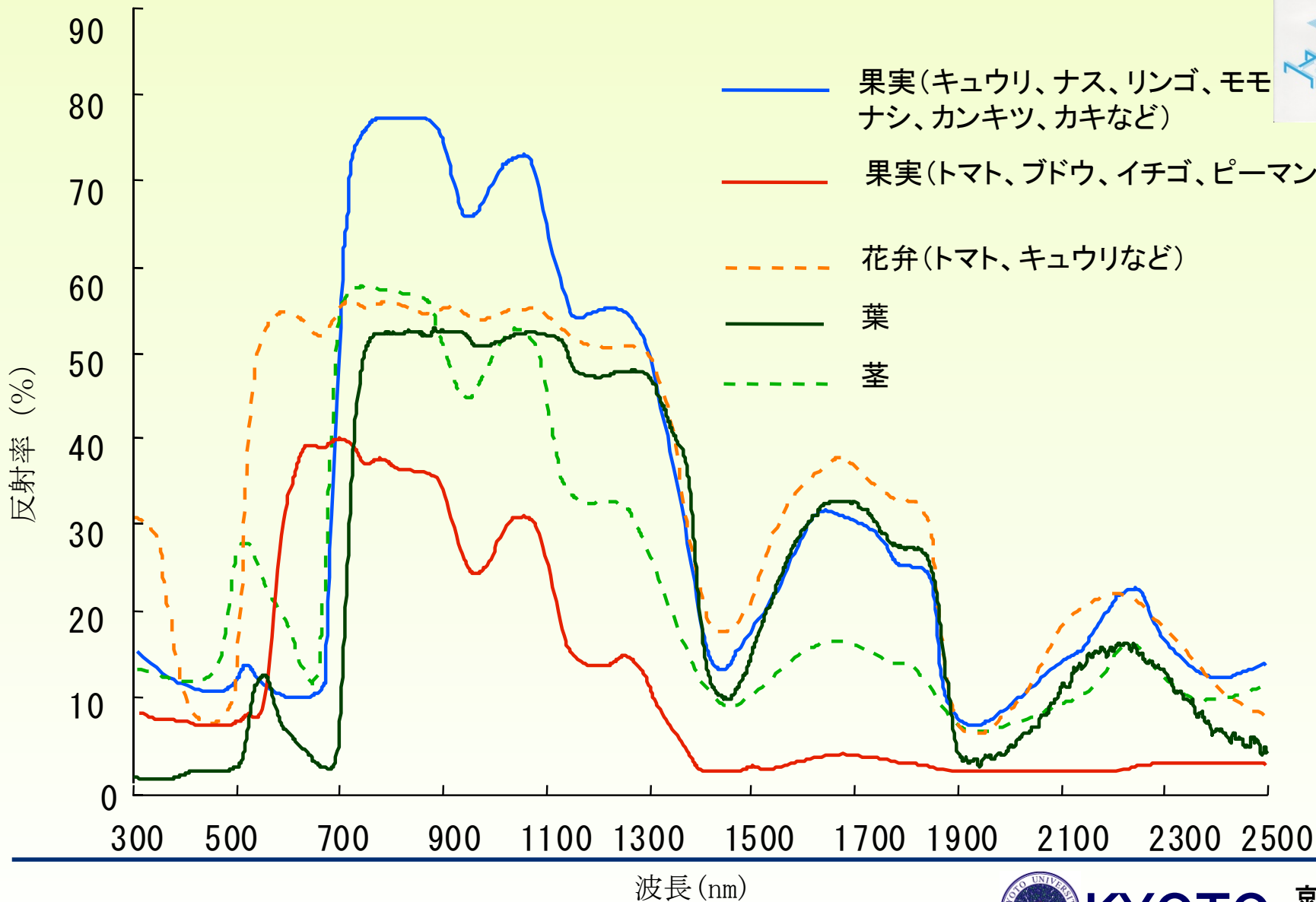
プランクの放射則

$$E_{\lambda} = \frac{C_1}{\lambda^5 (e^{C_2/\lambda T} - 1)}$$

$T$ : 色温度 (K)  
 $C_1 = 3.740 \times 10^{20}$  (W·m<sup>-2</sup>·nm<sup>4</sup>)  
 $C_2 = 1.438 \times 10^7$  (nm·deg)

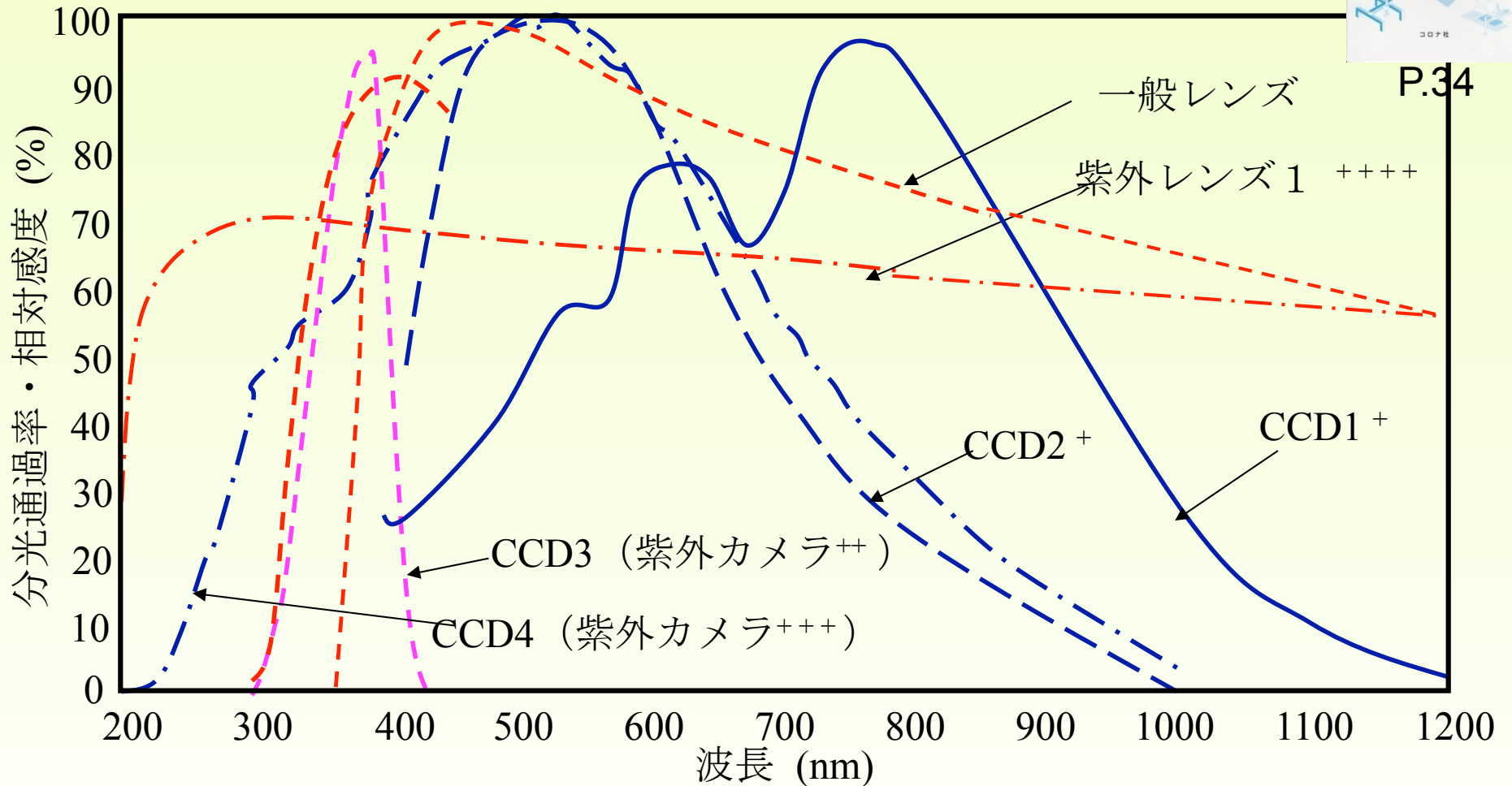


# 植物各部位の反射特性 (Spectral Reflectance)



P.15

# 撮像素子の感度およびレンズの透過率



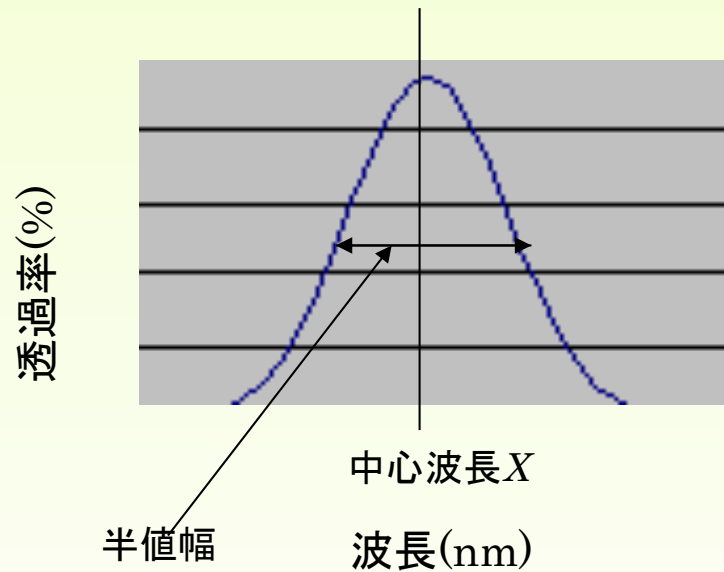
P.34

撮像素子の感度およびレンズの透過率 (+東京電子カタログ、++蝶理イメージングカタログ、+++ソニーカタログ、++++ペンタックス資料、)



# フィルタの透過率 Transmittance of Filter

## フィルタの透過率 $T(x)$



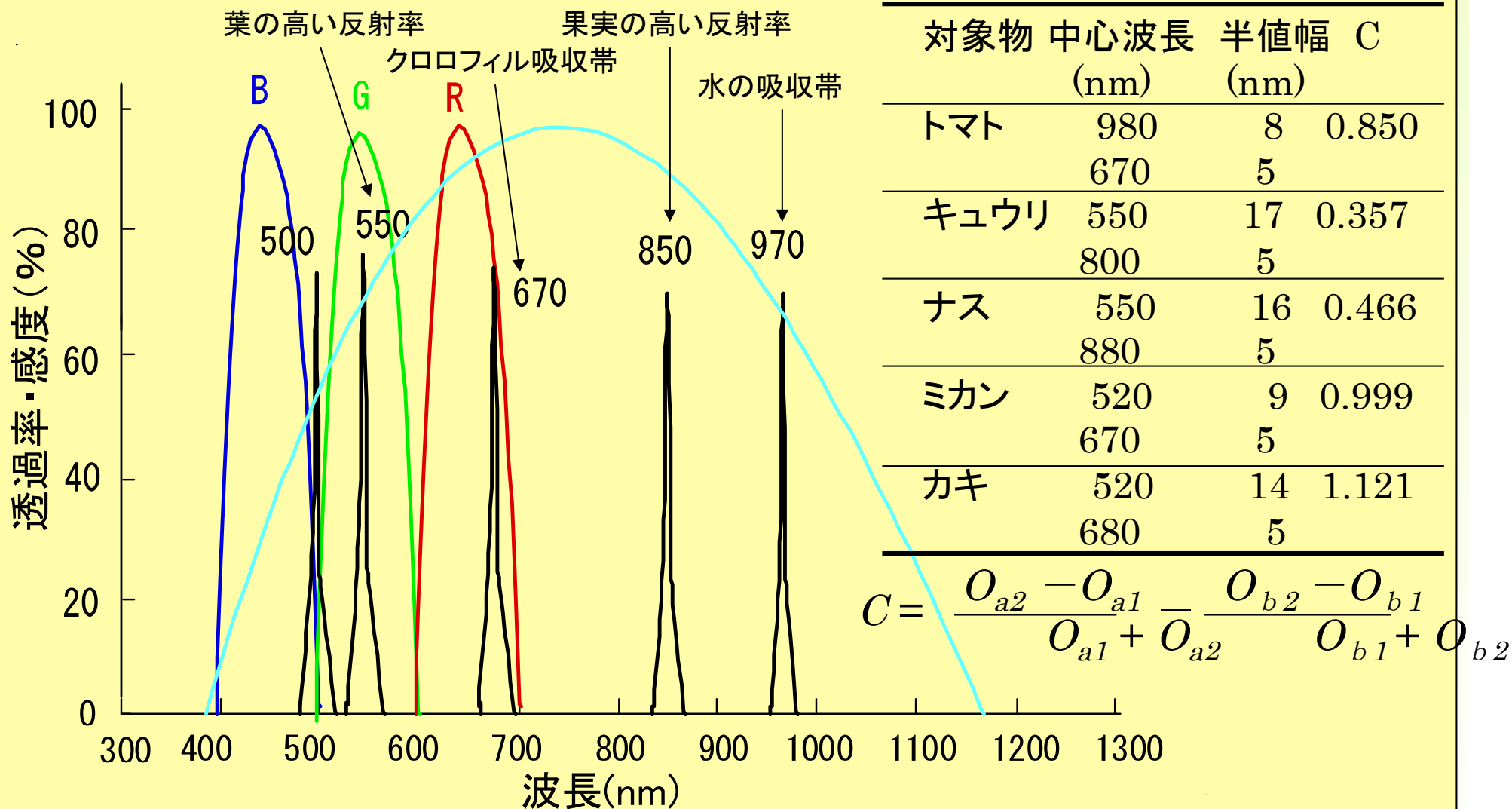
## ガウス関数

$$T(x) = N_{X,\sigma}(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x - X)^2}{2\sigma^2}\right)$$



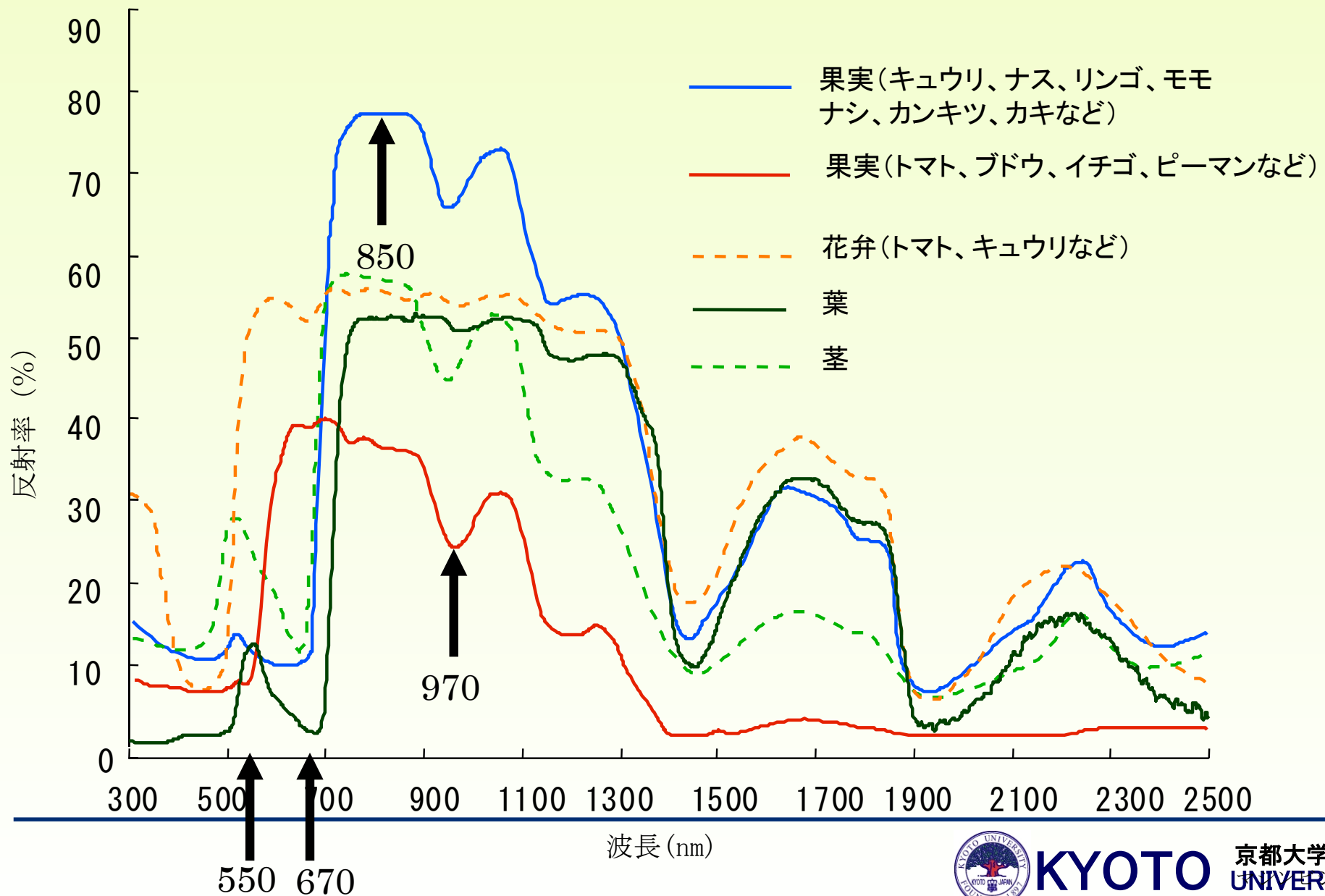
# 果実と葉の識別のための最適波長帯の例

## Most Suitable Wavelength Bands

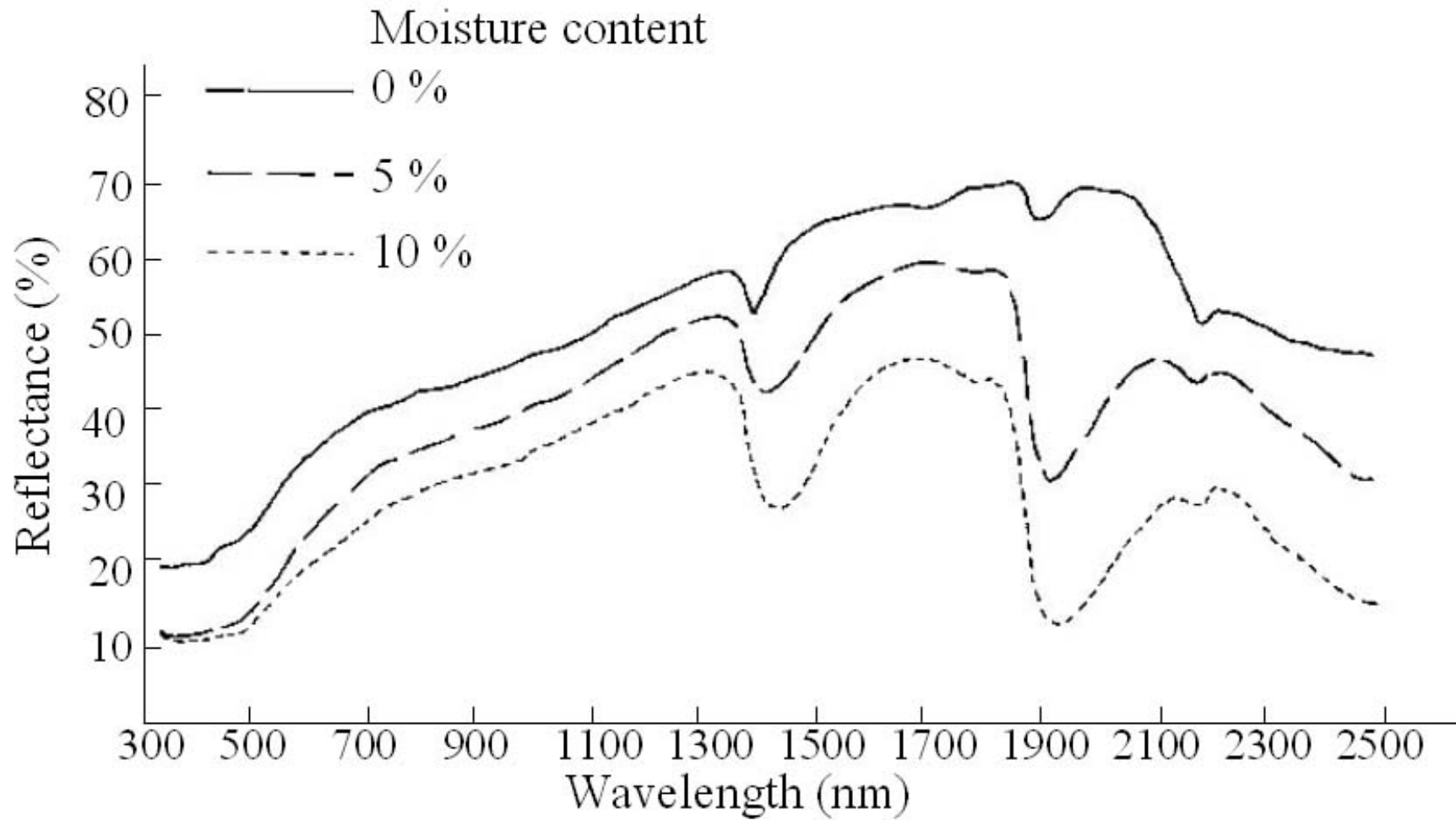




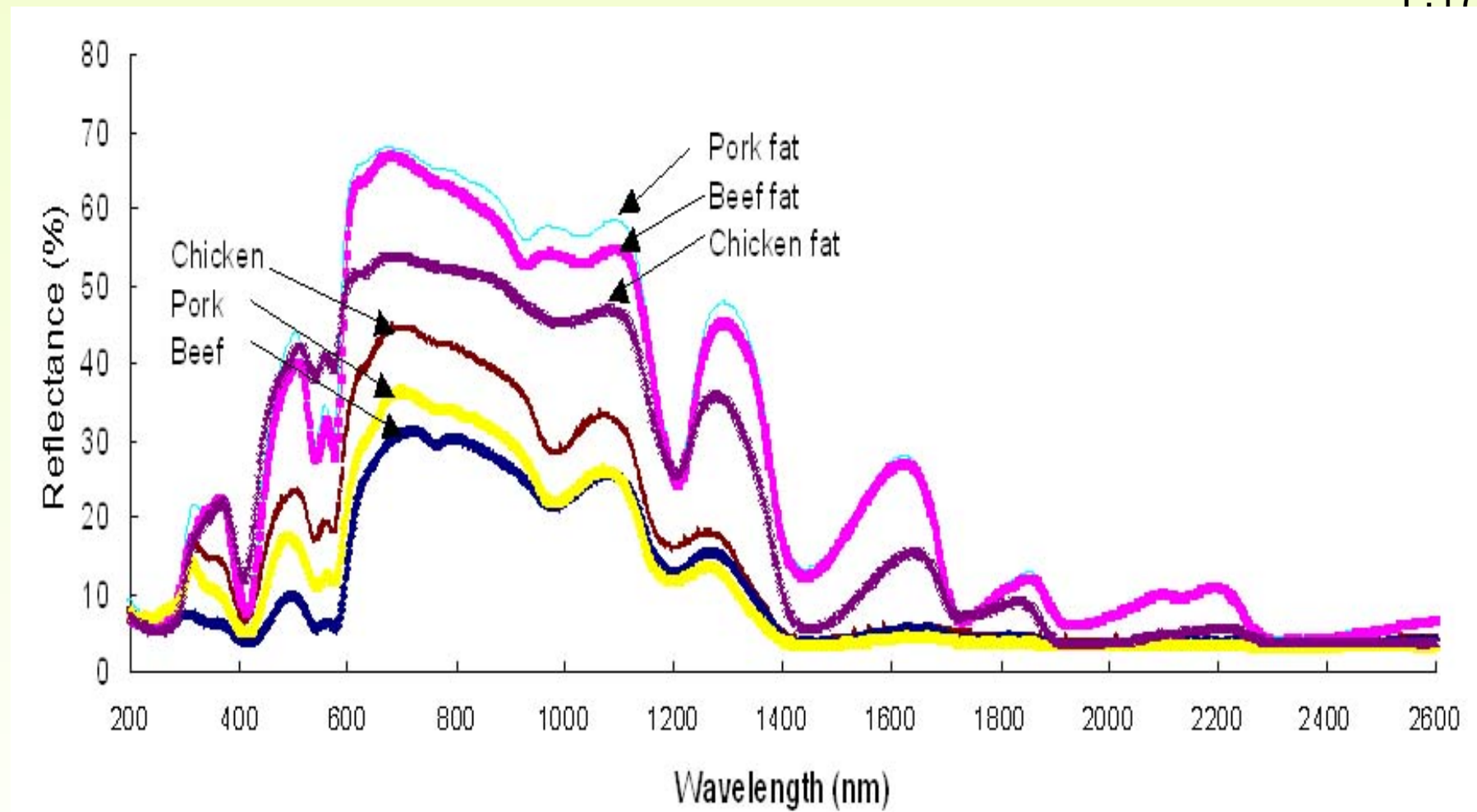
# 植物各部位の反射特性 (Spectral Reflectance)



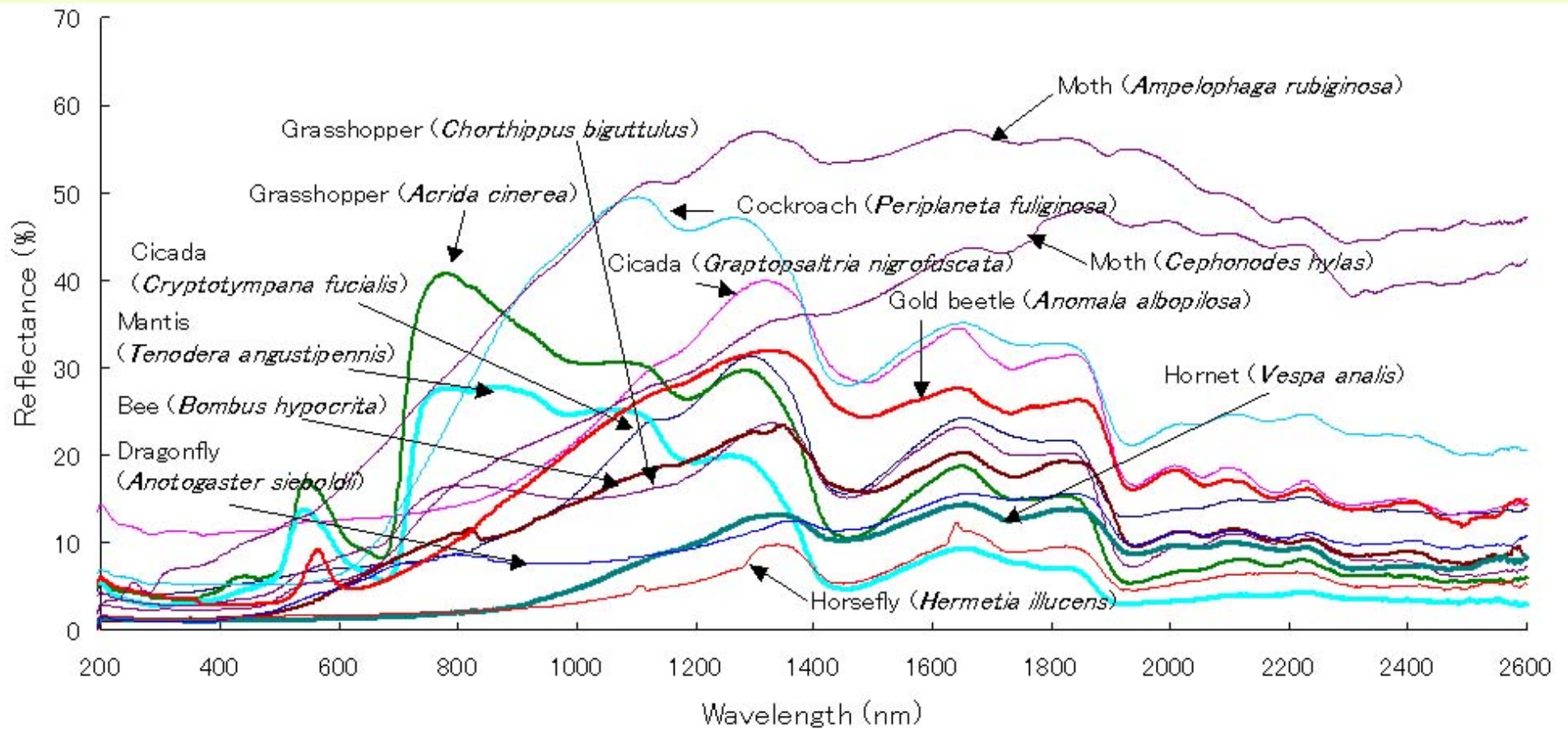
# 土壌の分光反射特性



# 牛肉、豚肉、鶏肉の分光反射特性



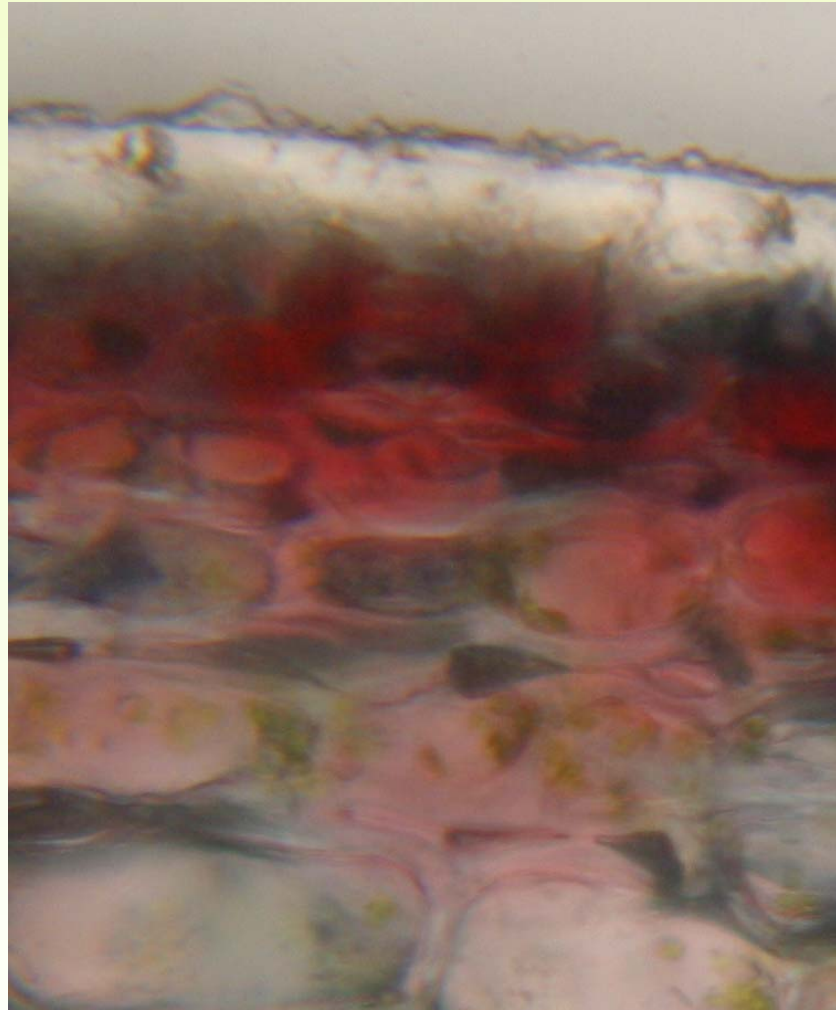
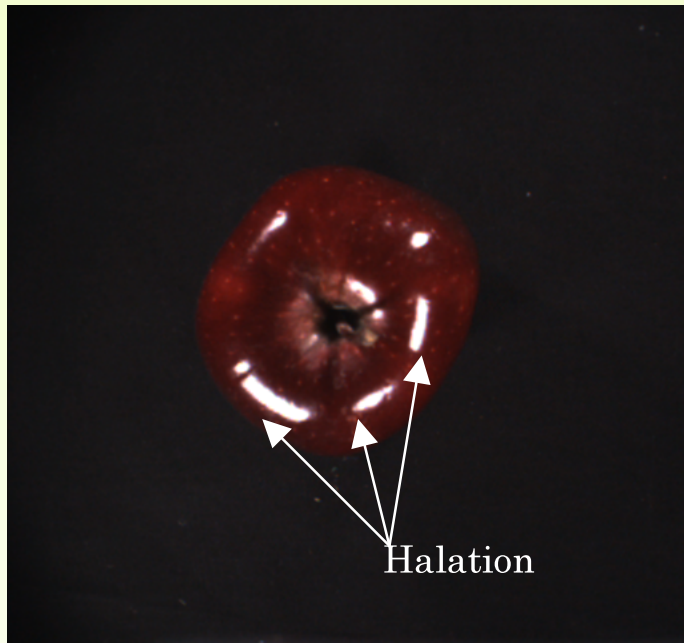
# 昆虫の胴部の分光反射特性



# ハレーション



# リンゴのクチクラ層



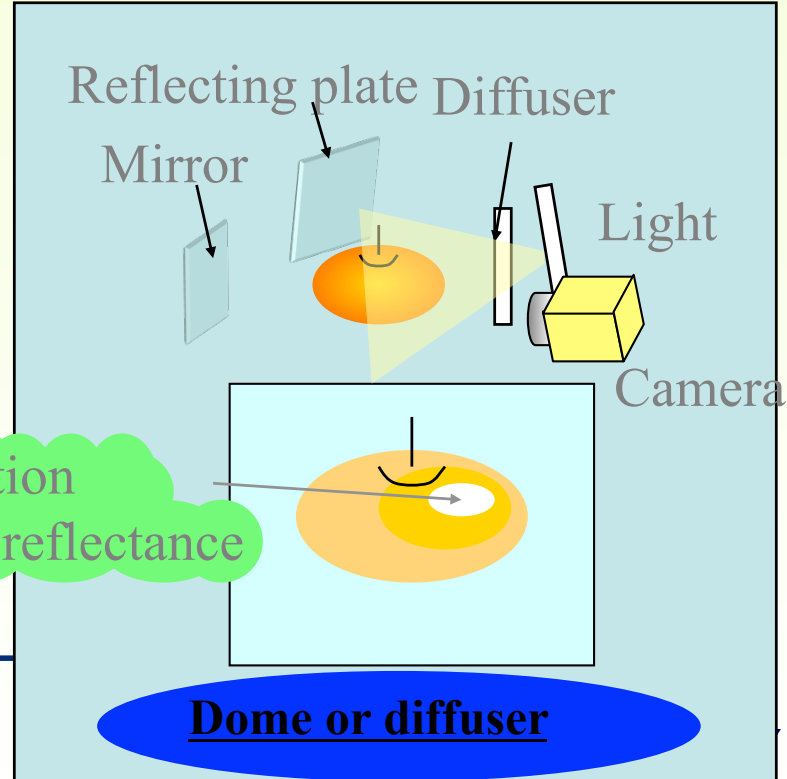
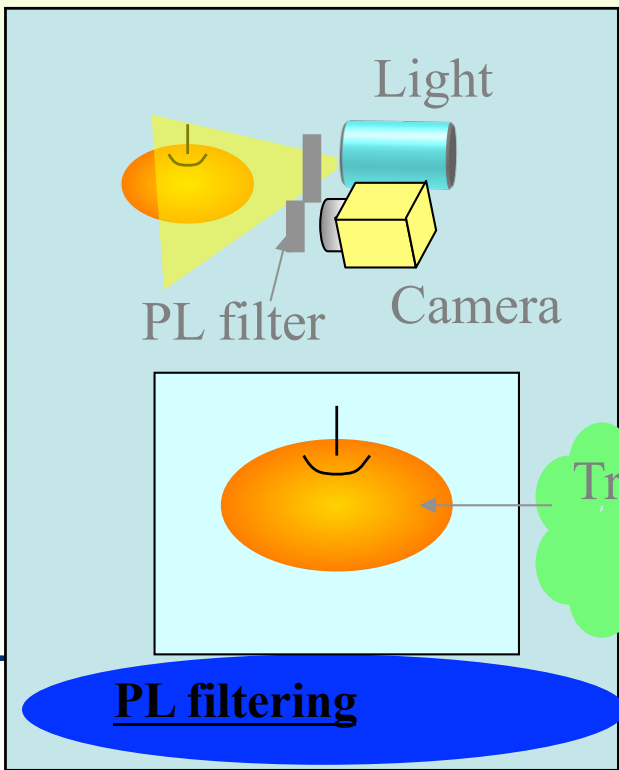
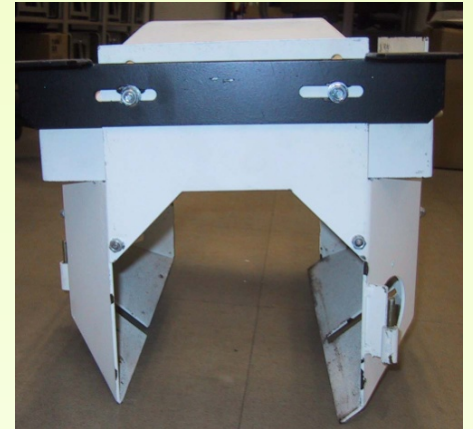
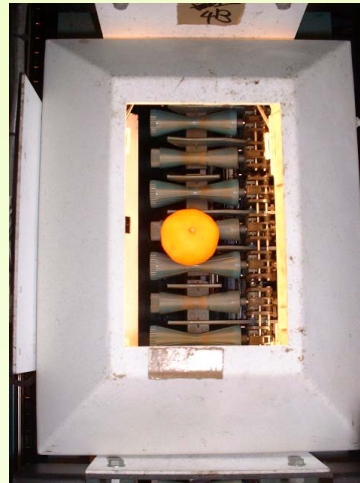
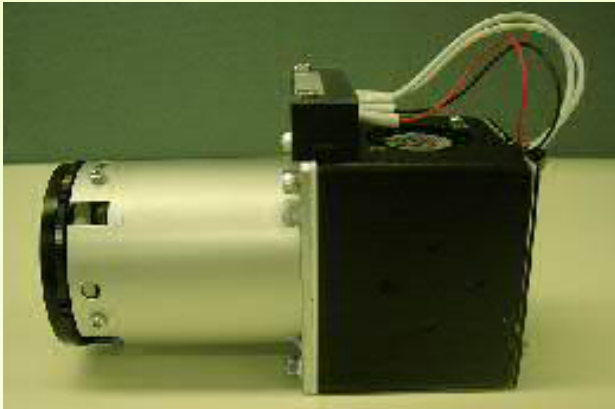
クチクラ層  
Cuticular layer

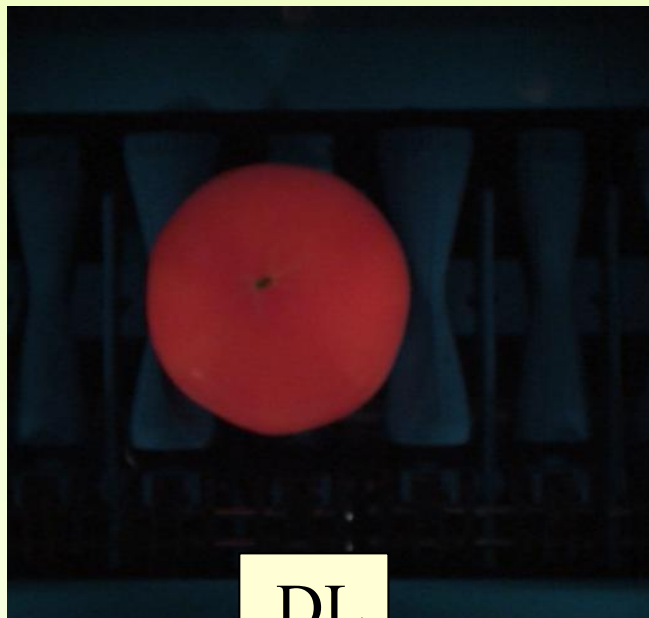
表皮細胞  
Epidermis

柔組織細胞  
Parenchyma

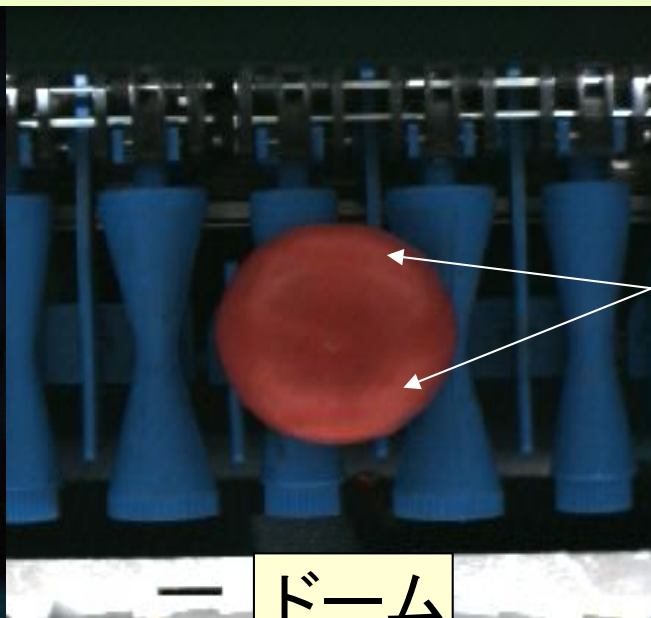


# PL filtering Light and Dome



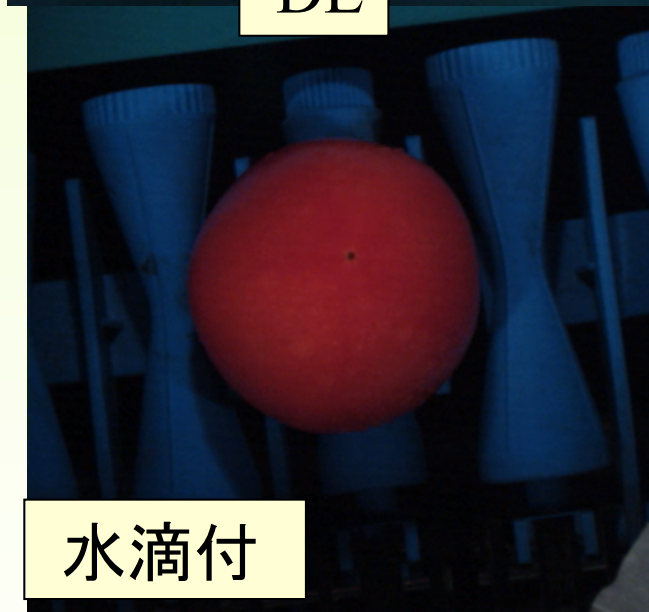


DL

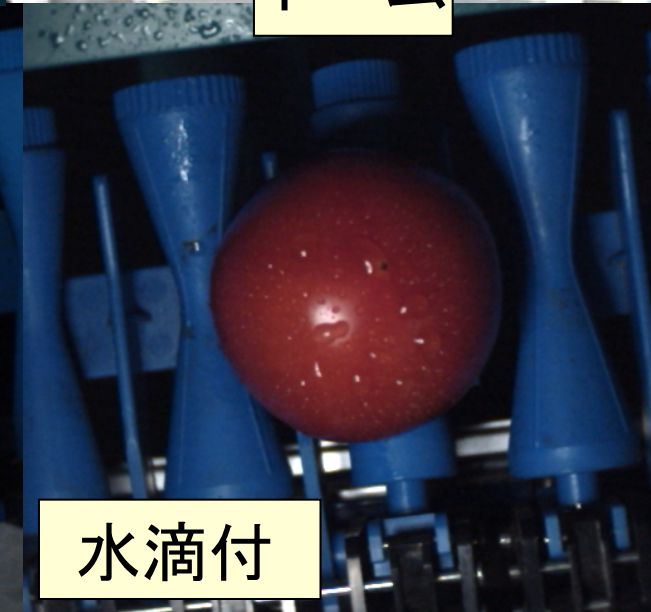


ドーム

ドームの壁面の映り込み

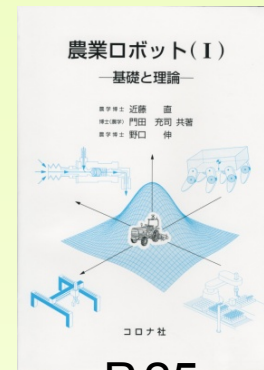


水滴付



水滴付

水滴等によるハレーション



P.25

直接照射方式と間接照射方式による相違(上)、

PLフィルタの有無による相違(下)

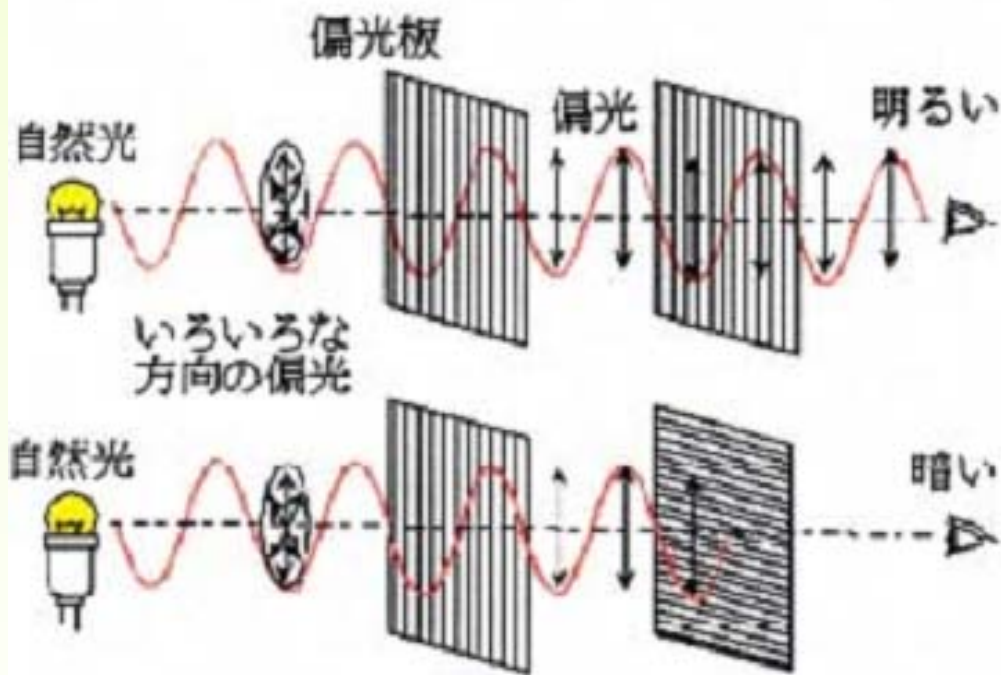
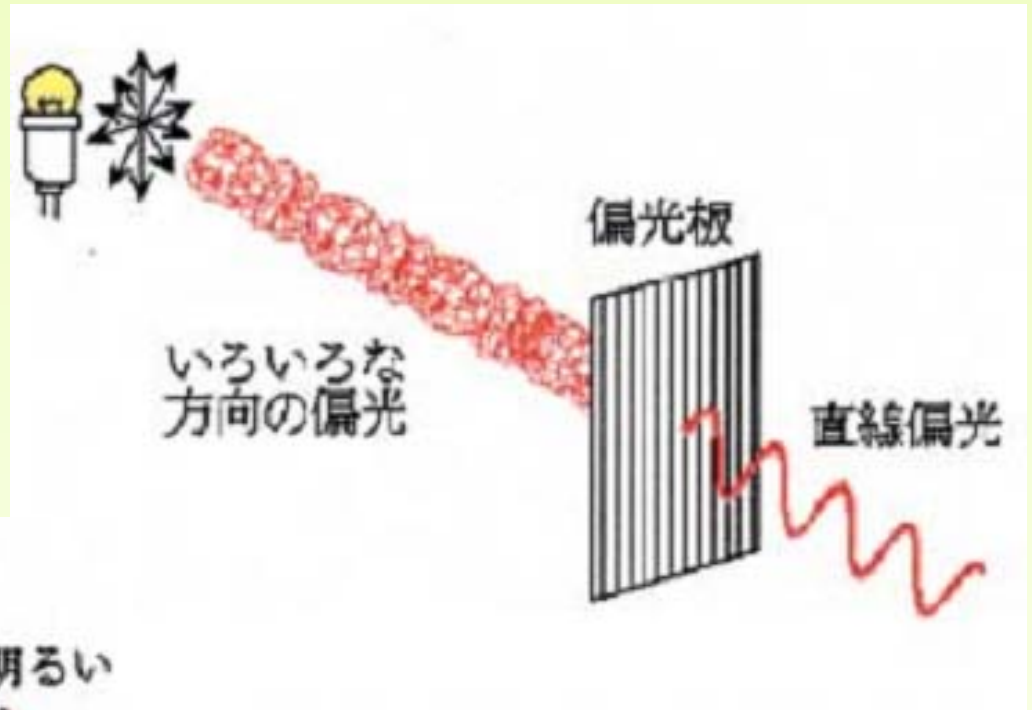


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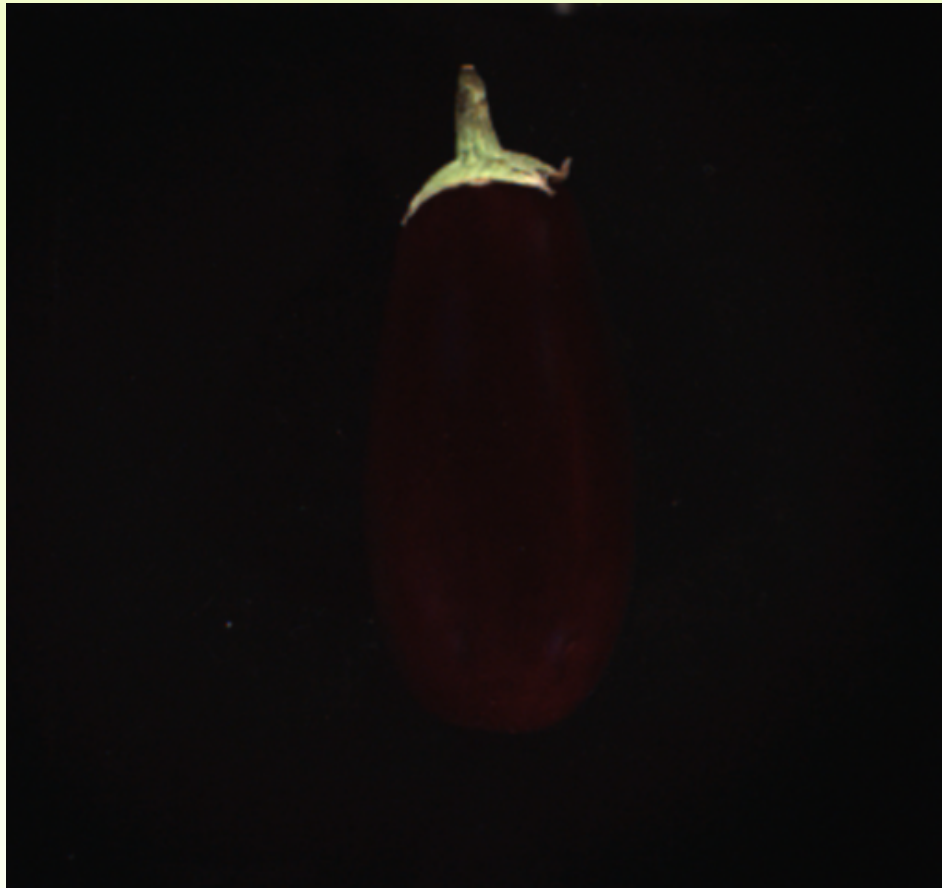
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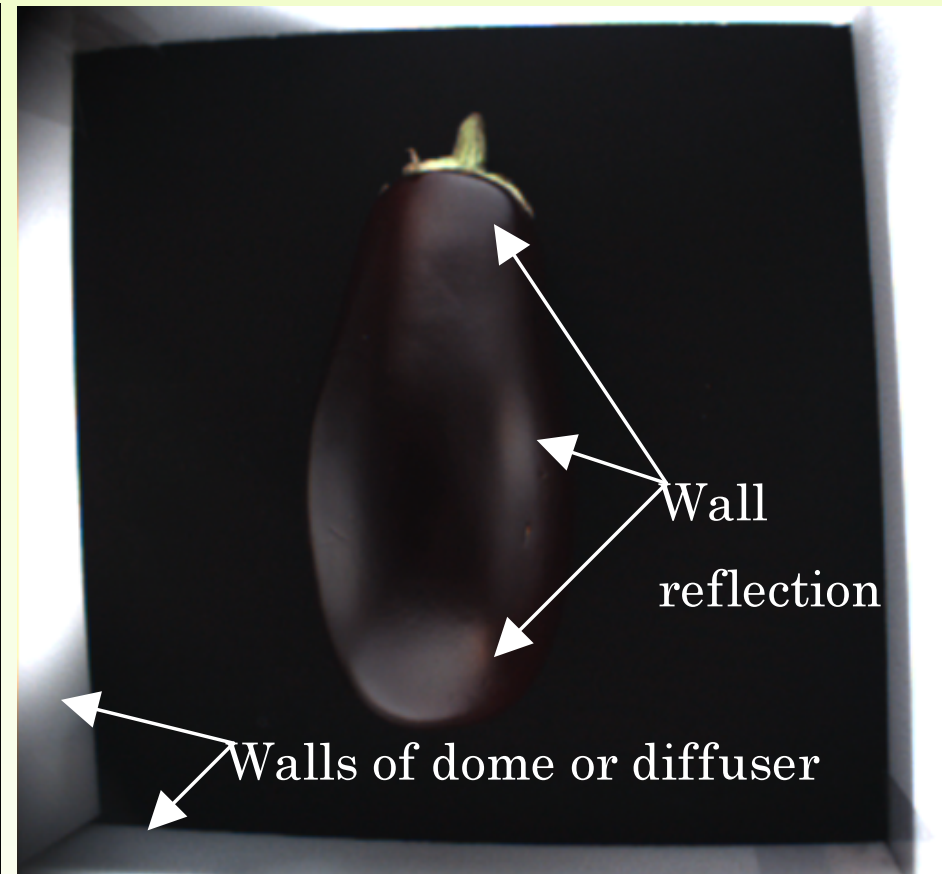
# 偏光



# Effect of PL filtering



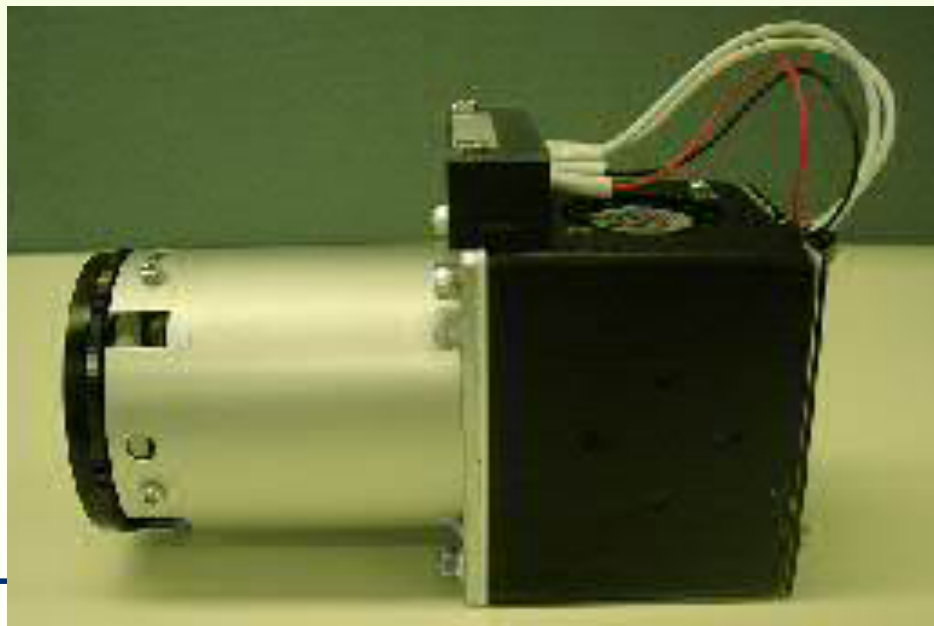
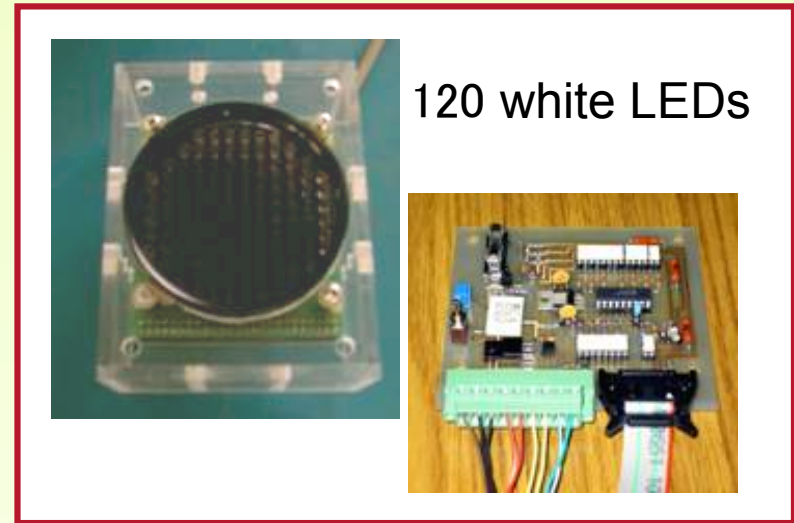
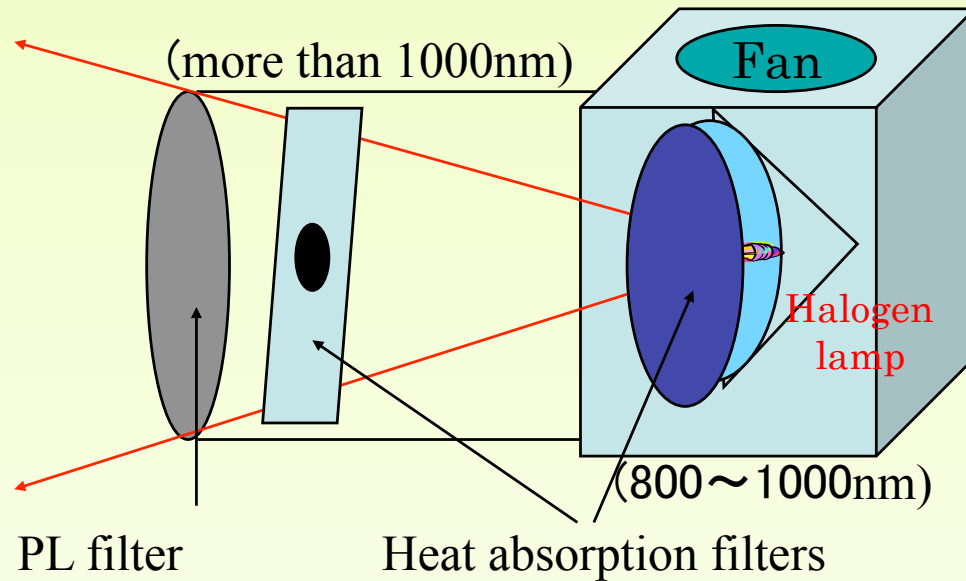
PL filtering image  
(Two PL filters are used in  
front of camera and light)



Dome image



# DL with PL filter

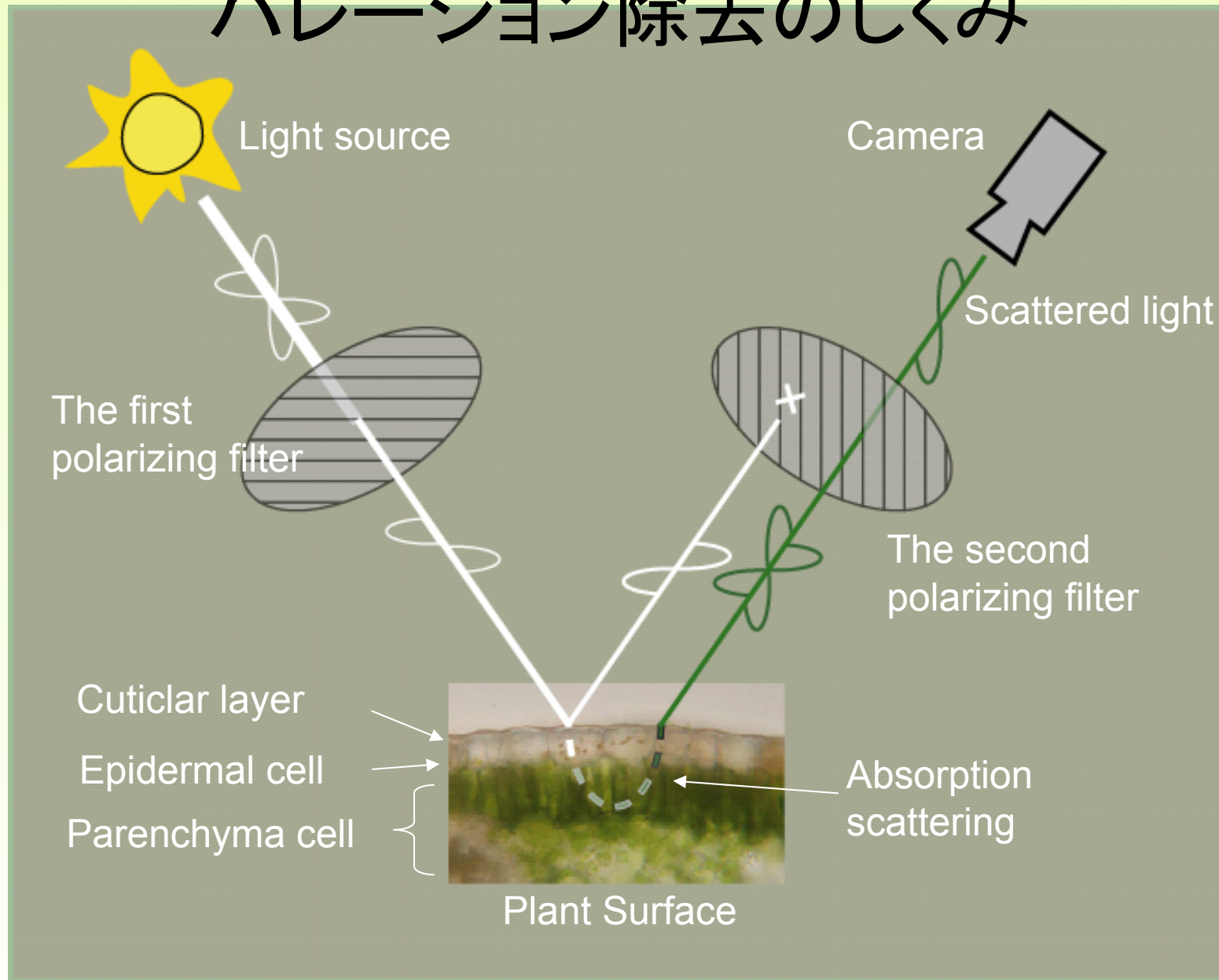


“DL” is an SI Seiko-original illumination equipment for image acquisition to make direct lighting possible.

Small power (50W) and high conversion efficiency from electricity into light.



# ハレーション除去のしくみ



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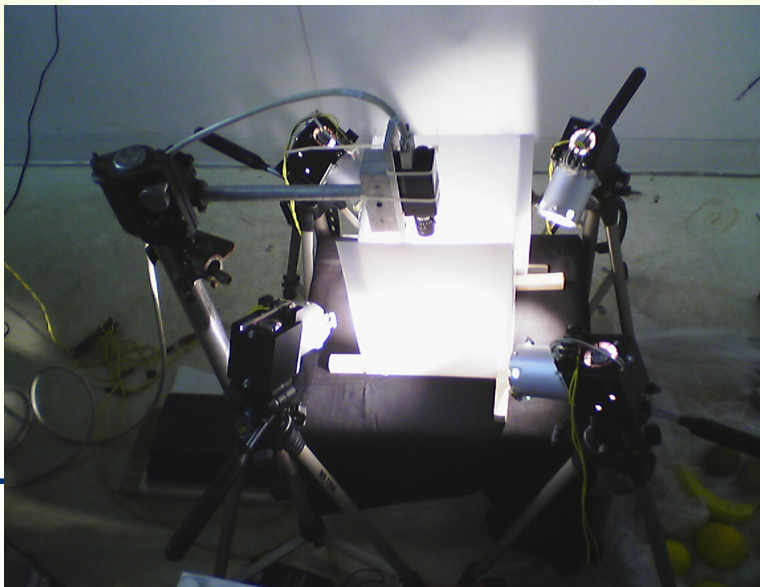
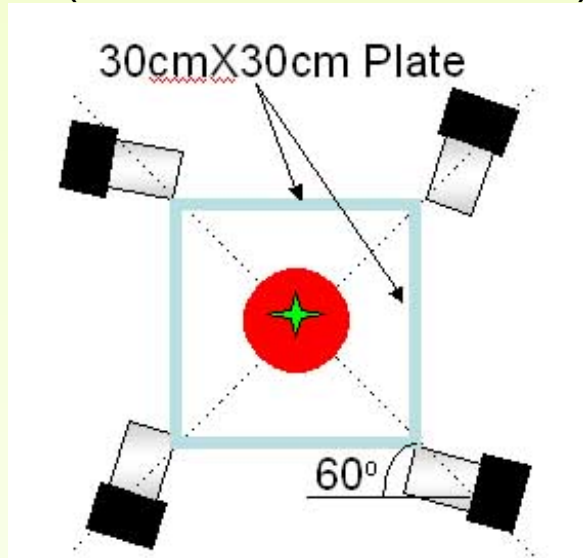
# Biological materials

- **category 1** (glossy surface fruits:  
apples, tomato, eggplant, pepper, lemon)
- **category 2** (short hair fruits or powdery fruits:  
kiwi, peach, pear, banana)
- **category 3** (root vegetables:  
potato, Daikon radish)

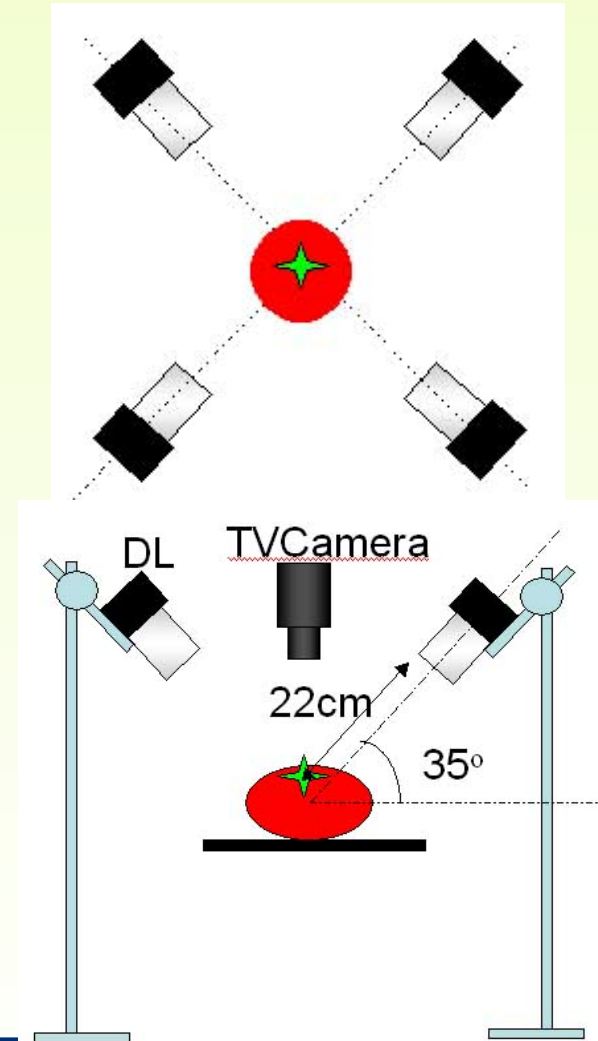


# Lighting Device Arrangement

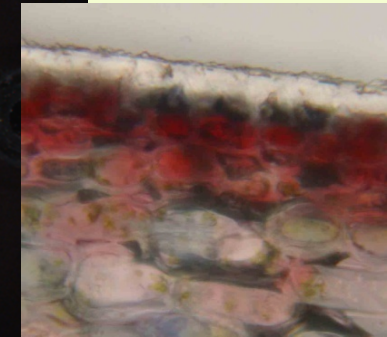
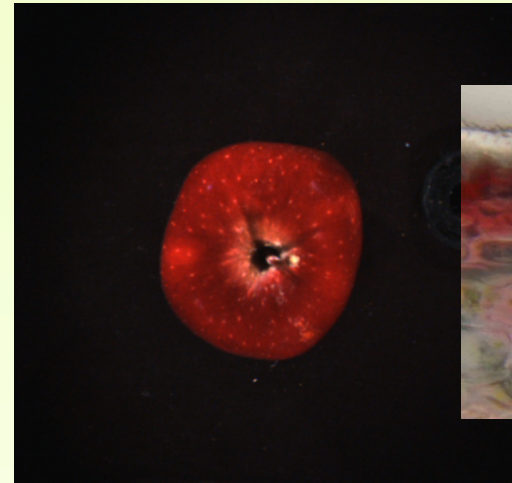
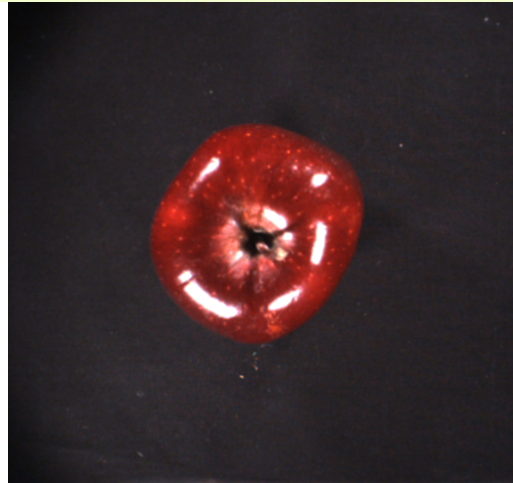
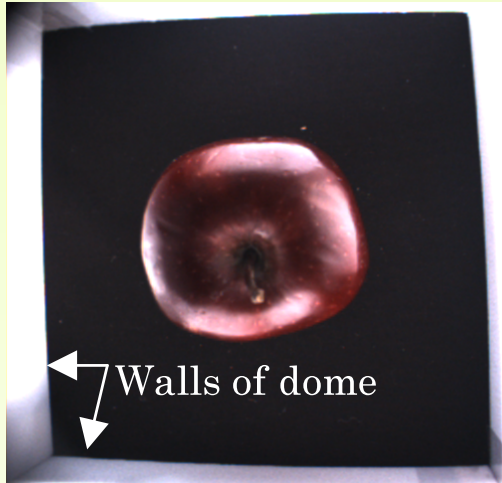
Arrangement 1  
(Dome walls and 4 DLs)



Arrangement 2 and 3  
(Diffusers or PL filters and 4 DLs)



# Category 1 (Smooth and thick cuticle)



Apple



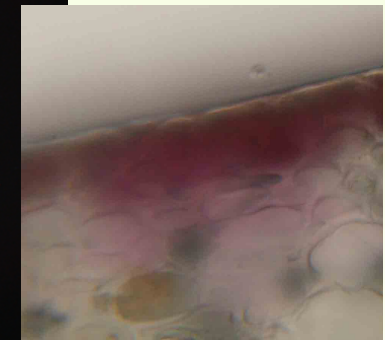
Dome



Diffuser



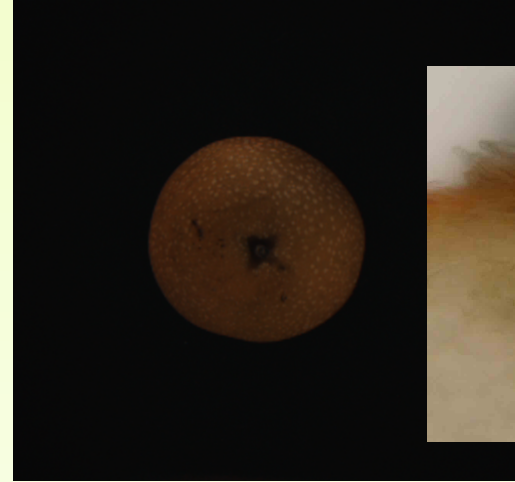
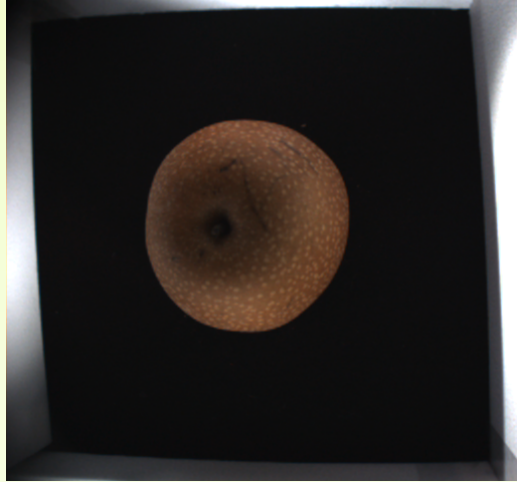
PL filter



Eggplant



# Category 2 (Rough cuticle)



Pear



Peach

Dome

Diffuser

PL filter

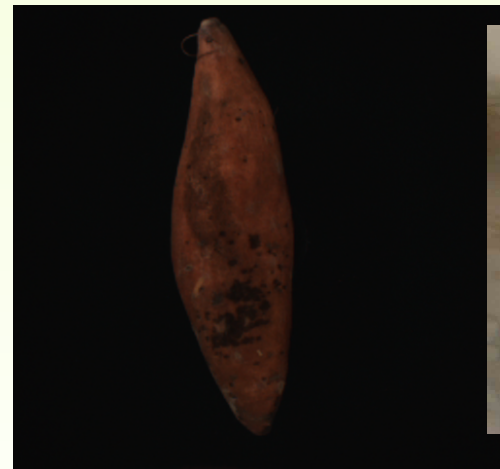




# Category 3 (No cuticle)



Daikon radish



Potato

Dome

Diffuser

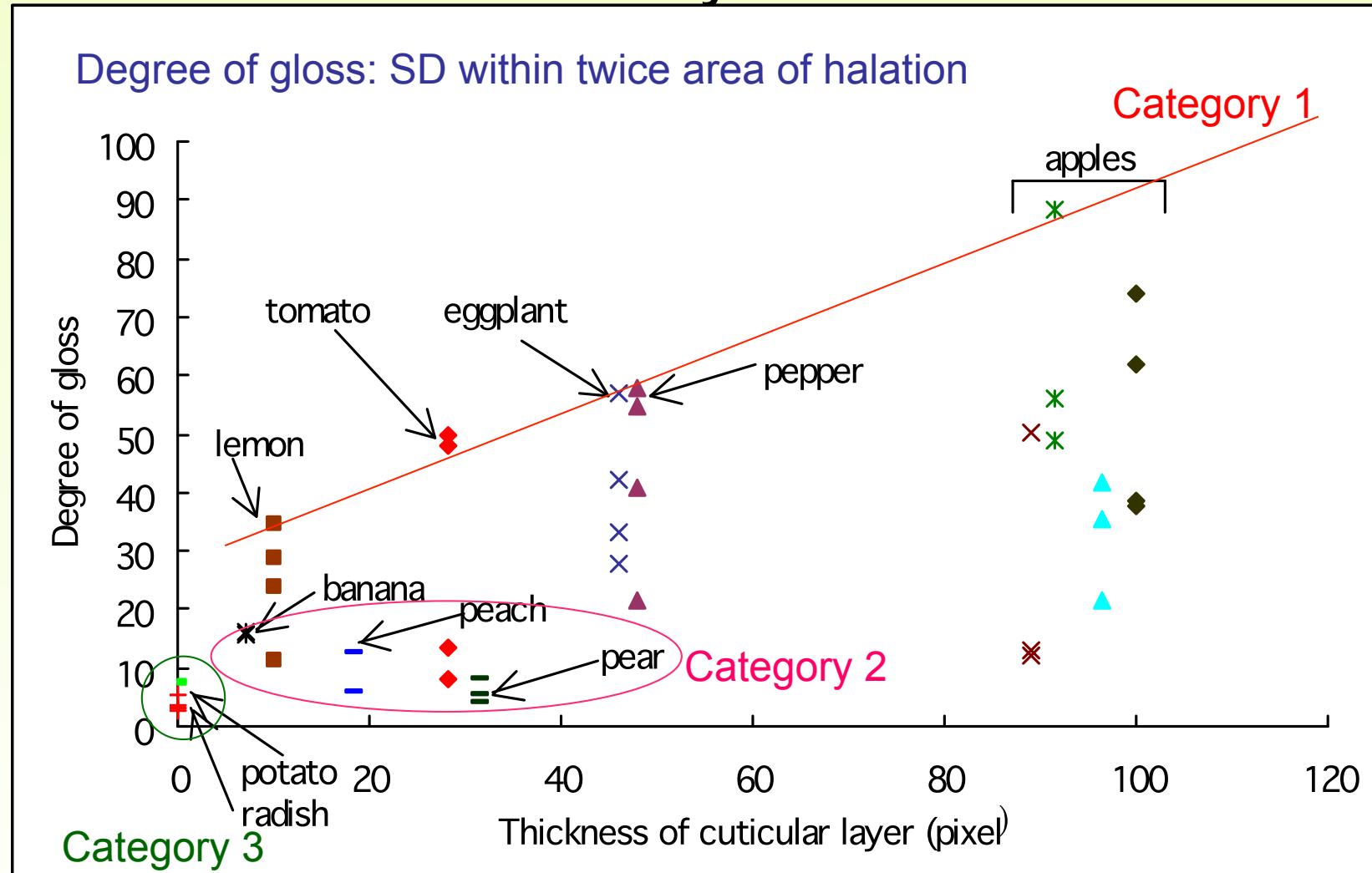
PL filter



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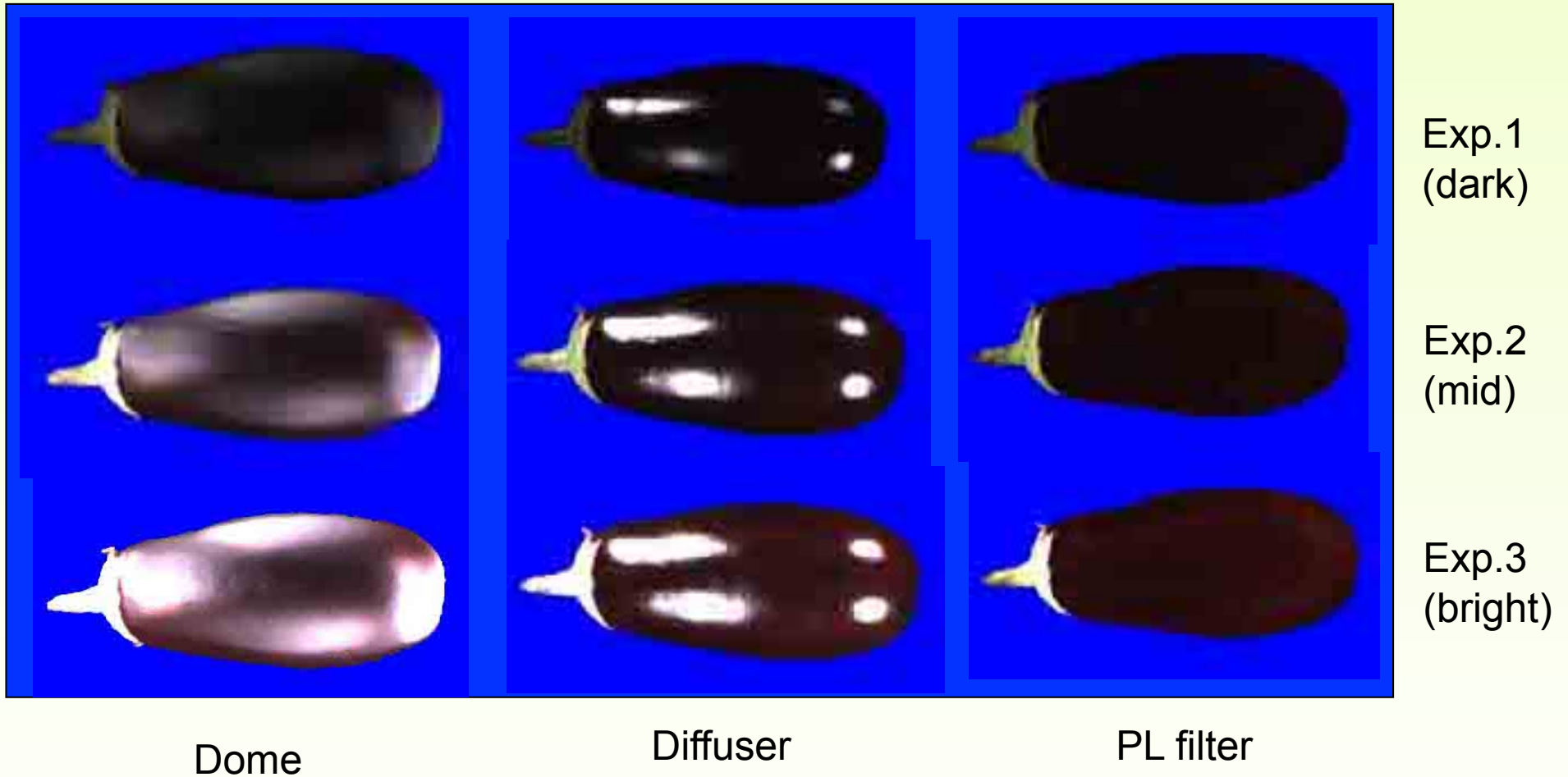
# Relation between degree of gloss and cuticular layer thickness



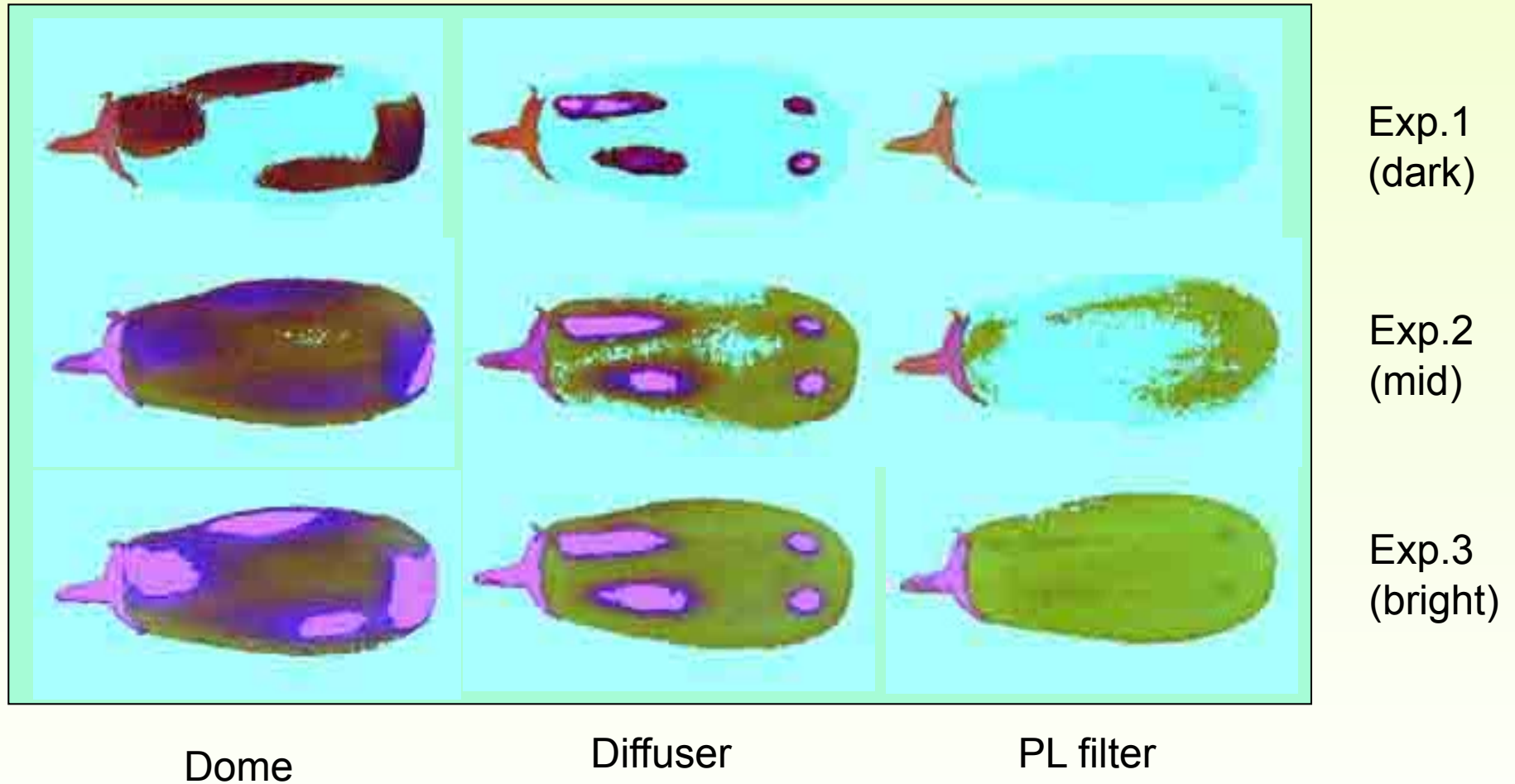
(100 pixels is almost 25  $\mu\text{m}$ .)



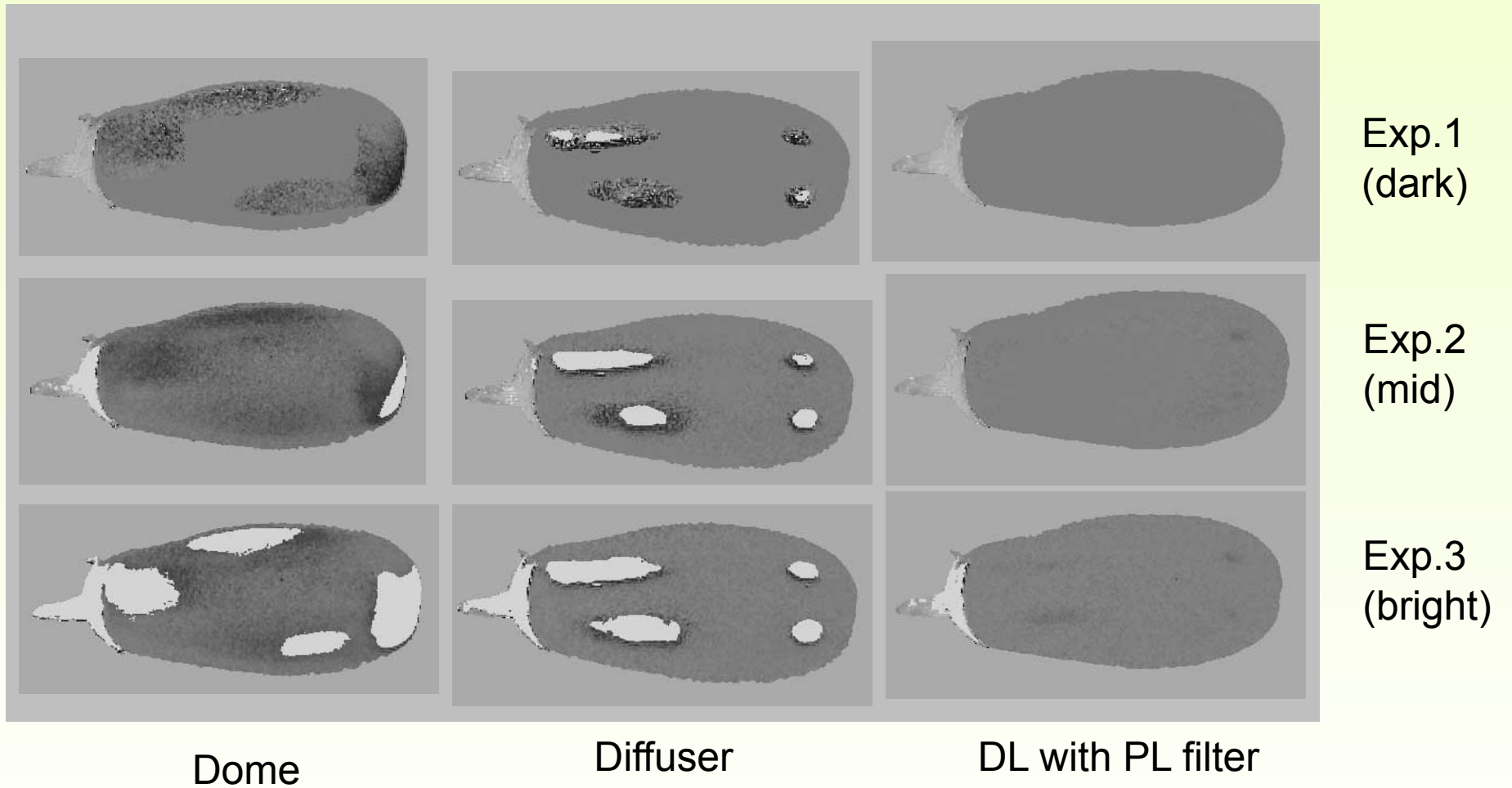
# Images on different exposure conditions



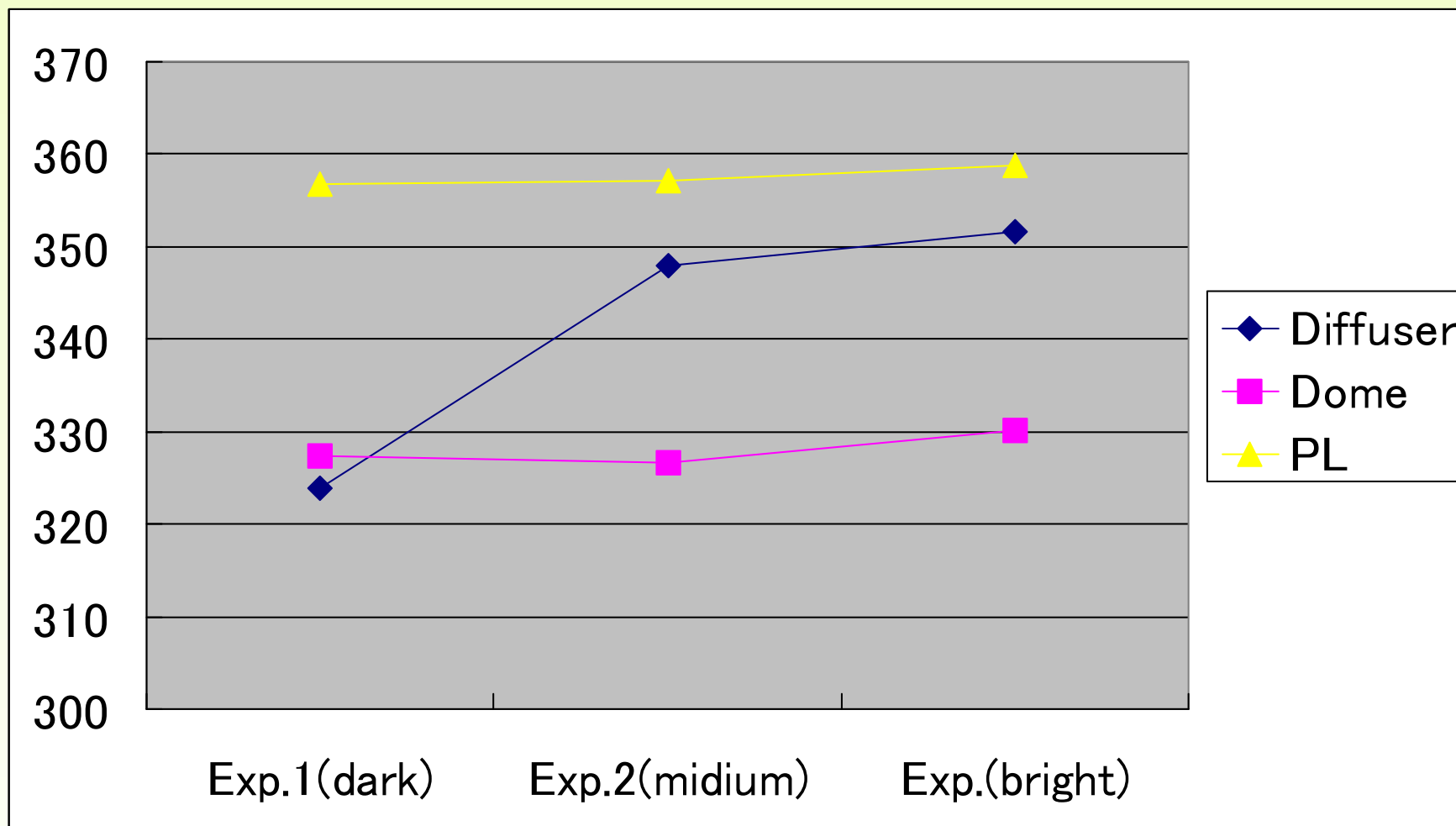
# HSI on different exposure conditions



# Hue



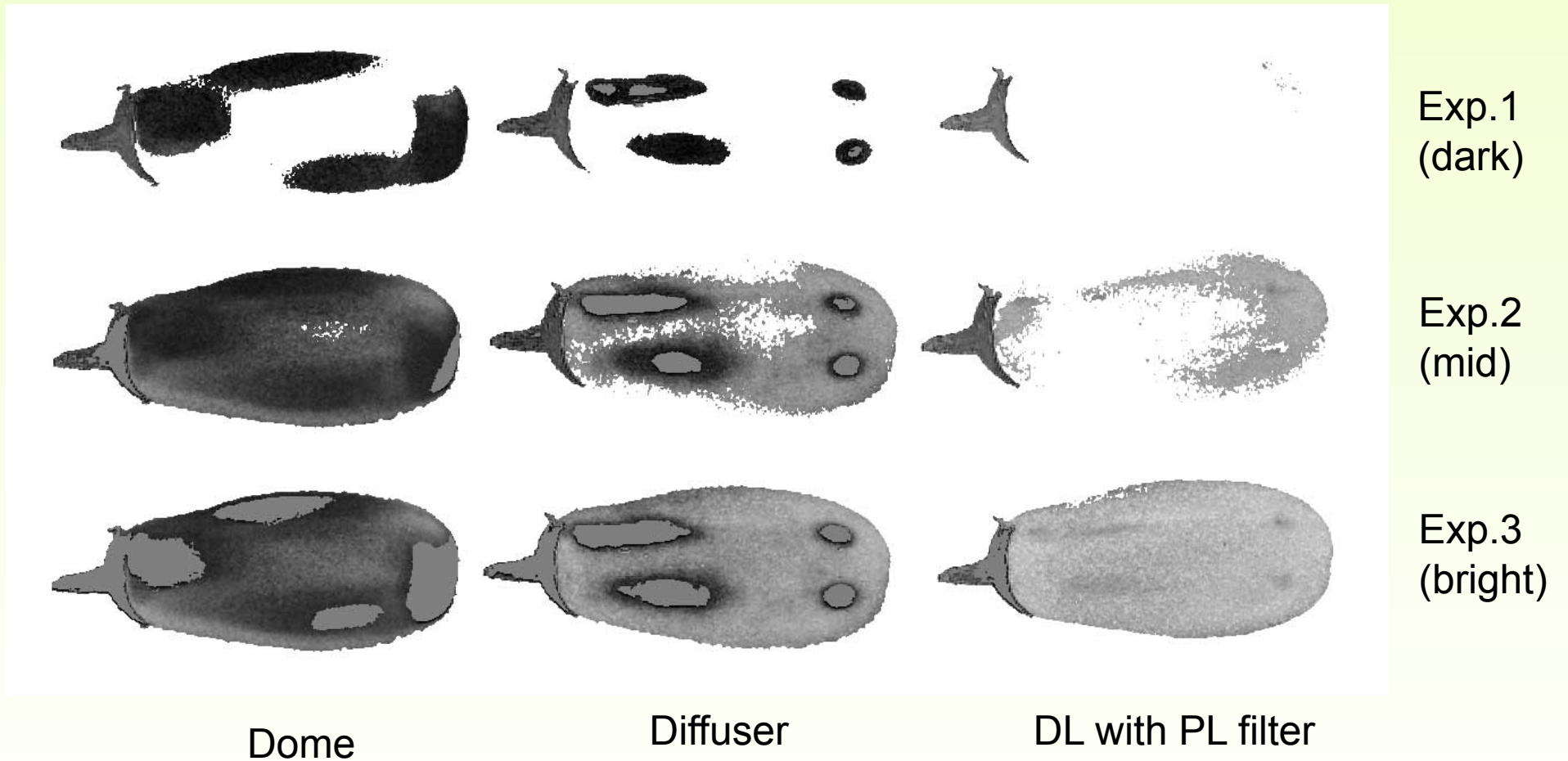
# Hue on different exposure conditions



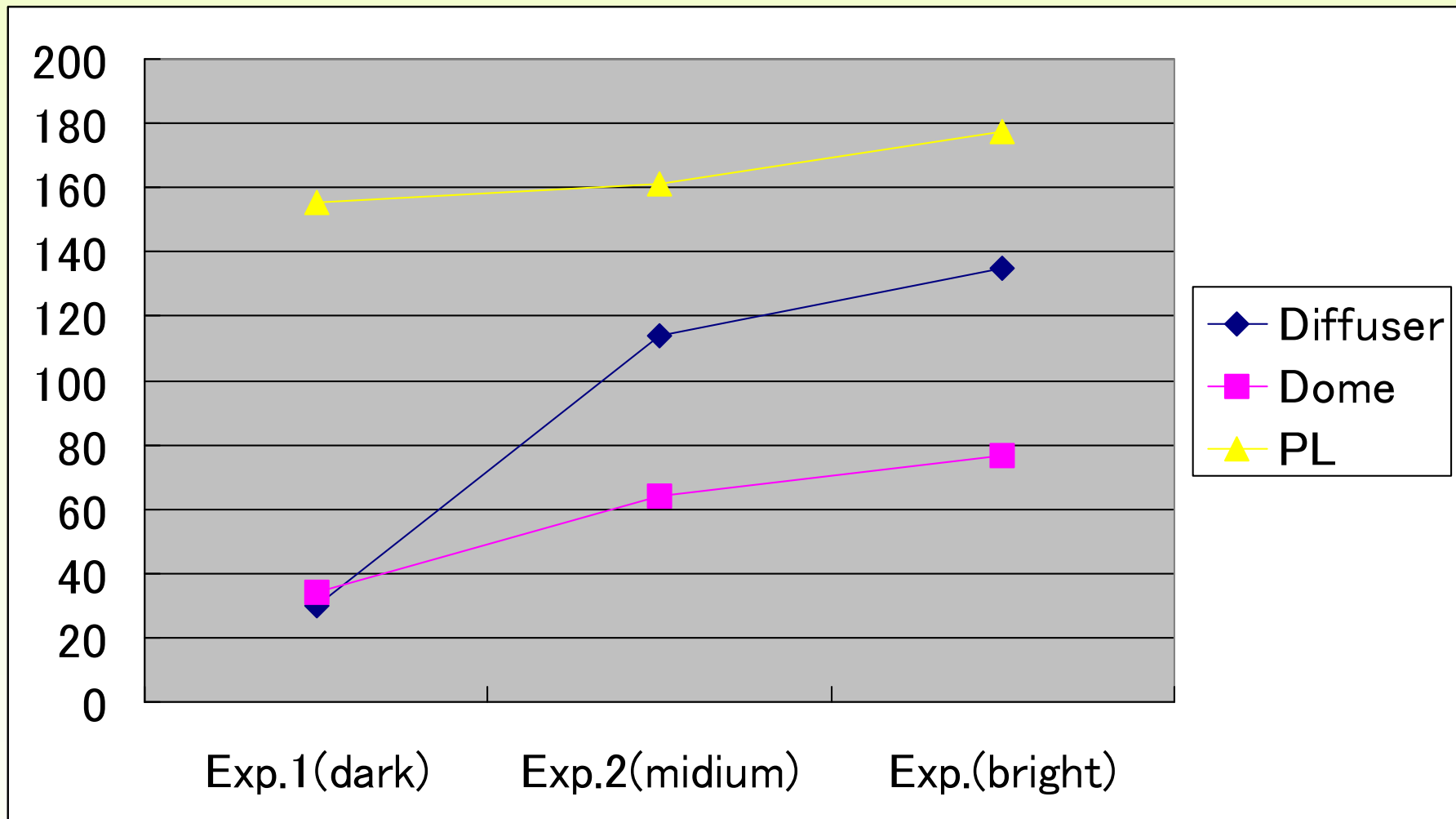
(Average hue value change except too bright and too dark pixels)



# Saturation



# Saturation on different exposure conditions

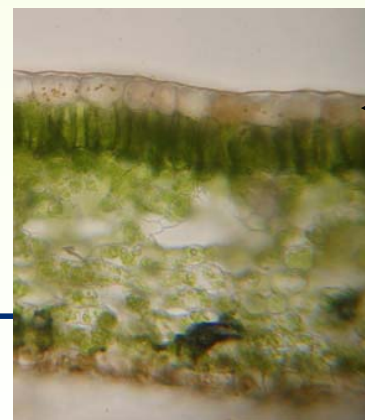


(Average hue value change except too bright and too dark pixels)





# Polarization on crops

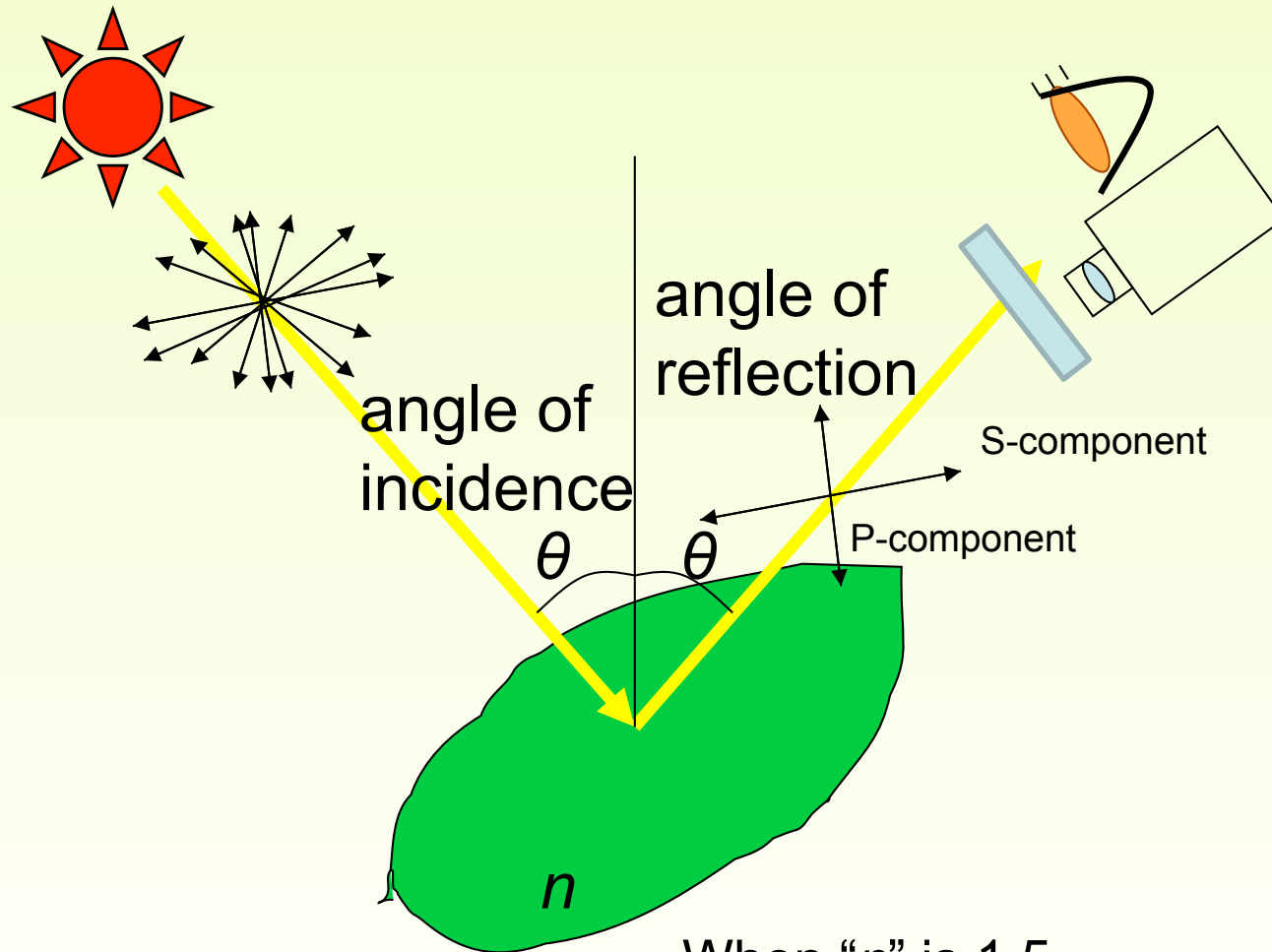


← Cuticular Layer

# Polarization

$$\tan \theta = n$$

$\theta$  : angle of incidence  
 $n$  : refractive index



When “ $n$ ” is 1.5,  
Brewster angle is 56.3.

