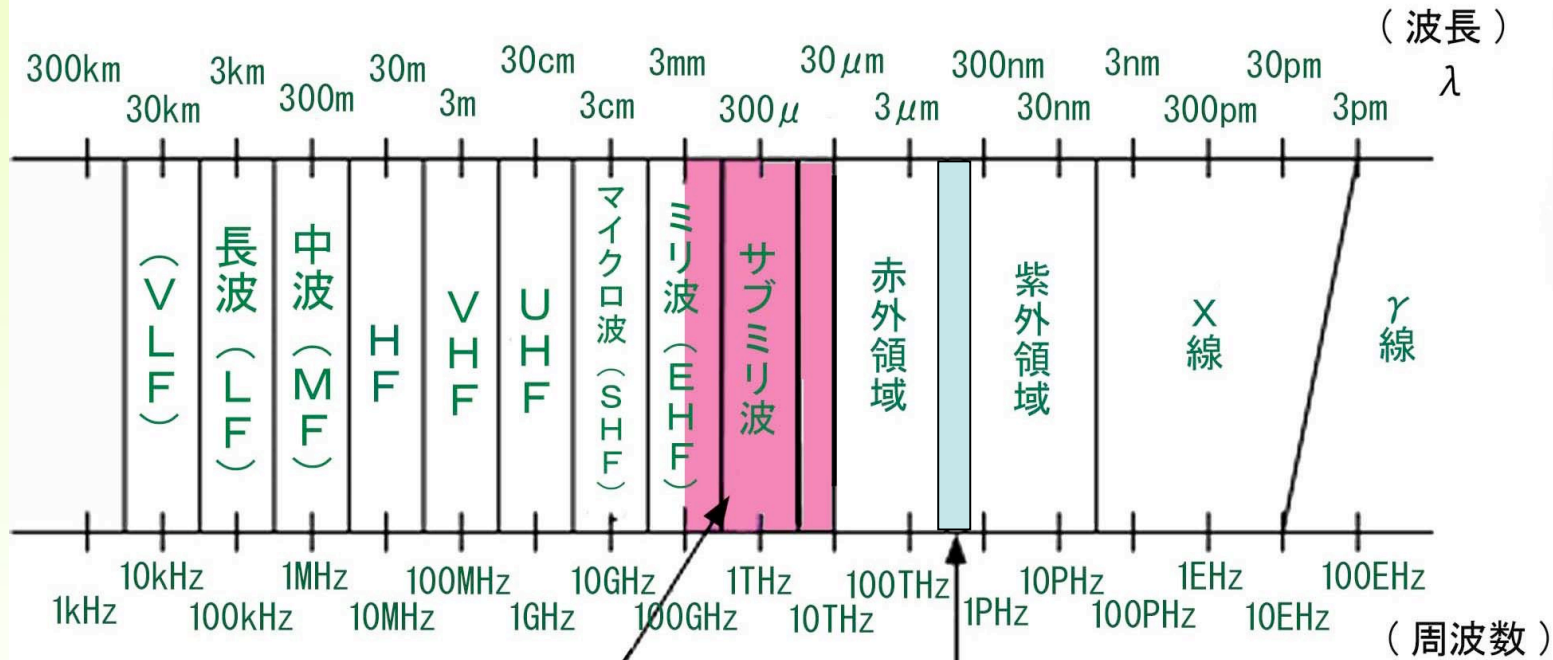


第4回

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。

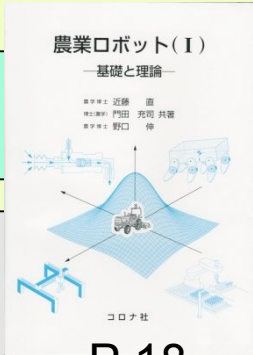
電磁波の分類



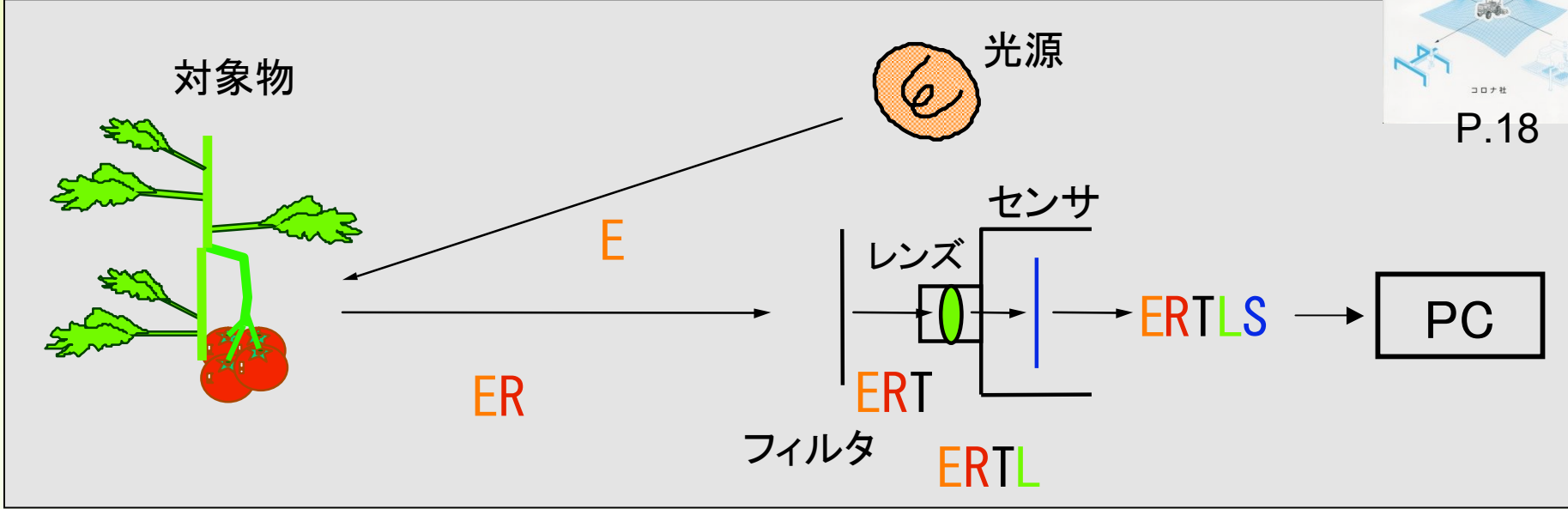
テラヘルツ帯
 (光と電波の中間)

可視領域

エネルギーの流れ (Energy Flow)



P.18



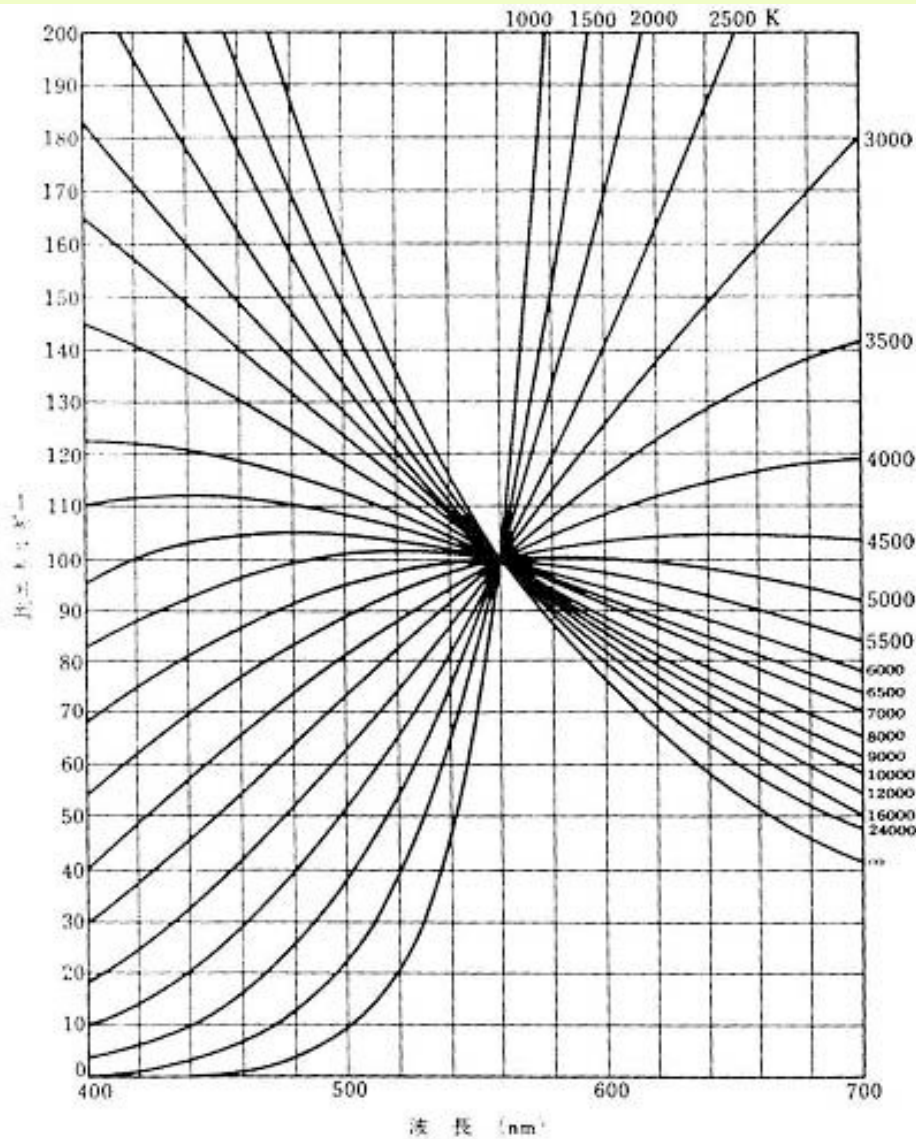
光源の放射エネルギー : E
 対象物 j の反射特性 : R_j
 フィルタの透過率 : T
 レンズの透過率 : L
 撮像素子の感度 : S
 対象物 j のセンサの出力 : O_j
 フィルタの番号 : i ($i=1, 2$)
 対象物 : j ($j= a, b$)

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

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

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⁻²·nm⁴)

$C_2 = 1.438 \times 10^7$ (nm·deg)



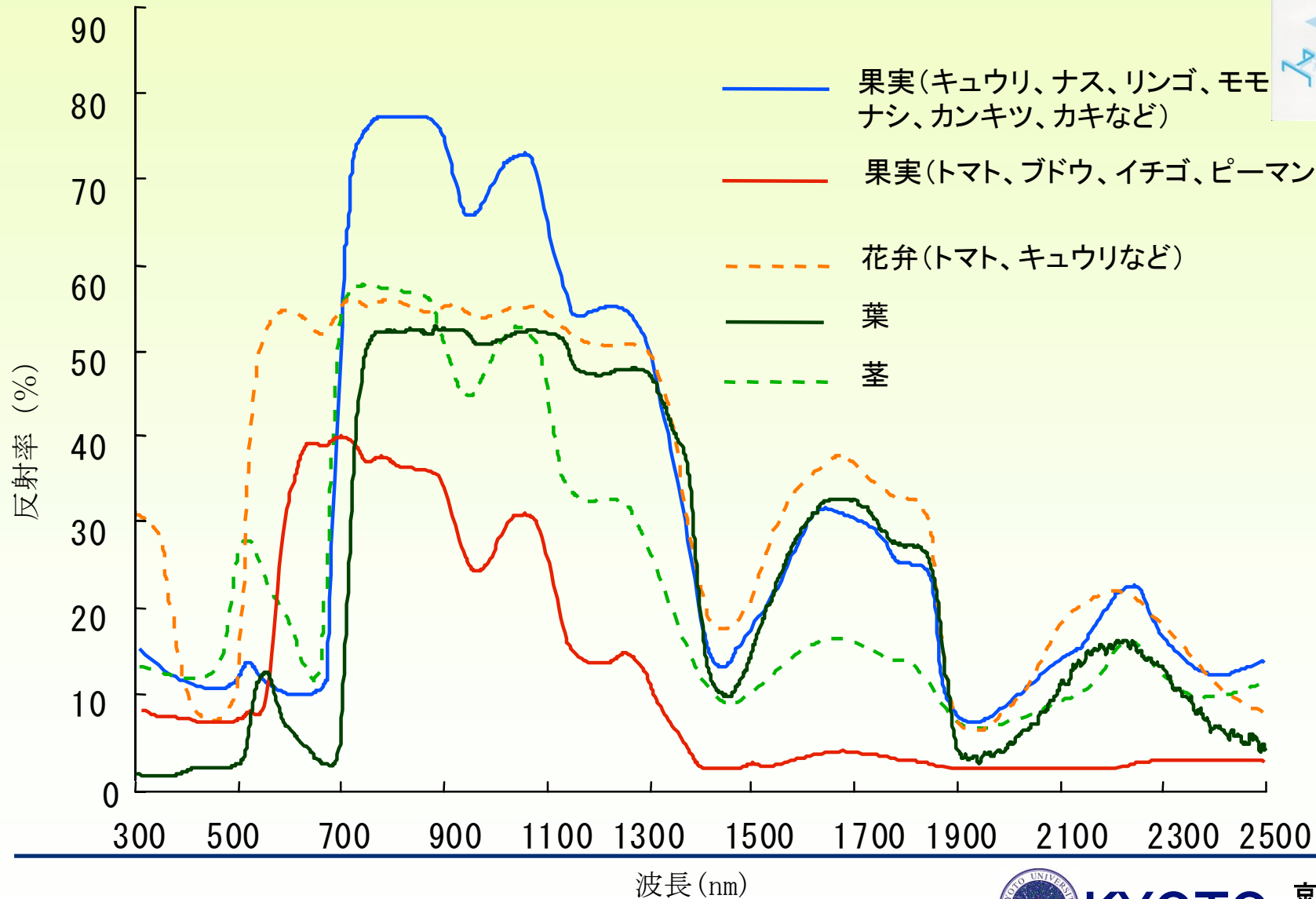
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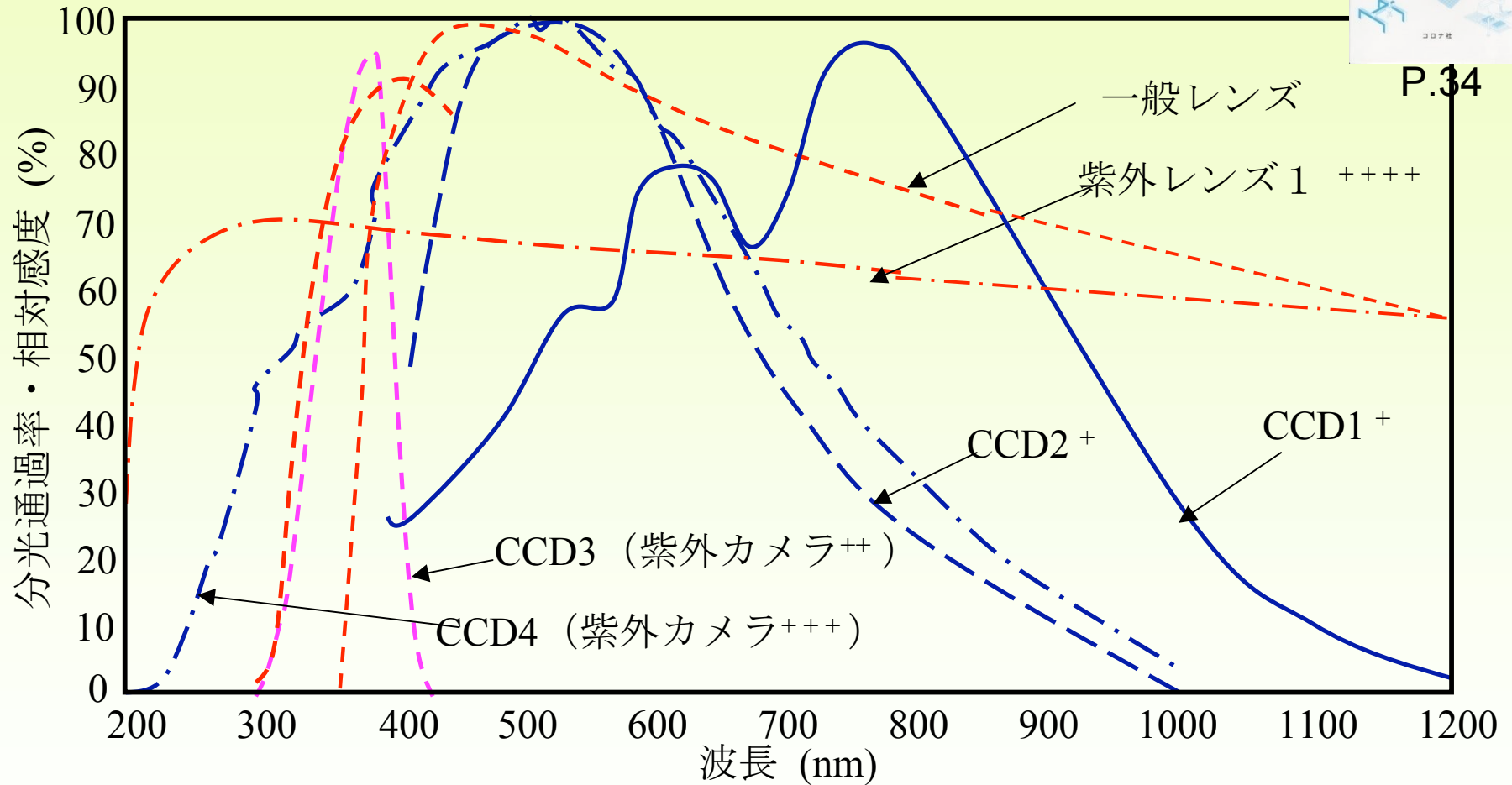
植物各部位の反射特性 (Spectral Reflectance)



P.15



撮像素子の感度およびレンズの透過率

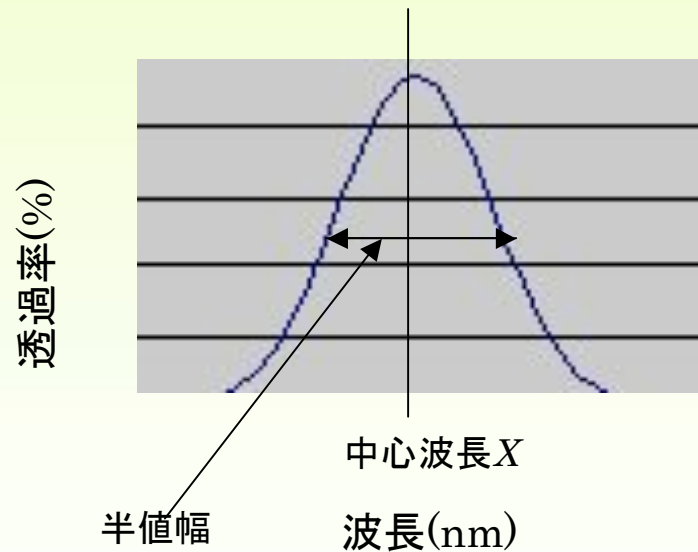


P.34

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 $T(x)$

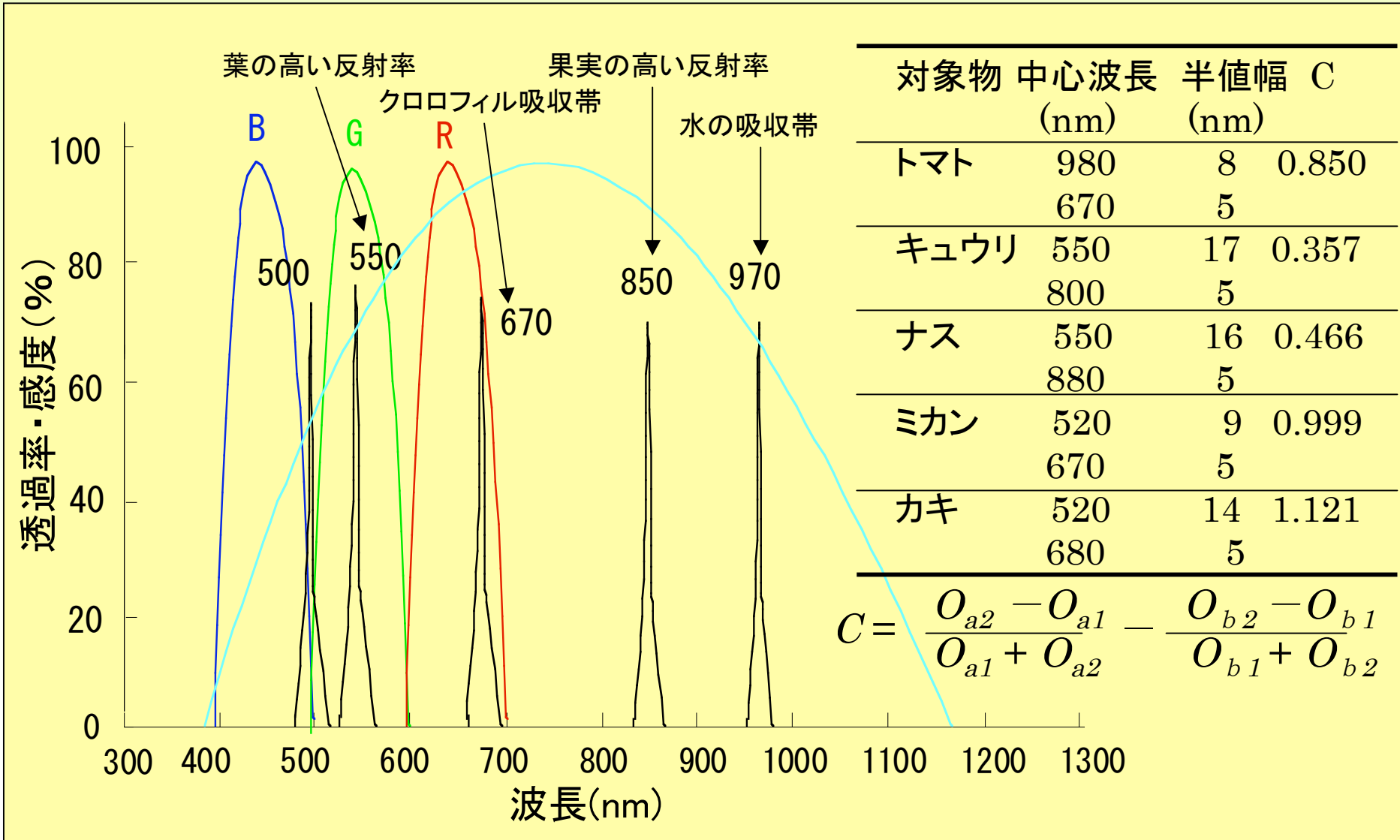


ガウス関数

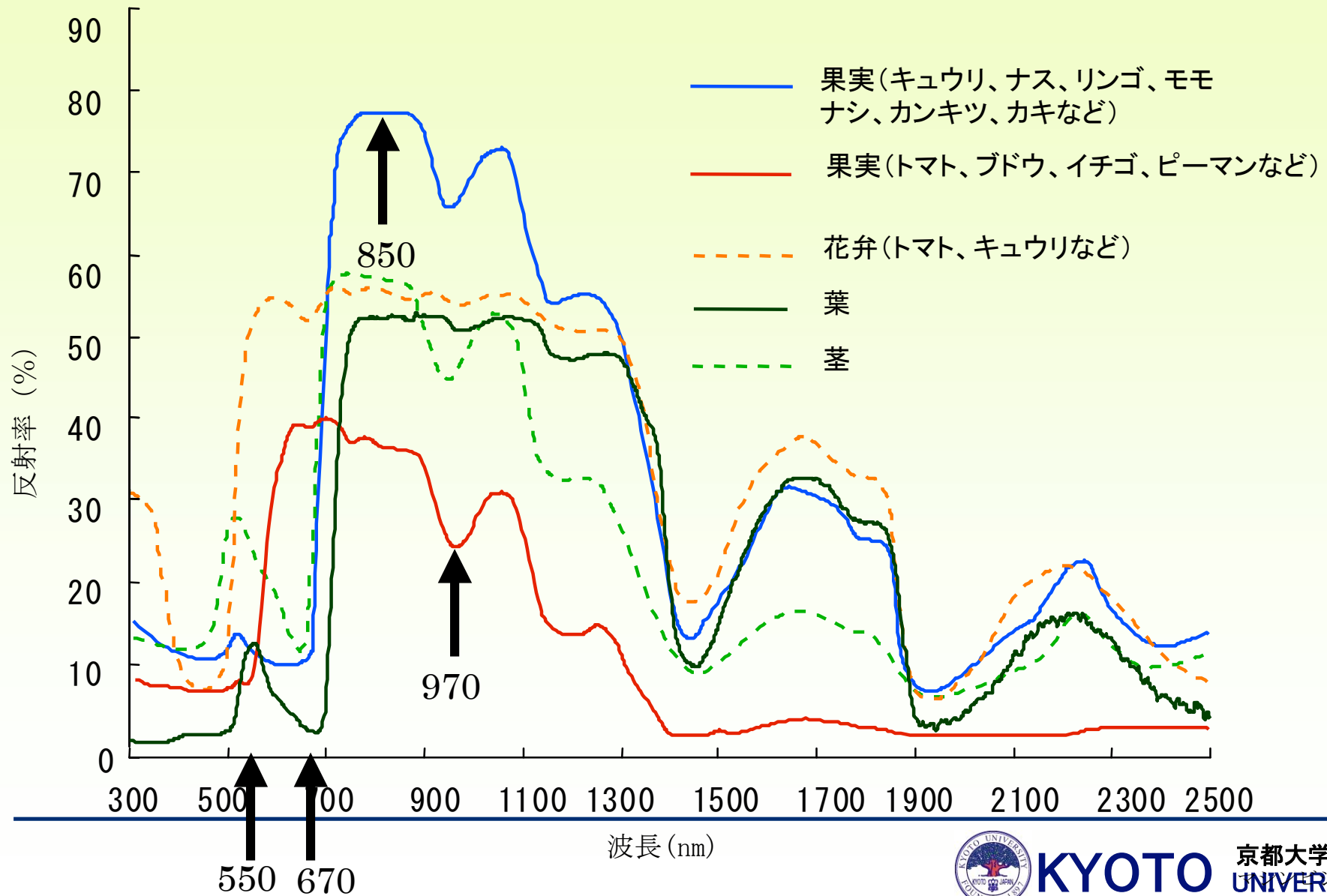
$$T(x) = N_{X,\sigma}(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-X)^2}{2\sigma^2}\right)$$



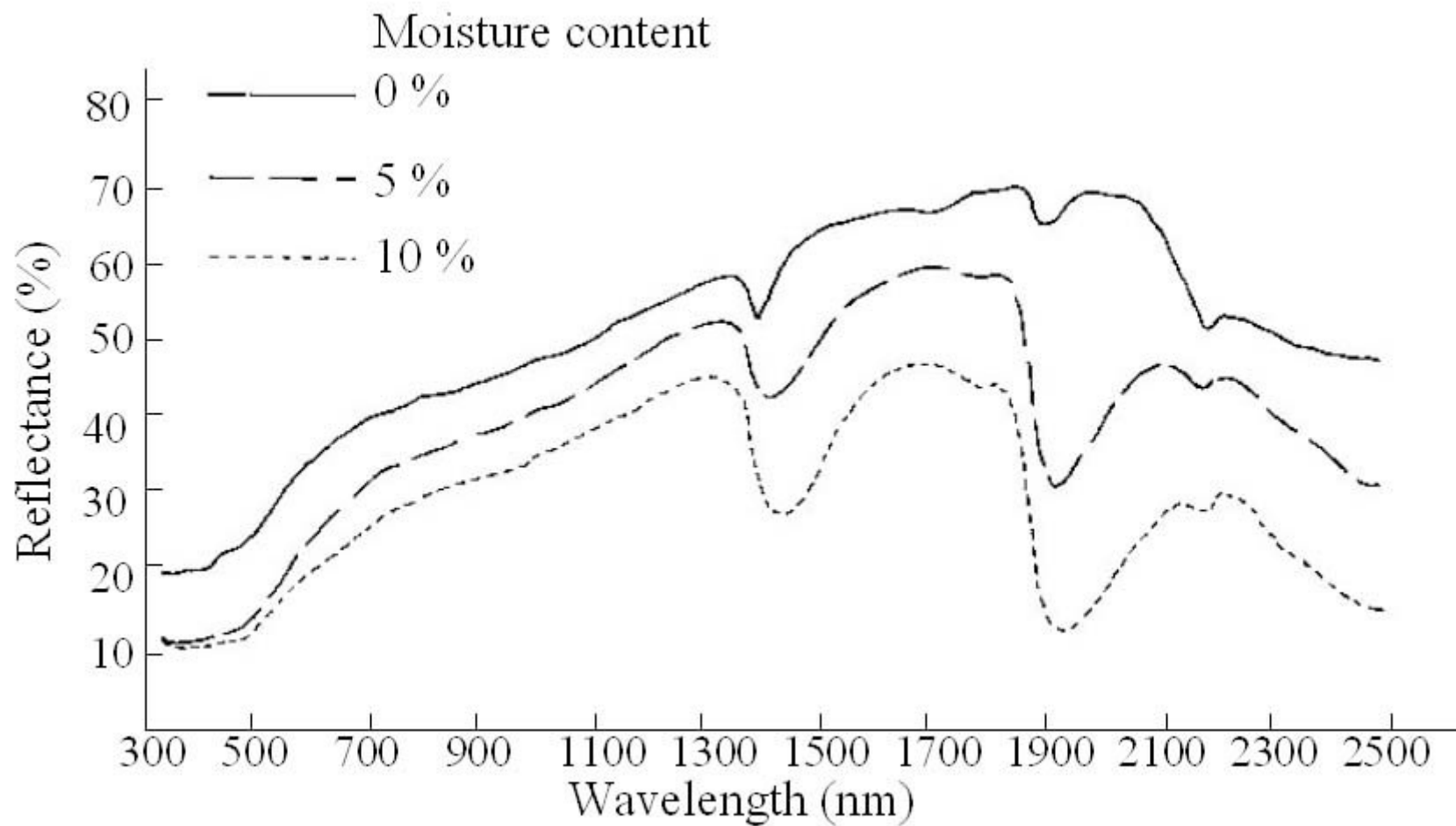
果実と葉の識別のための最適波長帯の例 Most Suitable Wavelength Bands



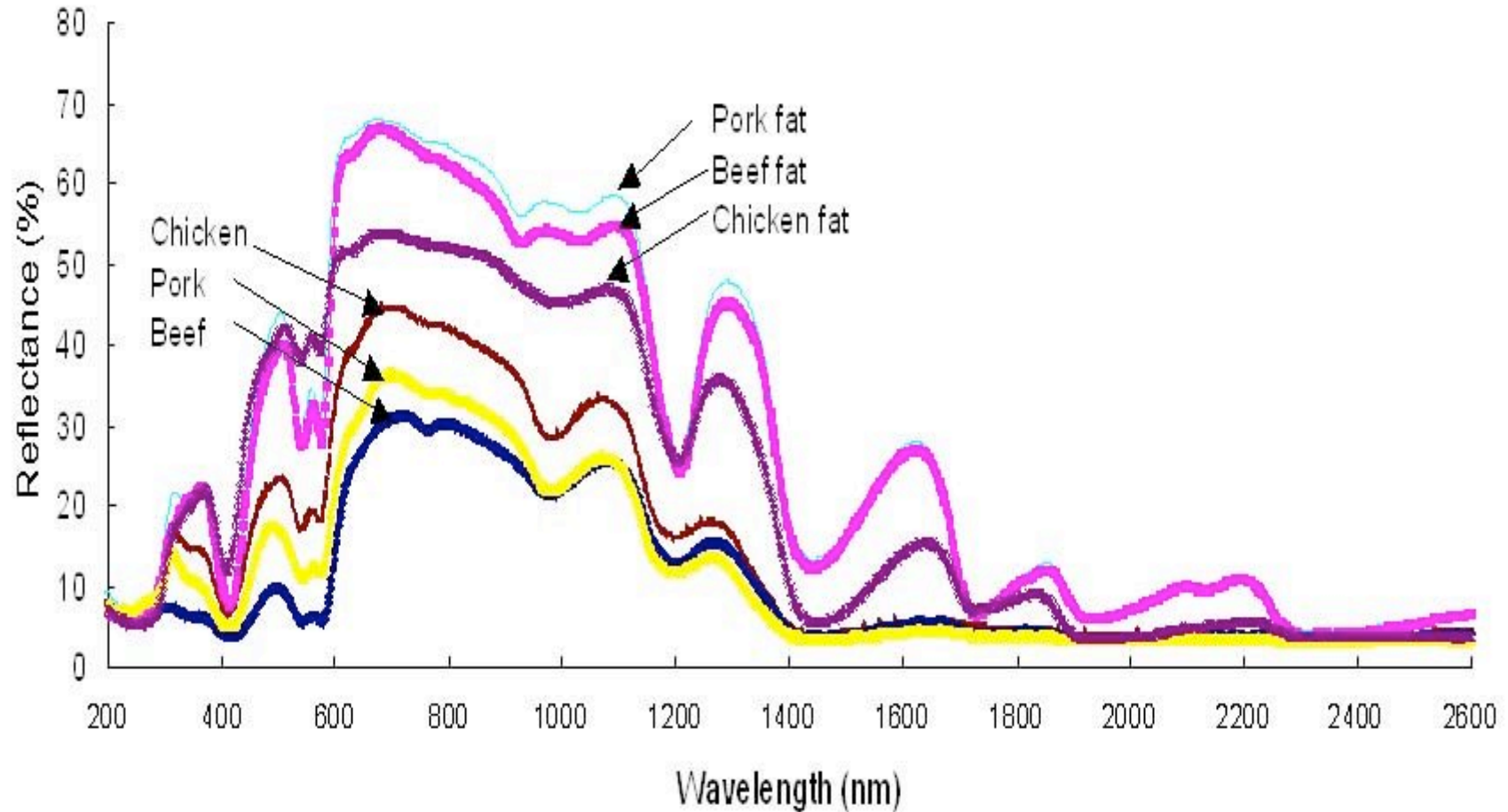
植物各部位の反射特性 (Spectral Reflectance)



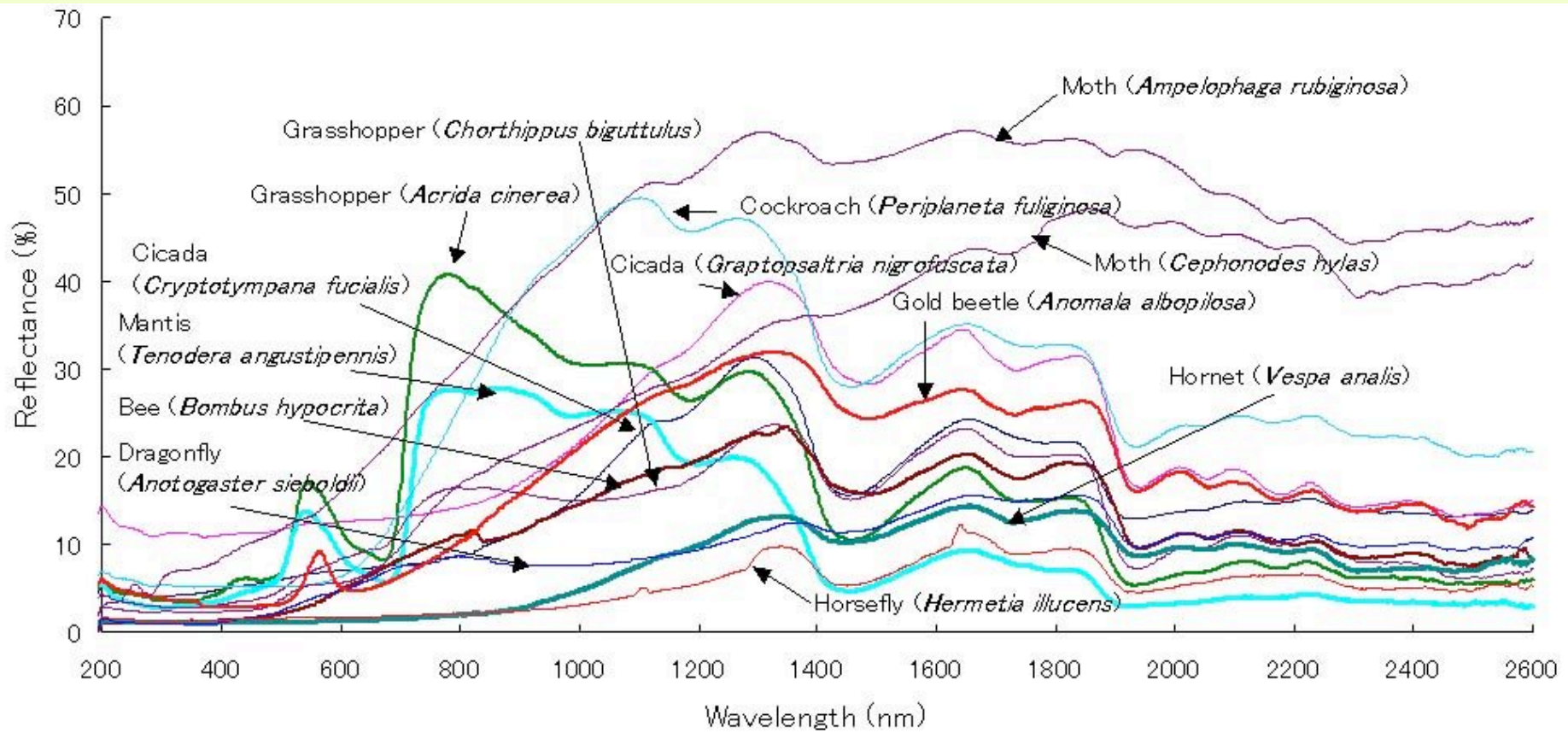
土壌の分光反射特性



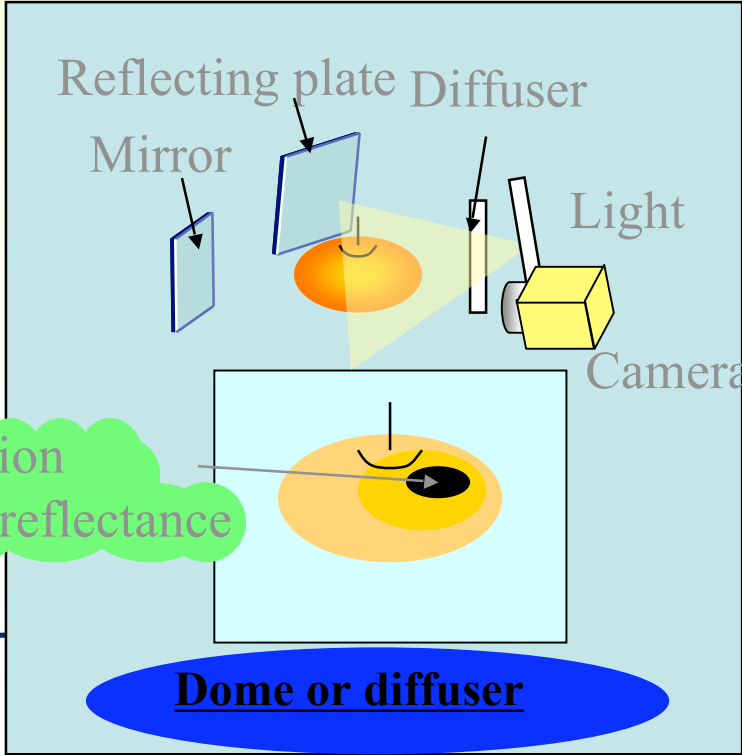
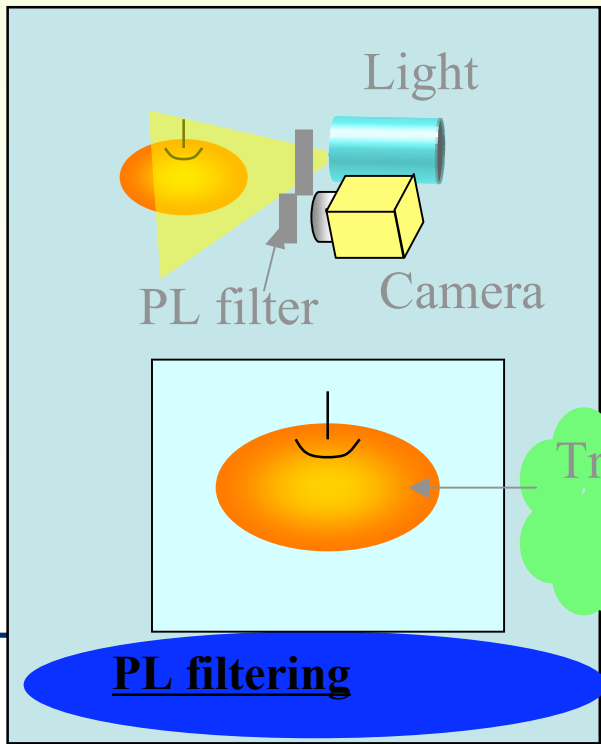
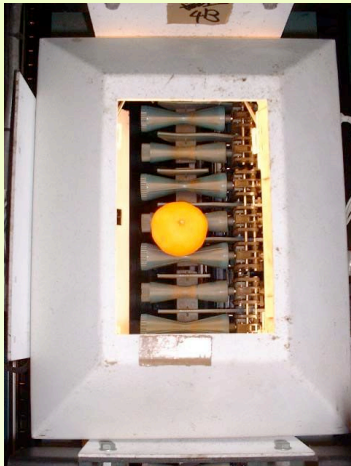
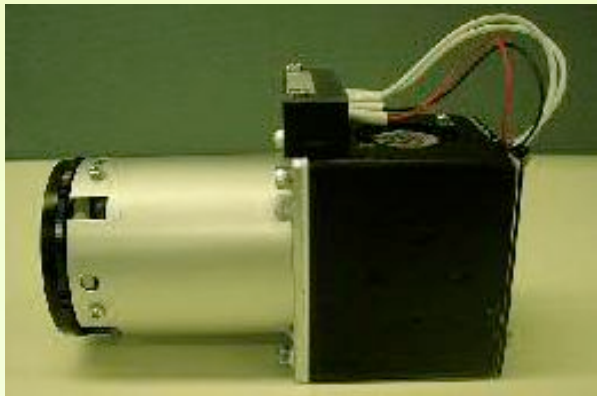
牛肉、豚肉、鶏肉の分光反射特性



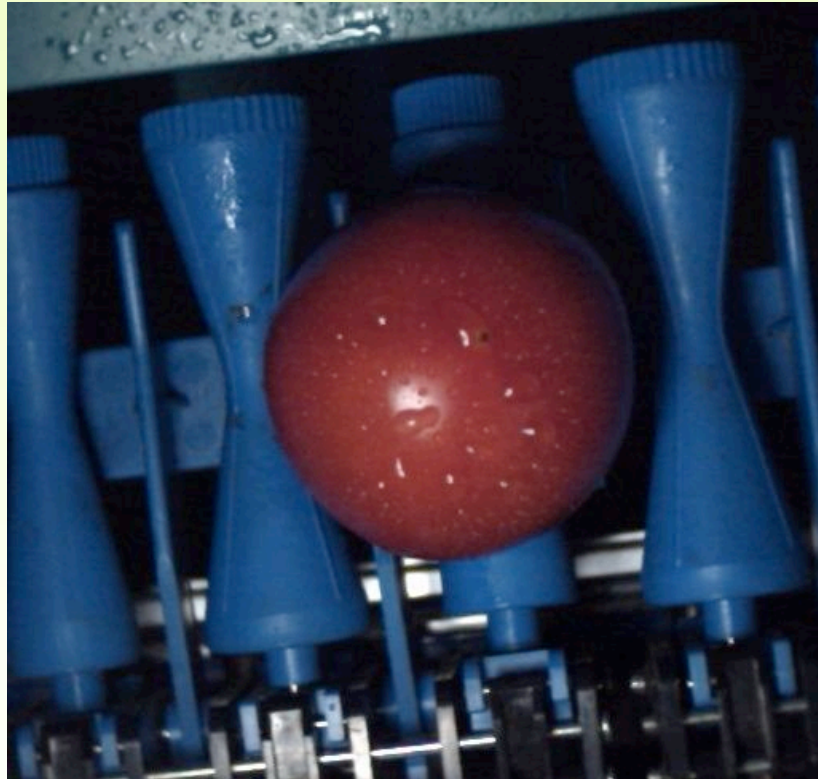
昆虫の胴部の分光反射特性



PL filtering Light and Dome



Problems on image acquisition (Dome and diffuser)



Halation

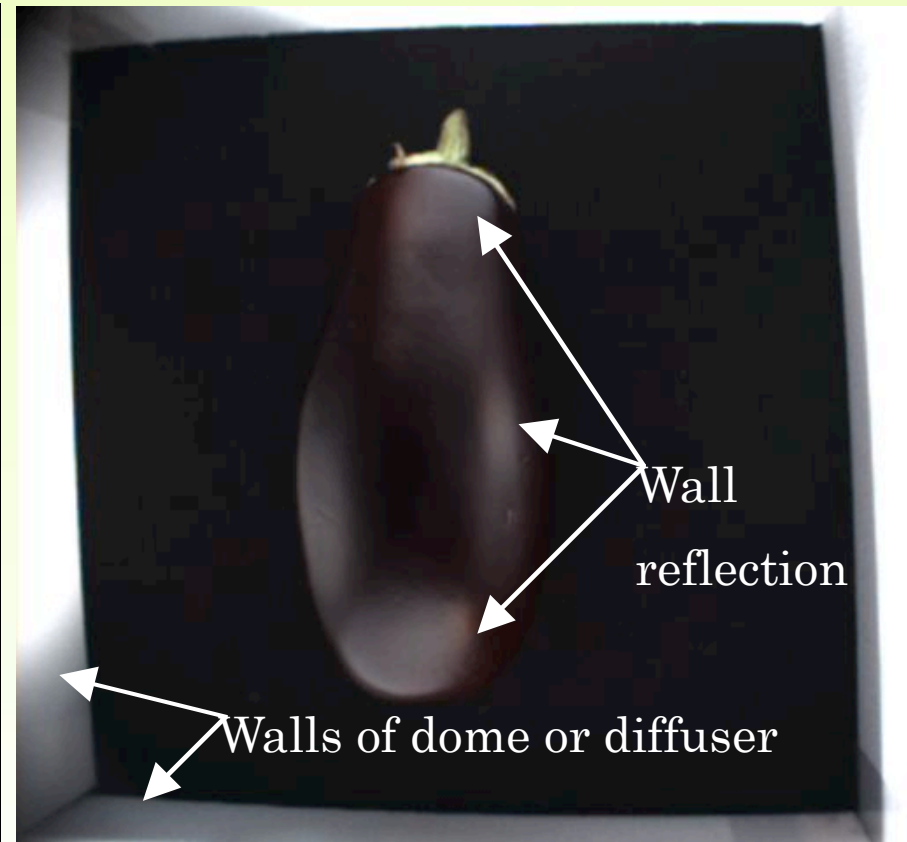


Surrounding walls reflection

Effect of PL filtering

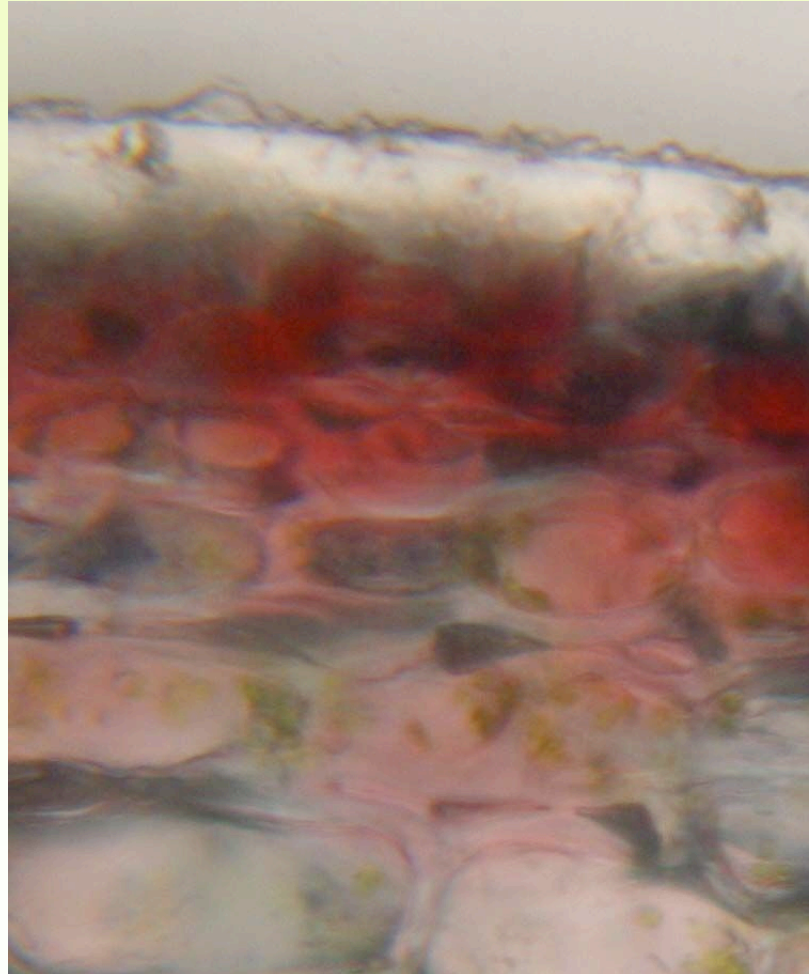
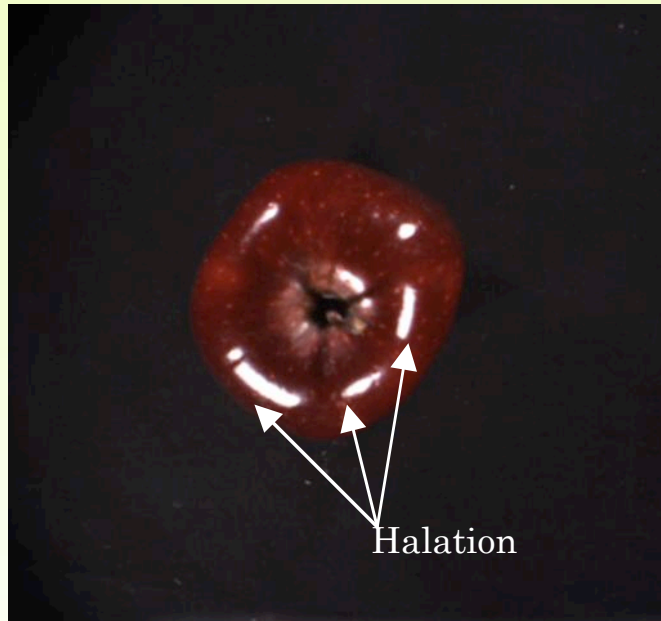


PL filtering image
(Two PL filters are used in
front of camera and light)



Dome image

Cuticular layer of apple fruit



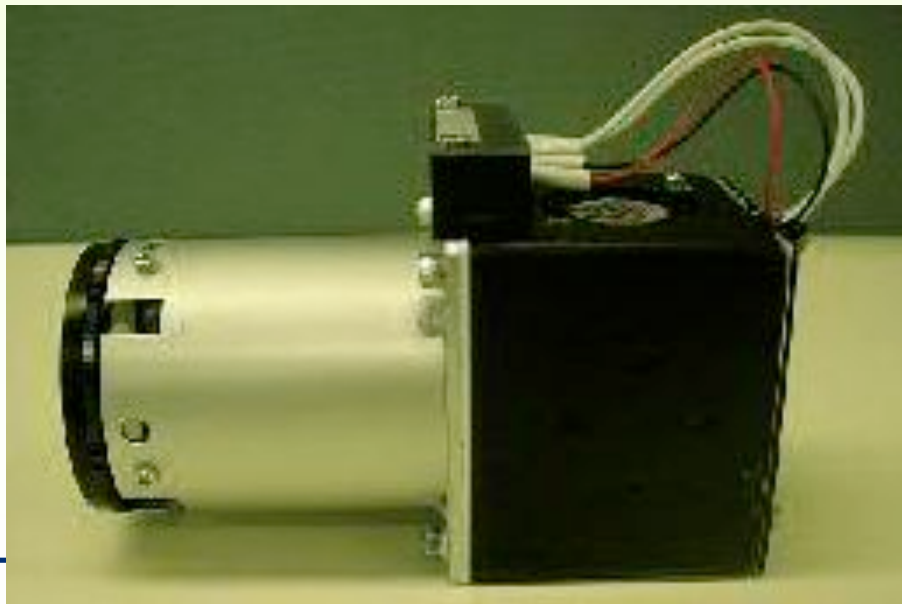
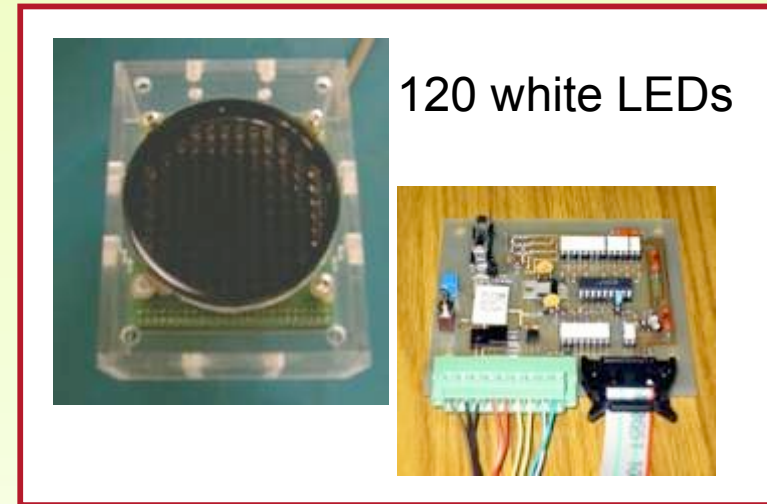
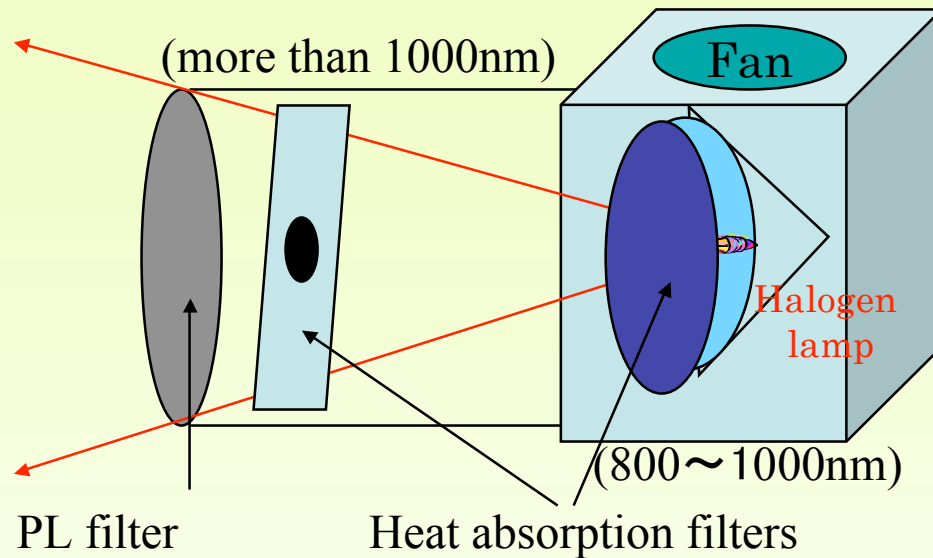
Cuticular layer

Epidermis

Parenchyma



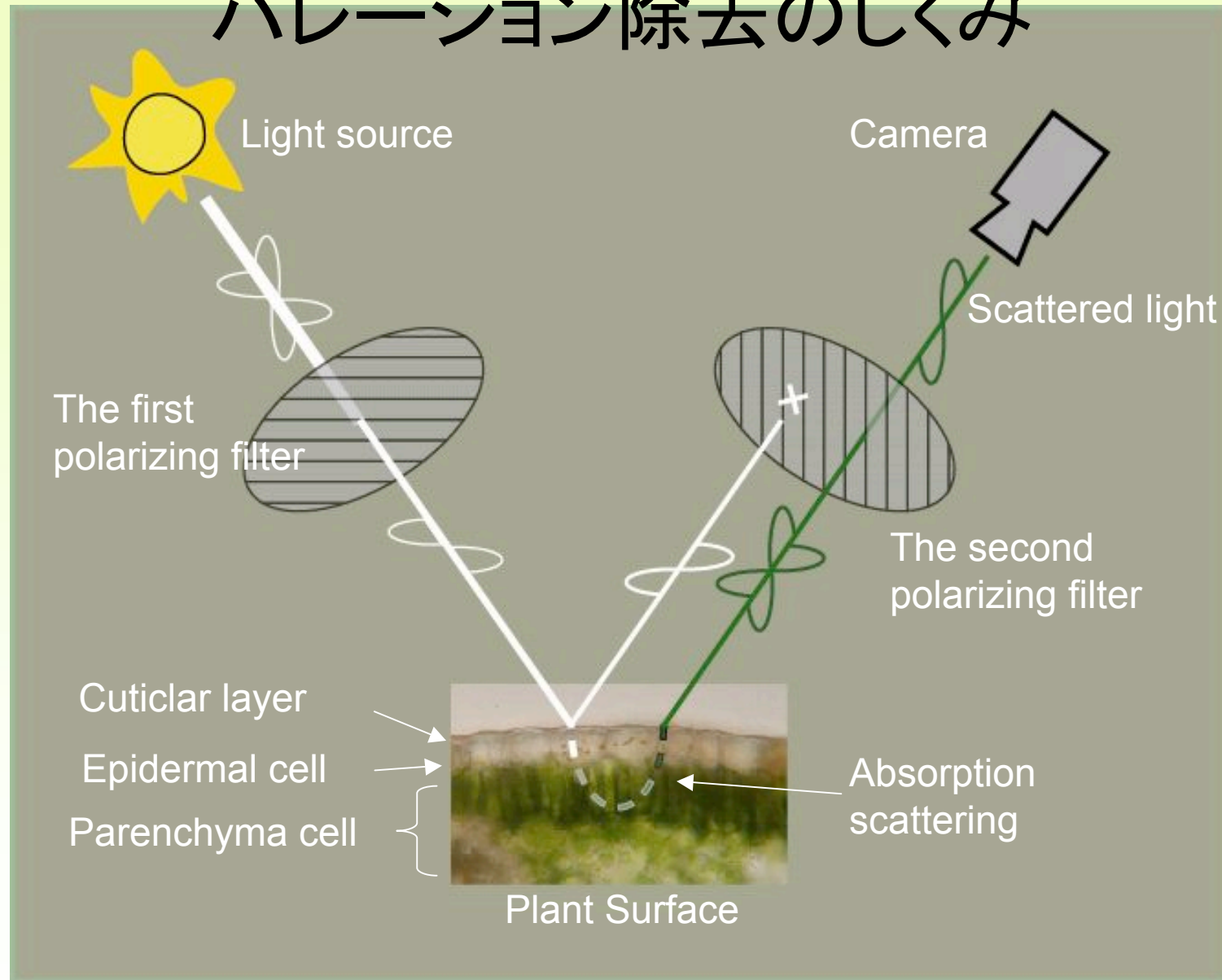
DL with PL filter



“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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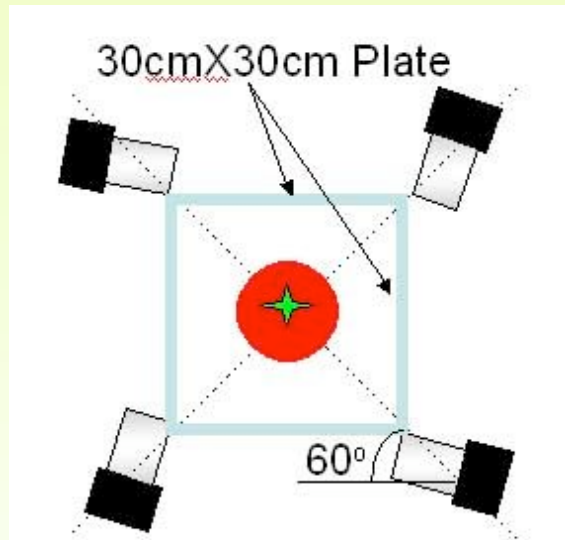
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Biological materials

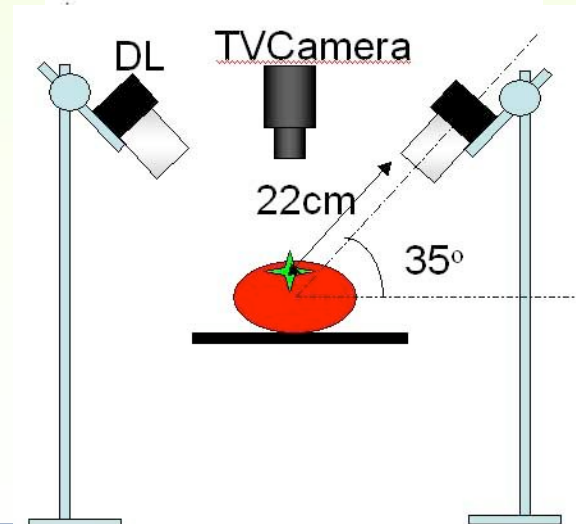
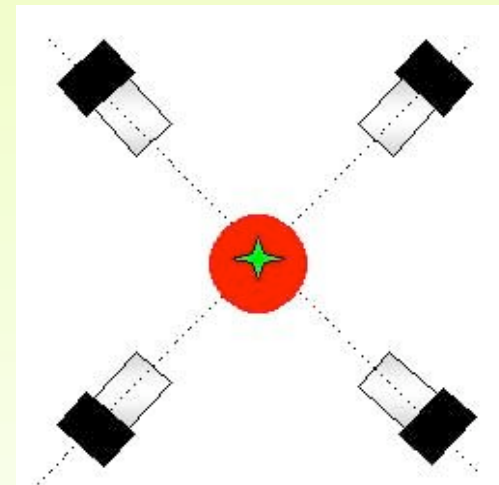
- **category 1** (glossy surface fruits:
apples, tomato, eggplant, pepper, lemon)
- **category 2** (short hair fruits or powdery
fruits:
kiwi, peach, pear, banana)
- **category 3** (root vegetables:
potato, Daikon radish)

Lighting Device Arrangement

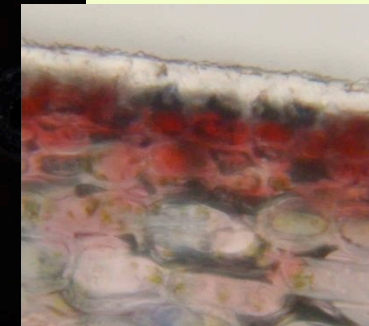
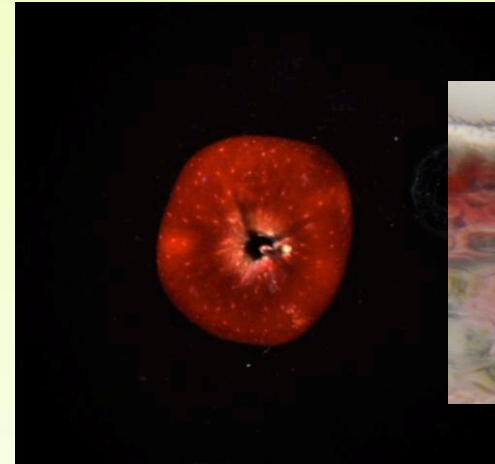
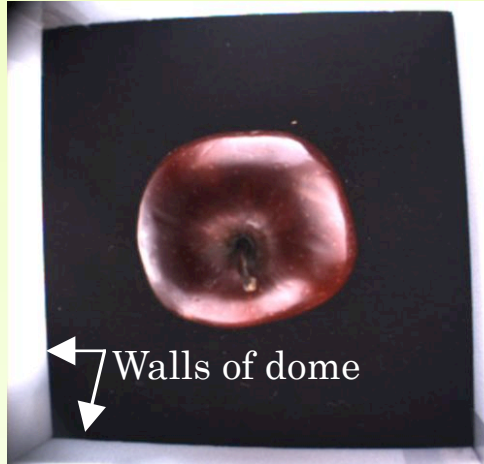
Arrangement 1
(Dome walls and 4 DLs)



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



Category 1 (Smooth and thick cuticle)



Apple



Eggplant

Dome

Diffuser

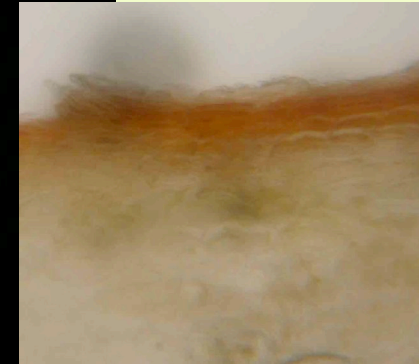
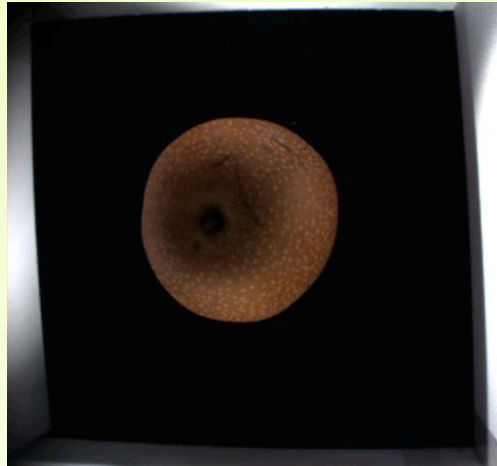
PL filter



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Category 2 (Rough cuticle)



Pear



Peach

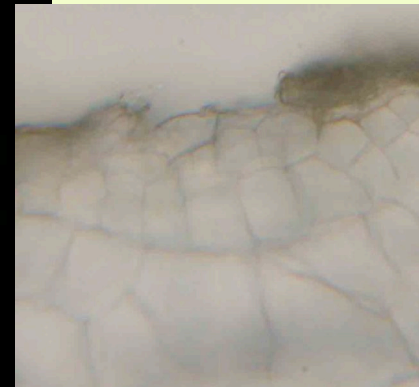
Dome

Diffuser

PL filter



Category 3 (No cuticle)



Daikon radish



Potato

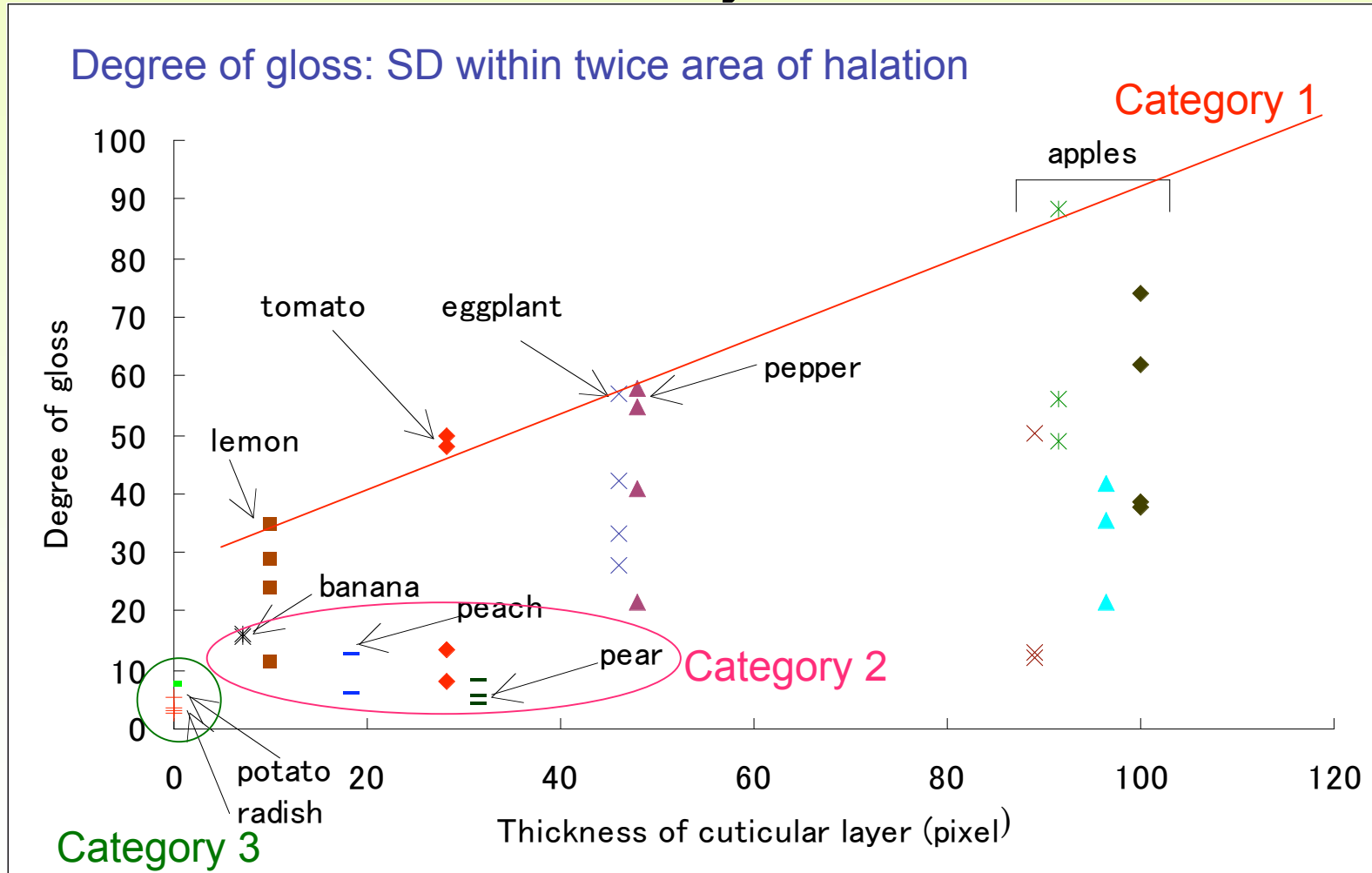
Dome

Diffuser

PL filter

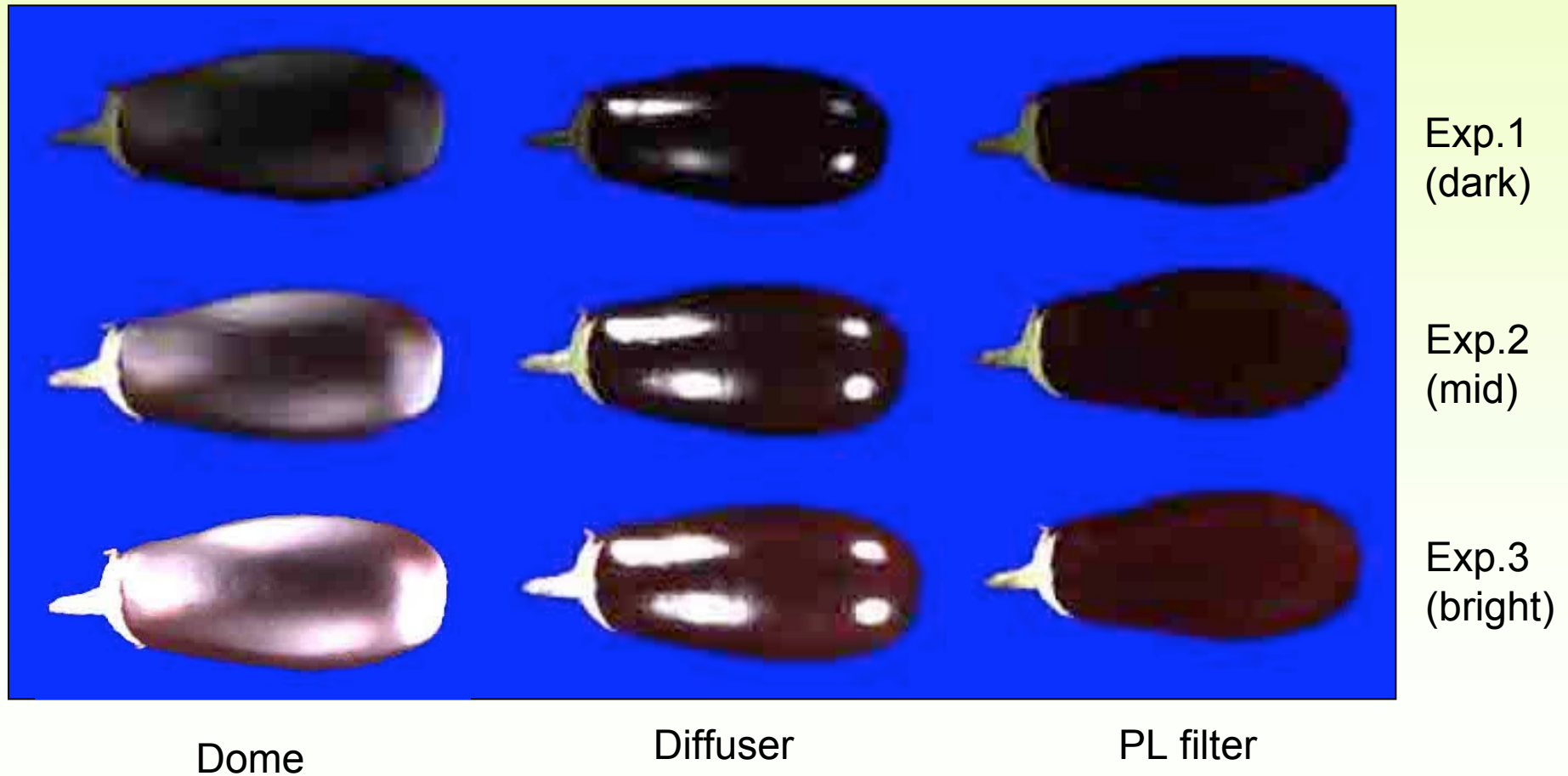


Relation between degree of gloss and cuticular layer thickness

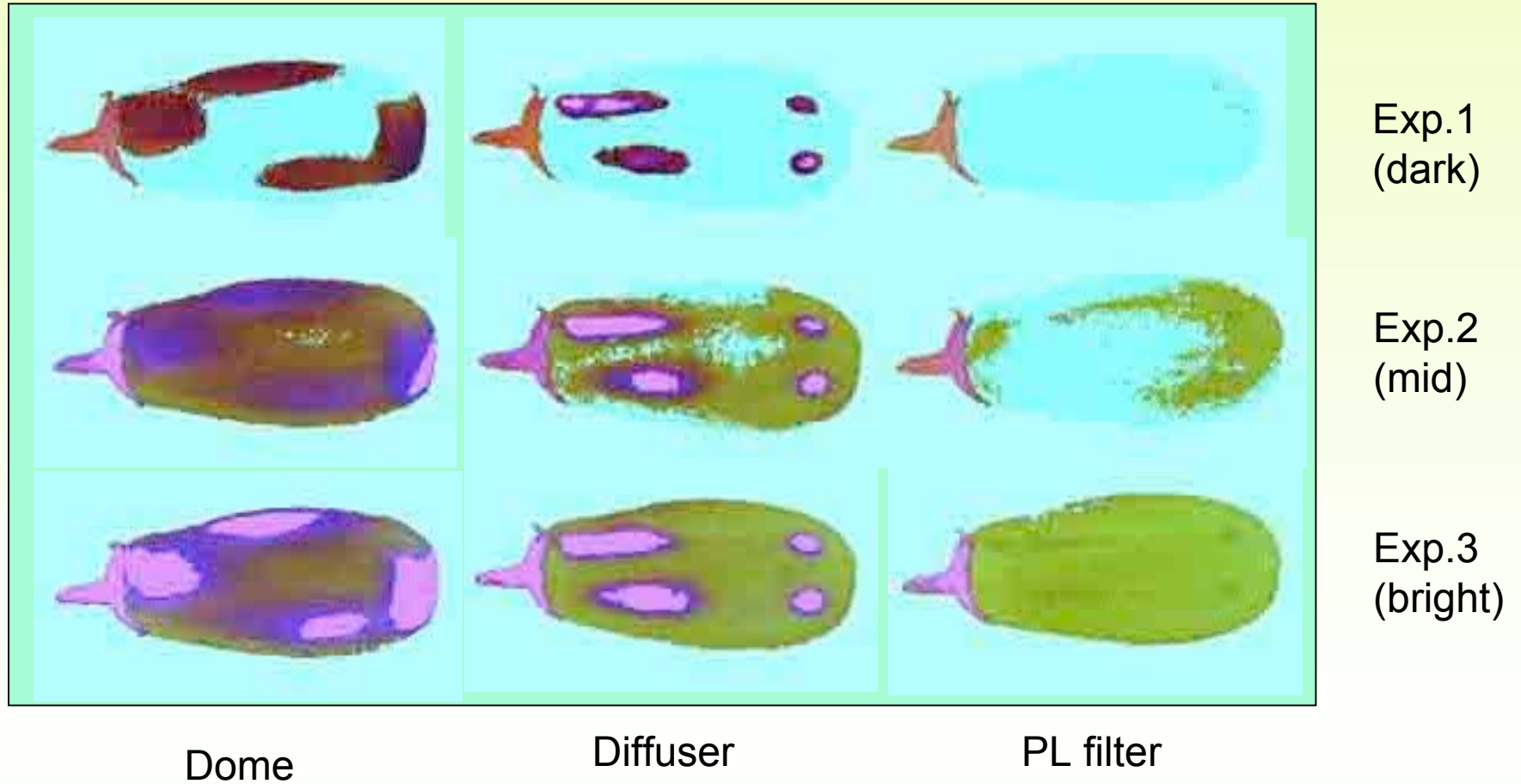


(100 pixels is almost 25 μm .)

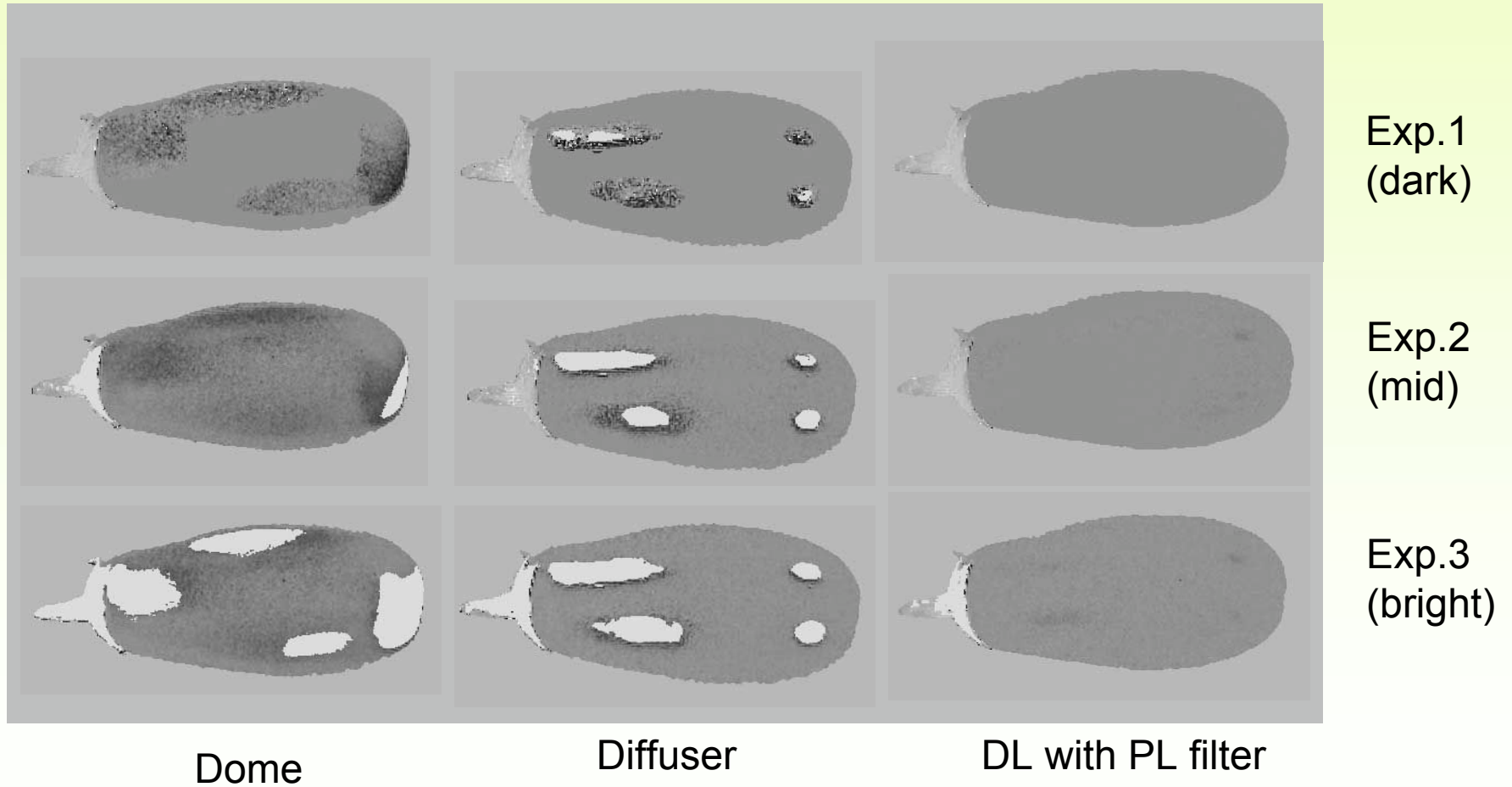
Images on different exposure conditions



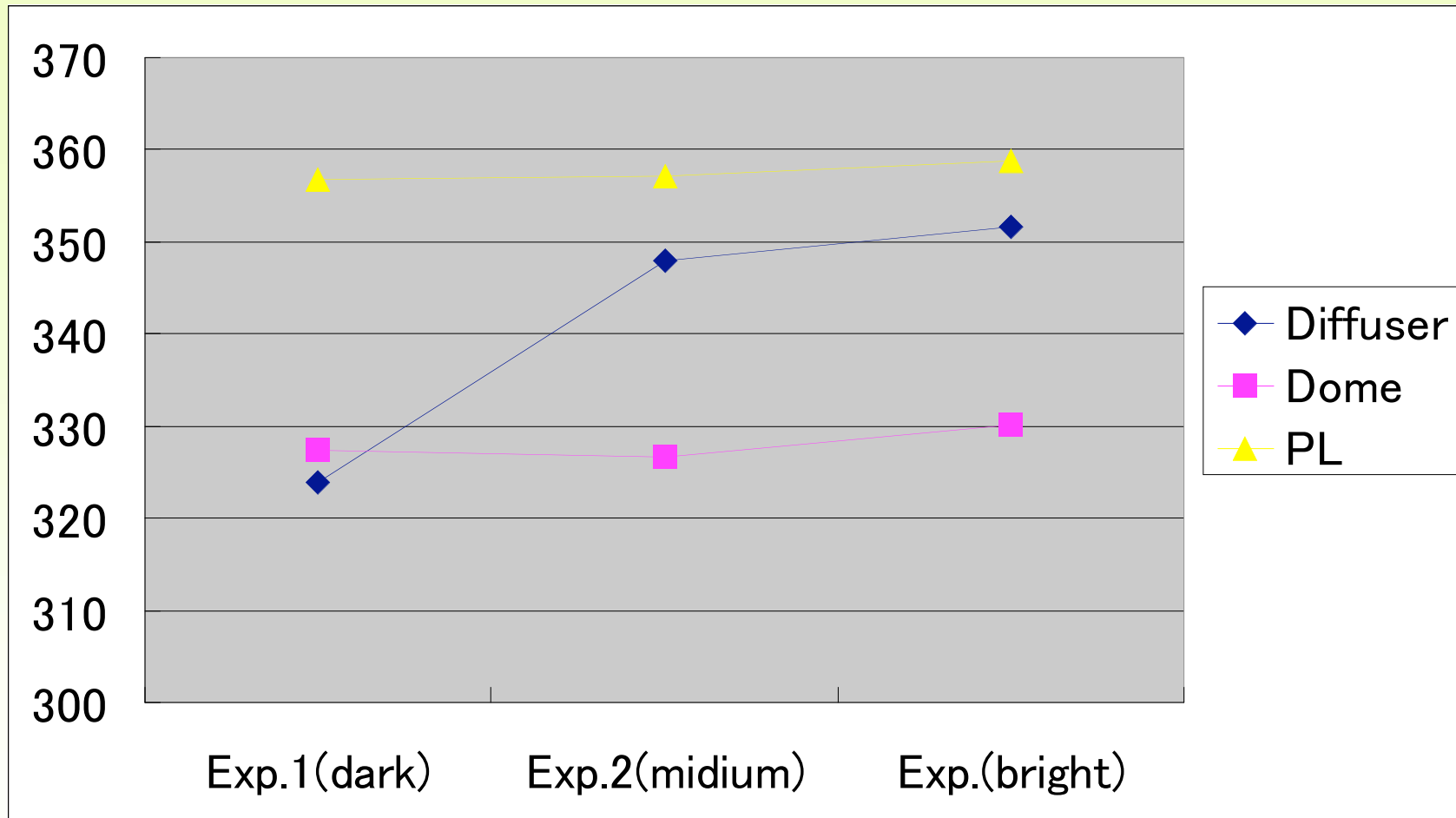
HSI on different exposure conditions



Hue

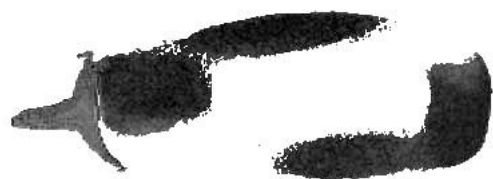


Hue on different exposure conditions

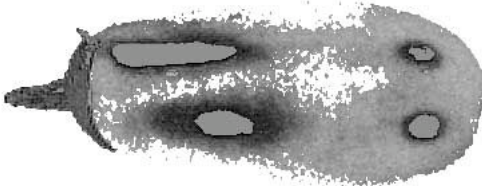
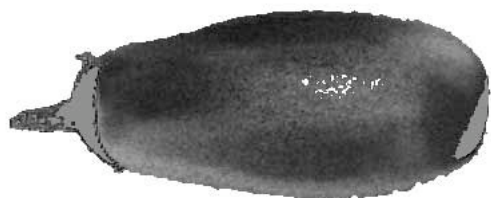


(Average hue value change except too bright and too dark pixels)

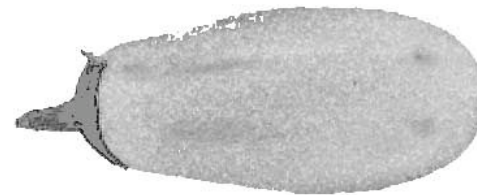
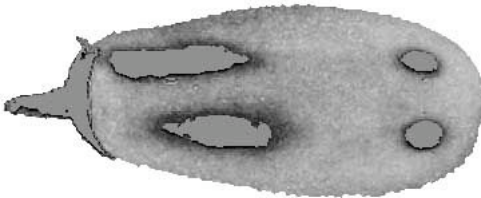
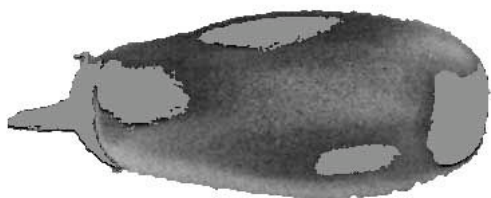
Saturation



Exp.1
(dark)



Exp.2
(mid)



Exp.3
(bright)

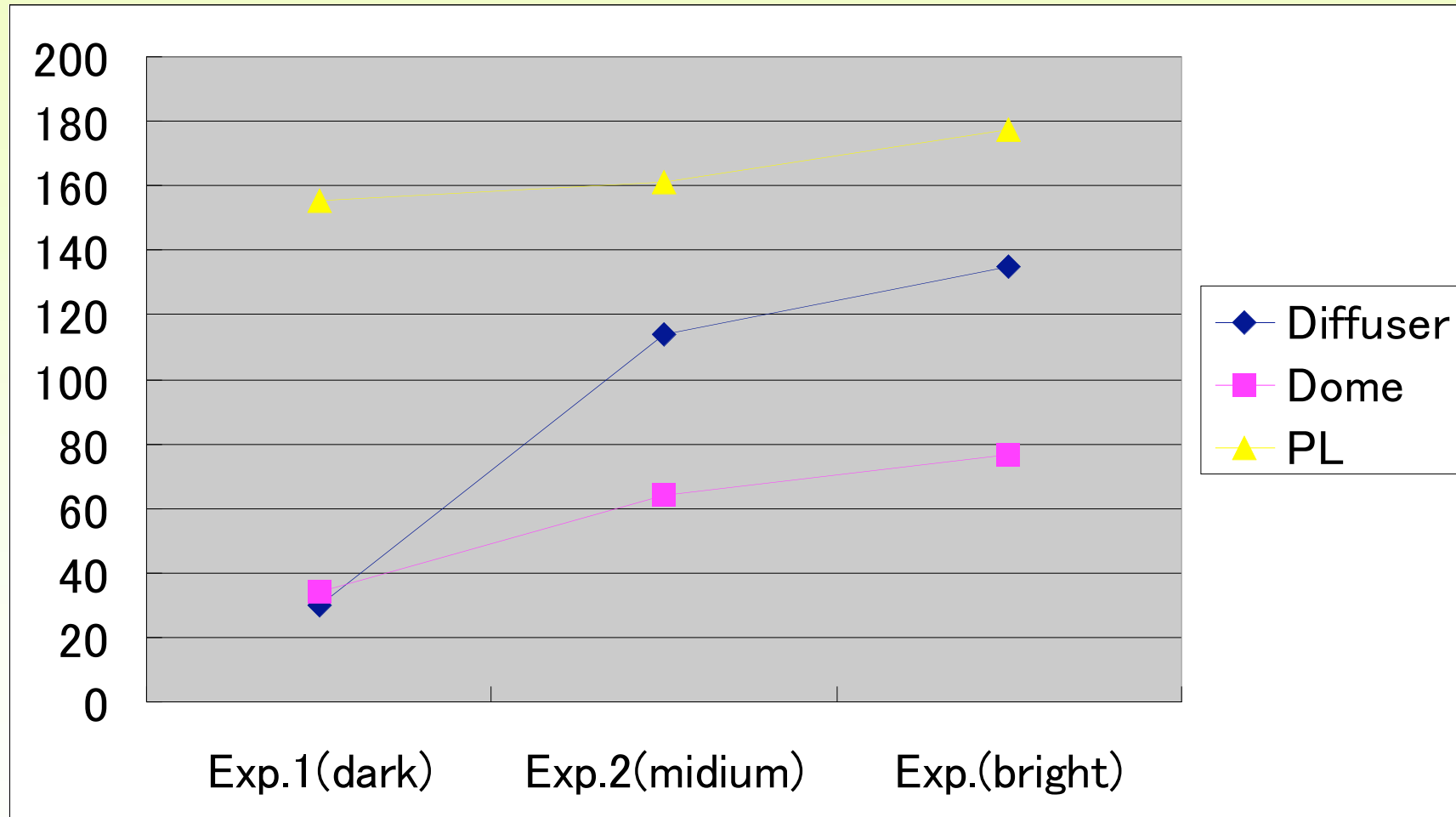
Dome

Diffuser

DL with PL filter

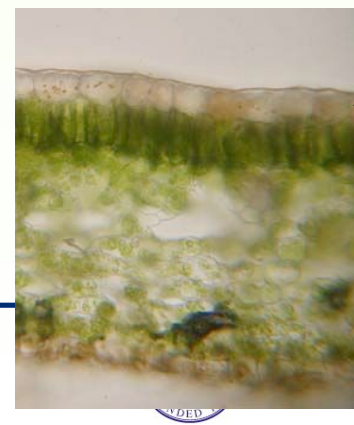


Saturation on different exposure conditions



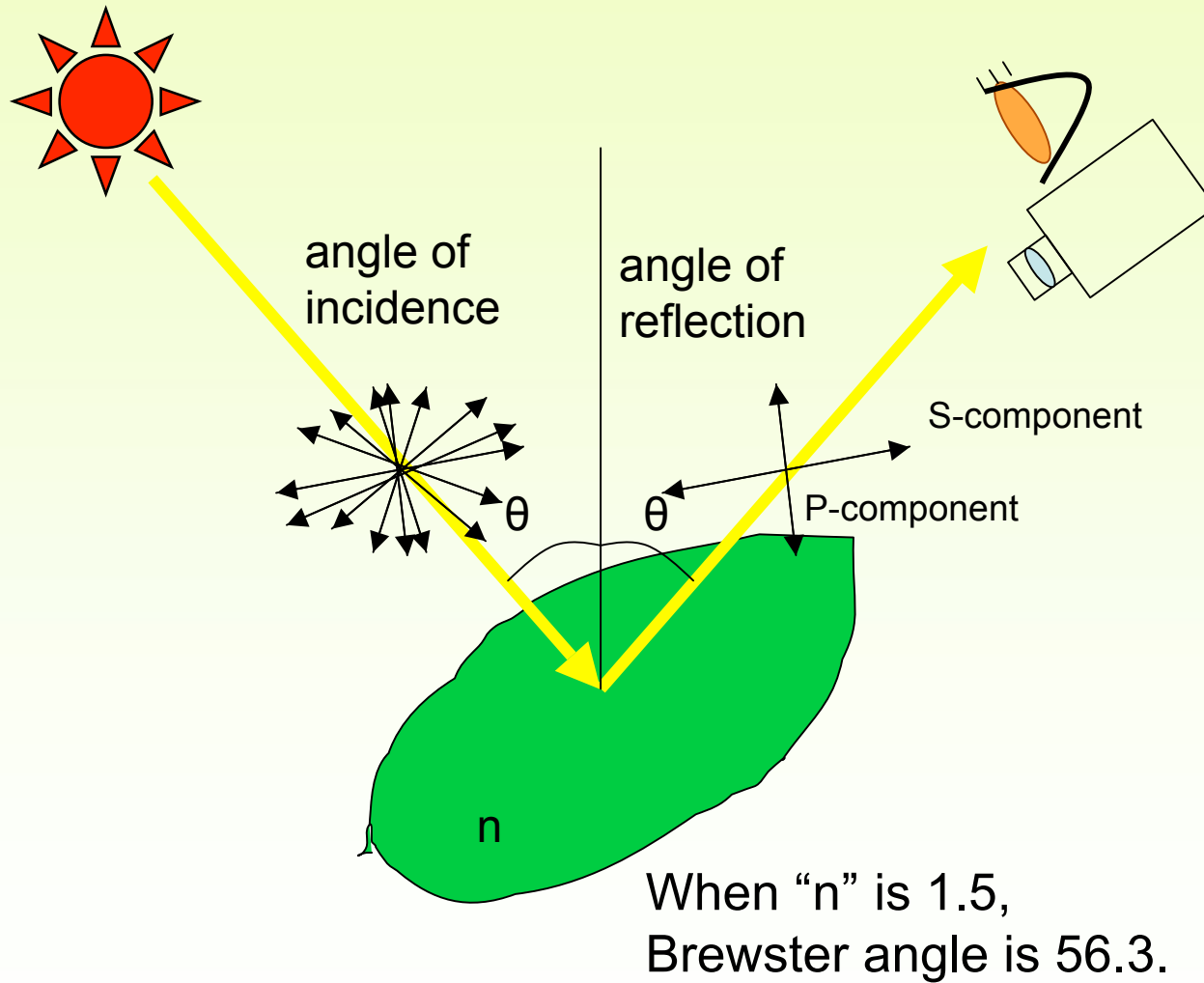
(Average hue value change except too bright and too dark pixels)

Polarization on crops



← Cuticular Layer

Polarization



$$\tan \theta = n$$

θ : angle of incidence
 n : refractive index

