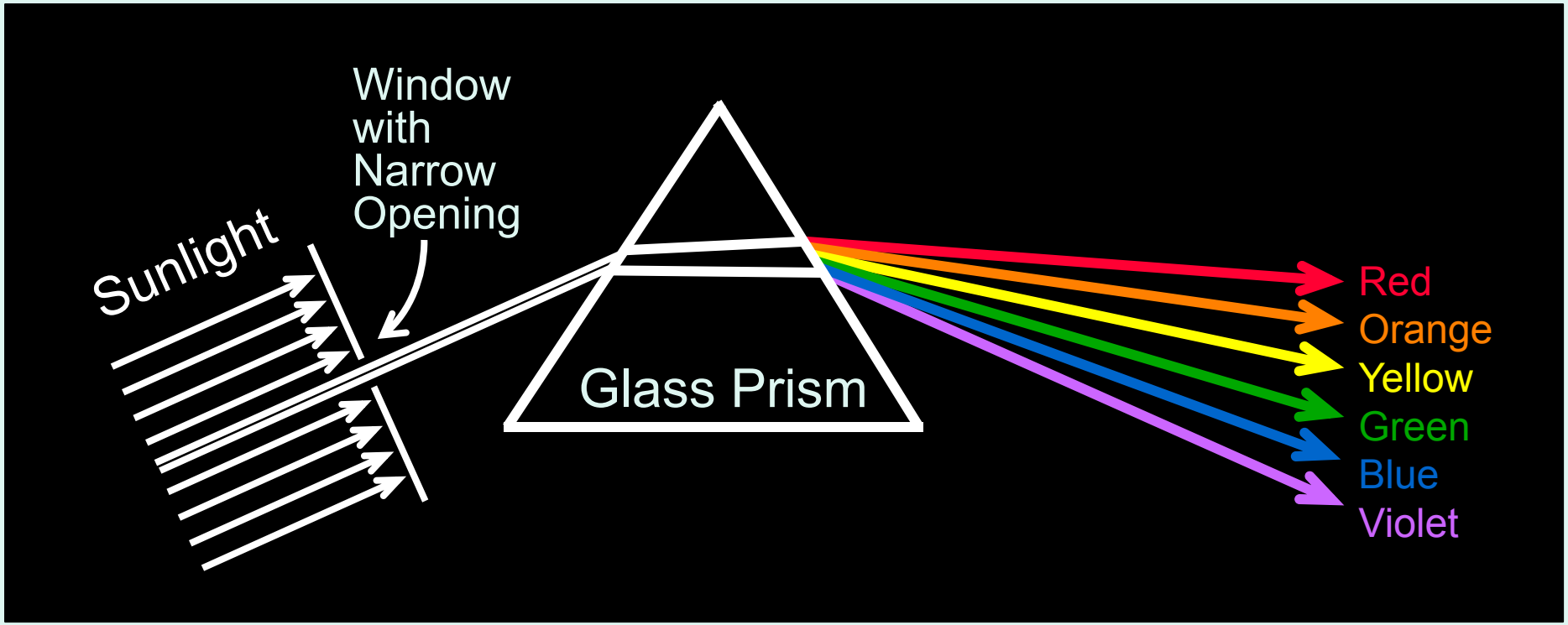
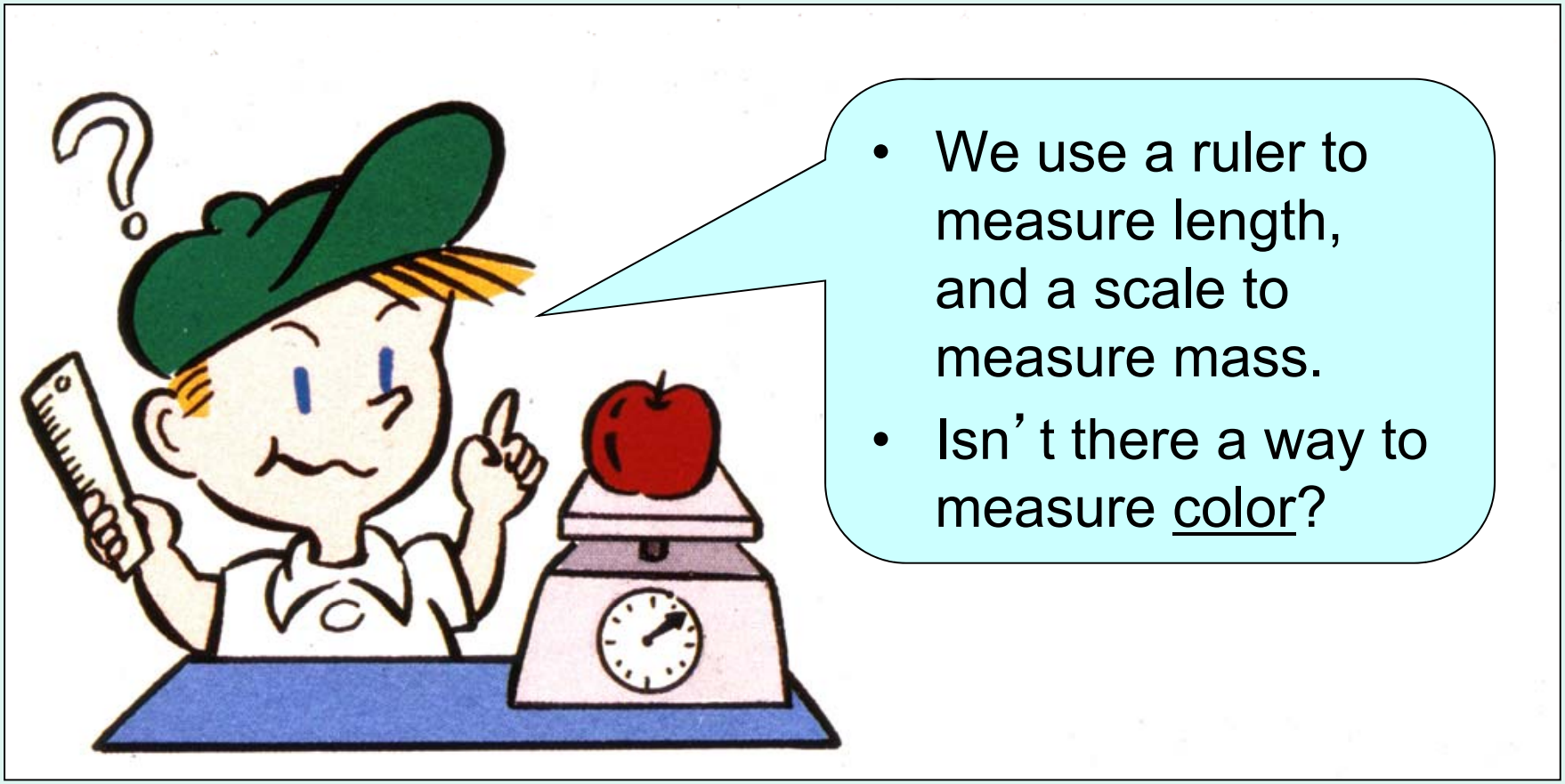
A Brief History of Color Measurement in Tomato

David Slaughter

University of California, Davis



Electromagnetic Radiation

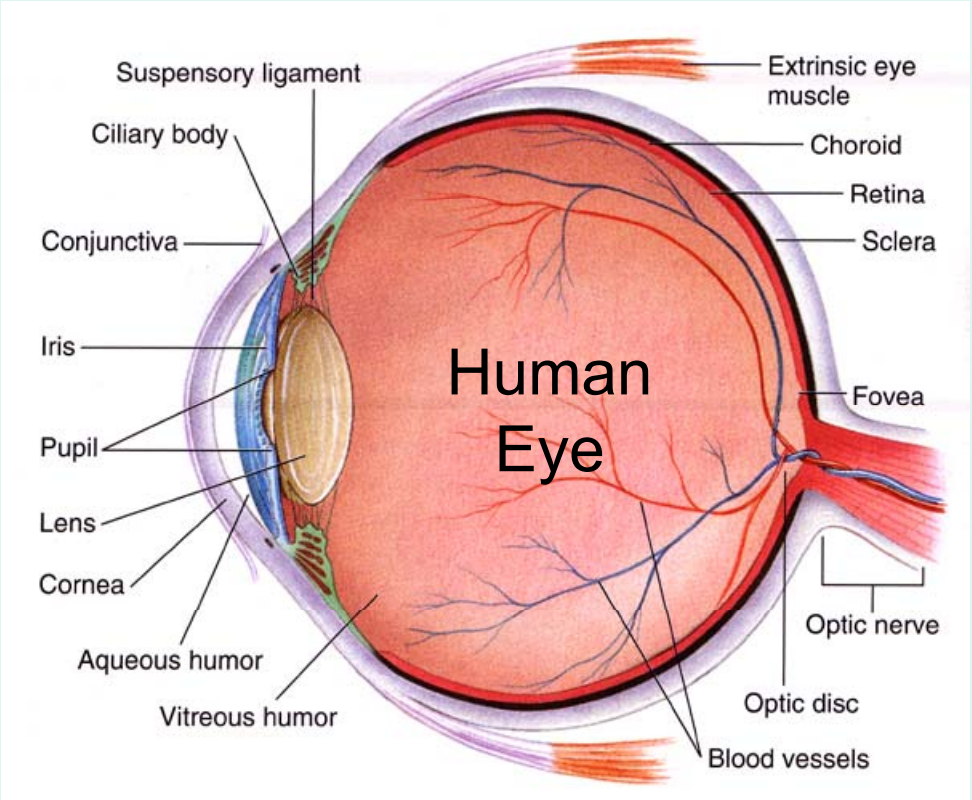


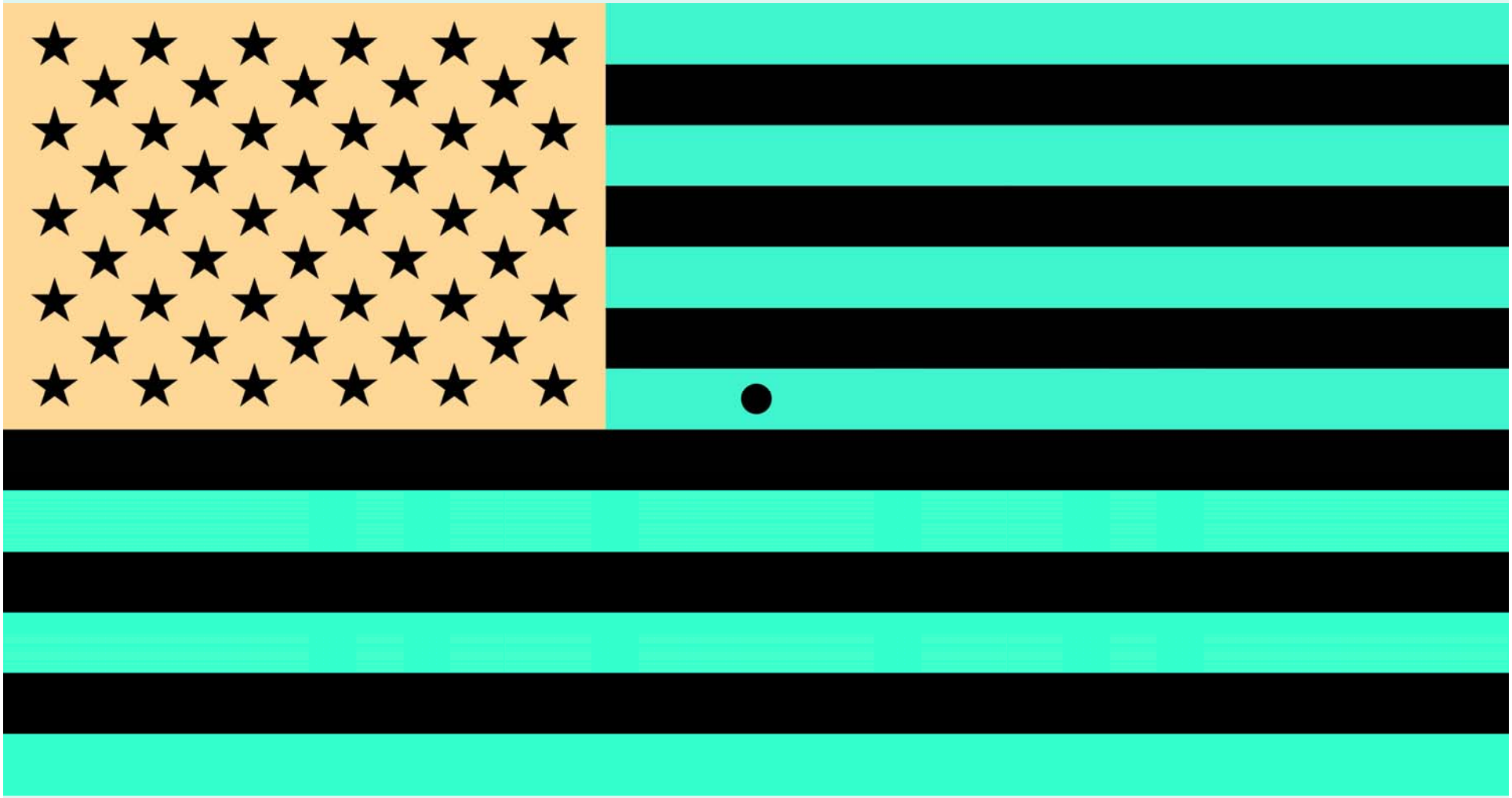
A Tale of Two Cities

Karl Ewald Hering (1834-1918) German Physiologist

- When viewing a mixture of psychologically pure red and pure green lights,
- a person will see: red, green, or white,
- never yellow.

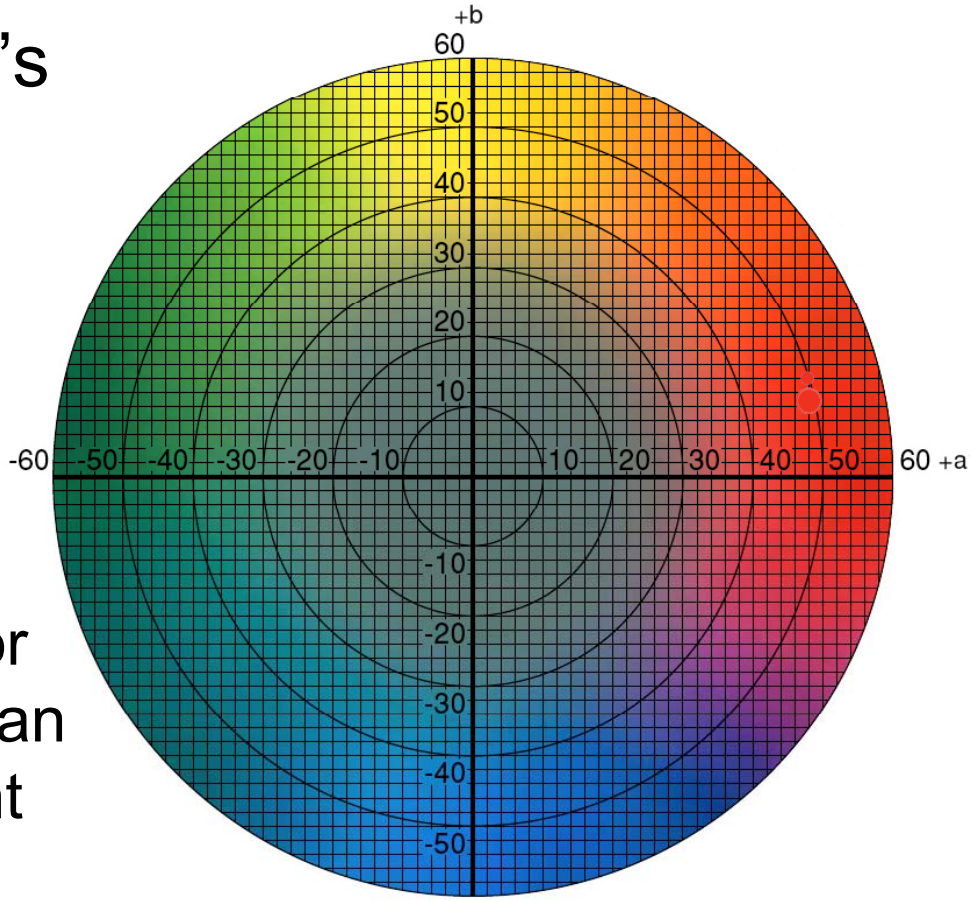
- Hering created a theory of color vision based on three opposing pairs:
- Red – Green
- Yellow – Blue, and
- Black - White





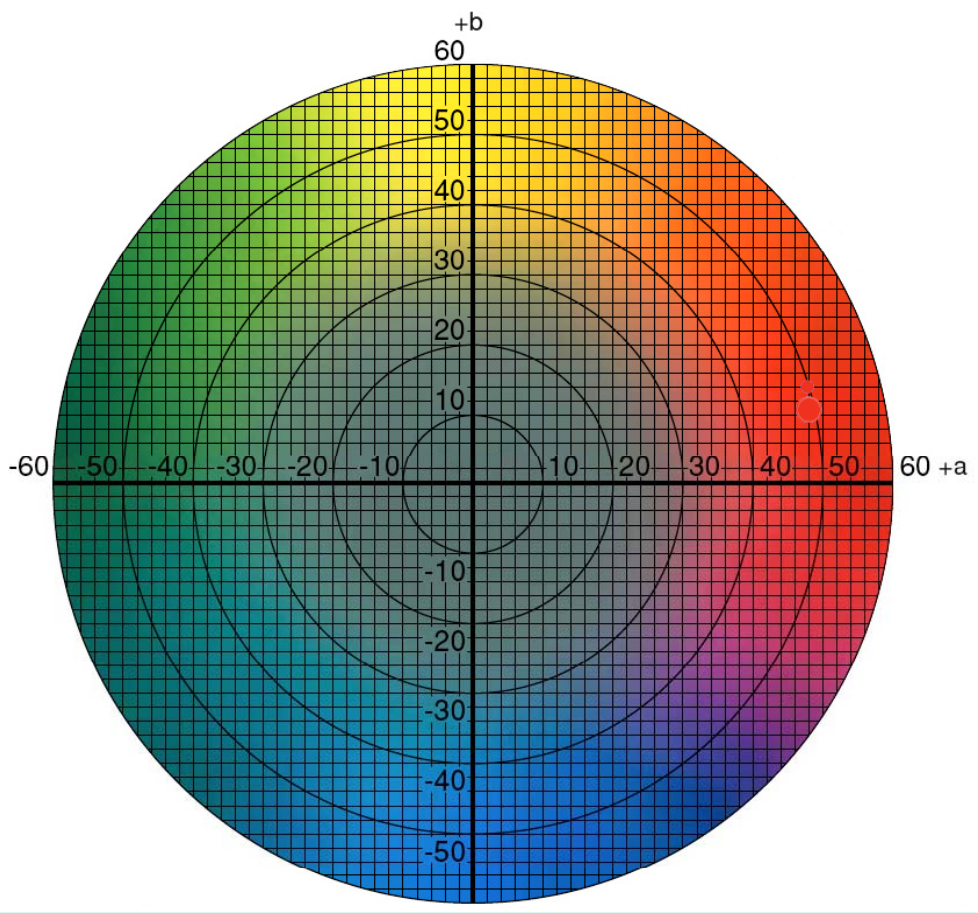
Richard S. Hunter
Optical Engineer

- In 1948, he developed the Hunter L, a, b color space
  - Based upon the Hering's red-green, yellow-blue opponent color axes
- Hunter's Objective:
  - Create a "Uniform" color space
    - A one-unit change in a or b is consistent with human perception of the amount of color change.



Hunter L, a, b color space

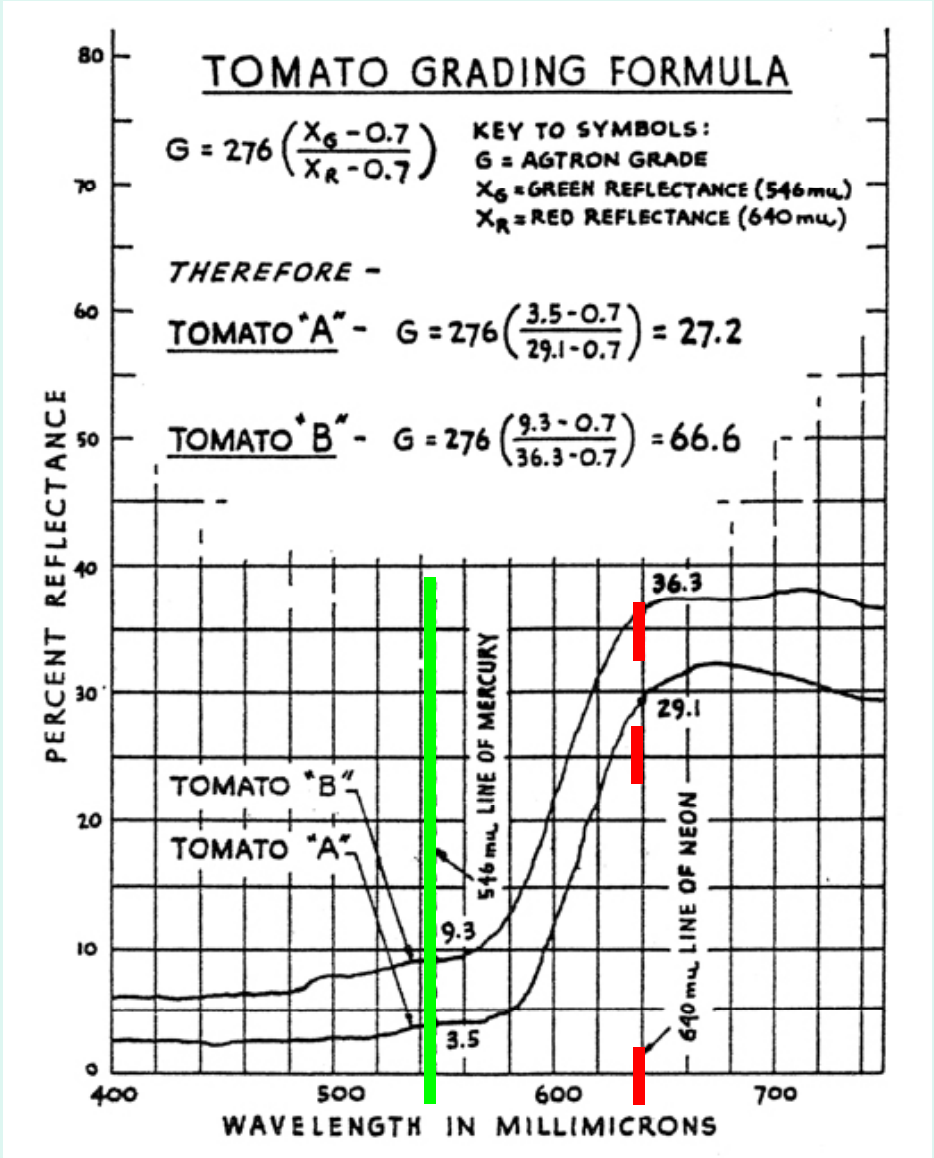
- Since color is the principal attribute that consumers use in purchasing decisions, the Hunter a & b color scores were adopted by the industry as a measure of quality.



  - USDA Processed Tomato Juice Color Score
    - USDA Color = 25.715 +K_1 * [a –K_2*b]
      - K_1 = 0.956, K_2 = 1.828

S. R. Whipple, 1955. COLOR INSPECTION—FRESH FRUITS AND VEGETABLES

- First electronic instrument to measure tomato ripeness was developed in the early 1950's.
- Designed to measure the color of the surface of two halves of a tomato.
- Color score was the G/R ratio of green reflectance (546nm) to red reflectance (640 nm).
- Initially used to train inspectors and to determine the grade of "doubtful" tomatoes.
- Modified in the 1970's to measure the color of de-aerated juice.



Measuring Tomato Ripeness

- Kader & Morris, 1978
  - Used an Agtron E5-W
- Agtron score was well correlated with ripeness stage.

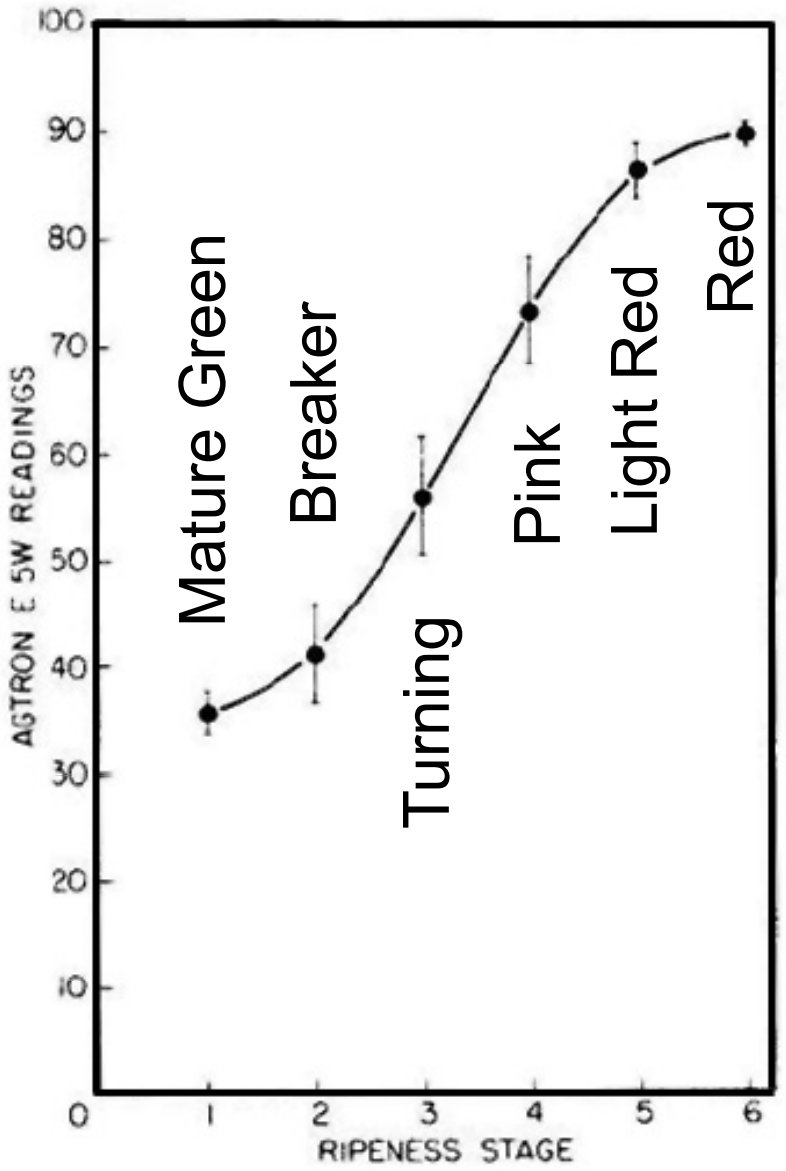
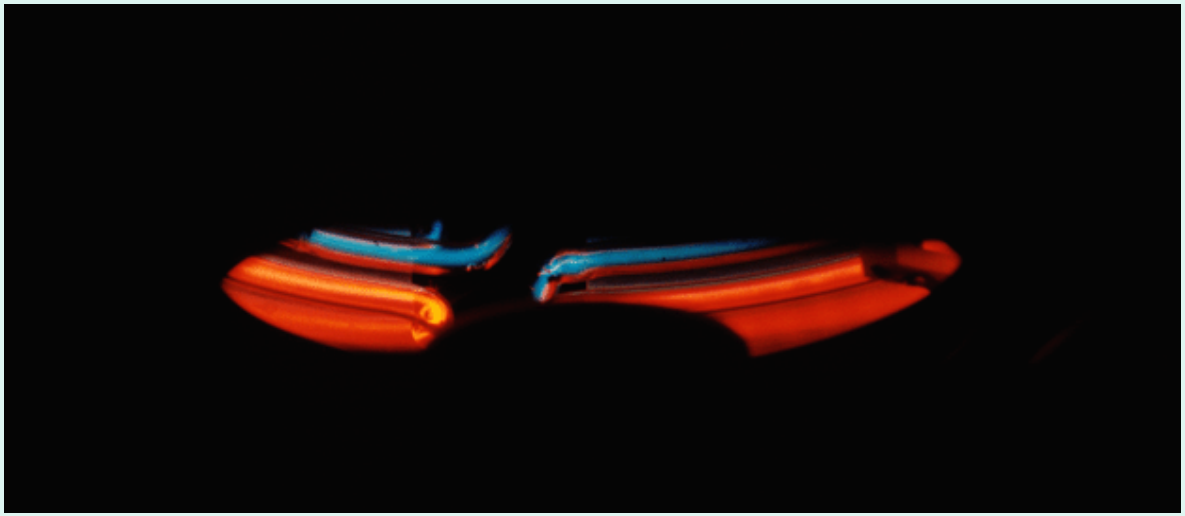
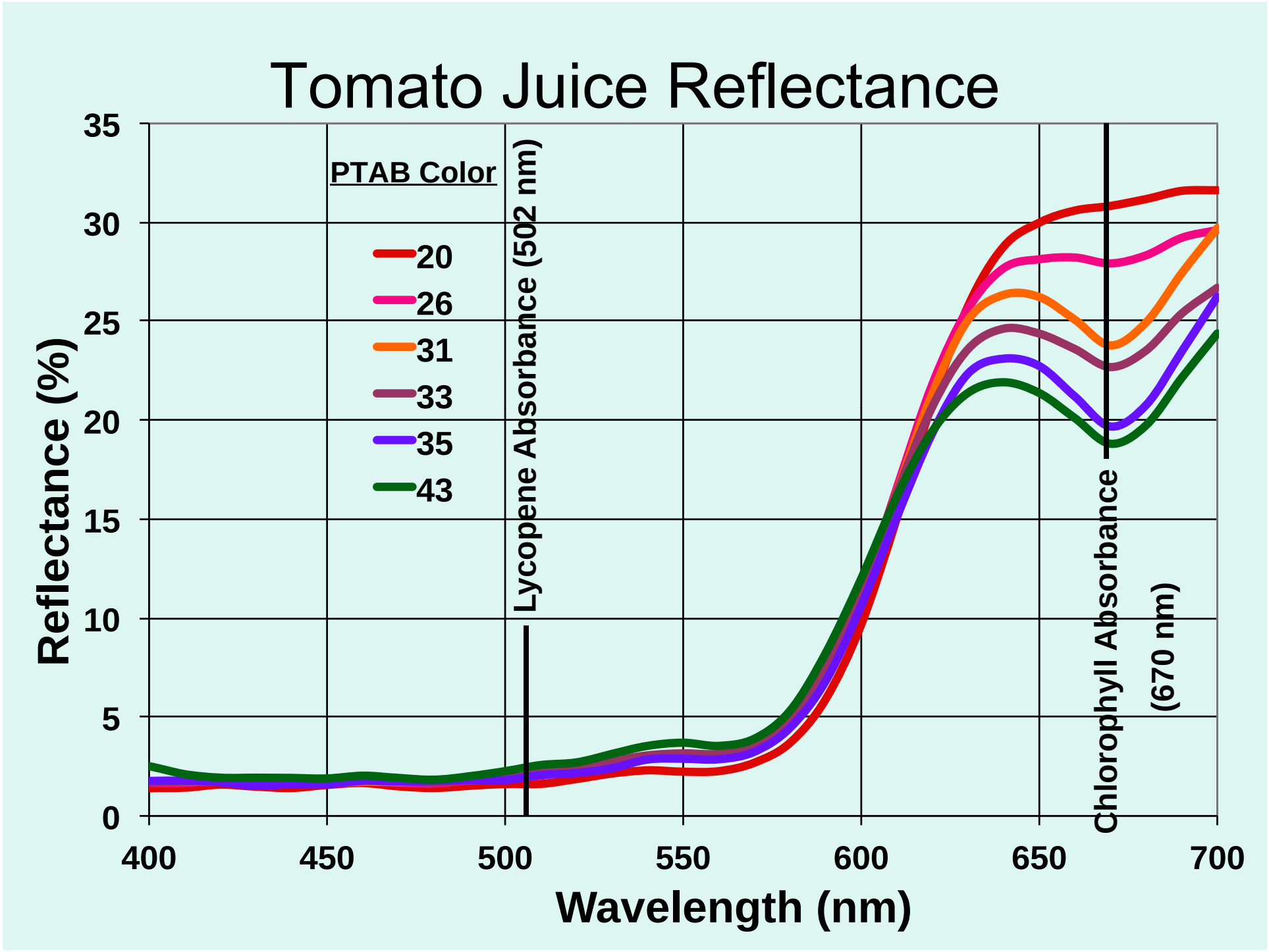


Fig. 1. Agtron E5-W reflectance readings vs ripeness classes of 'Ace 55' fruits. Each point represents a mean for 50 fruits and vertical lines indicate standard deviation.

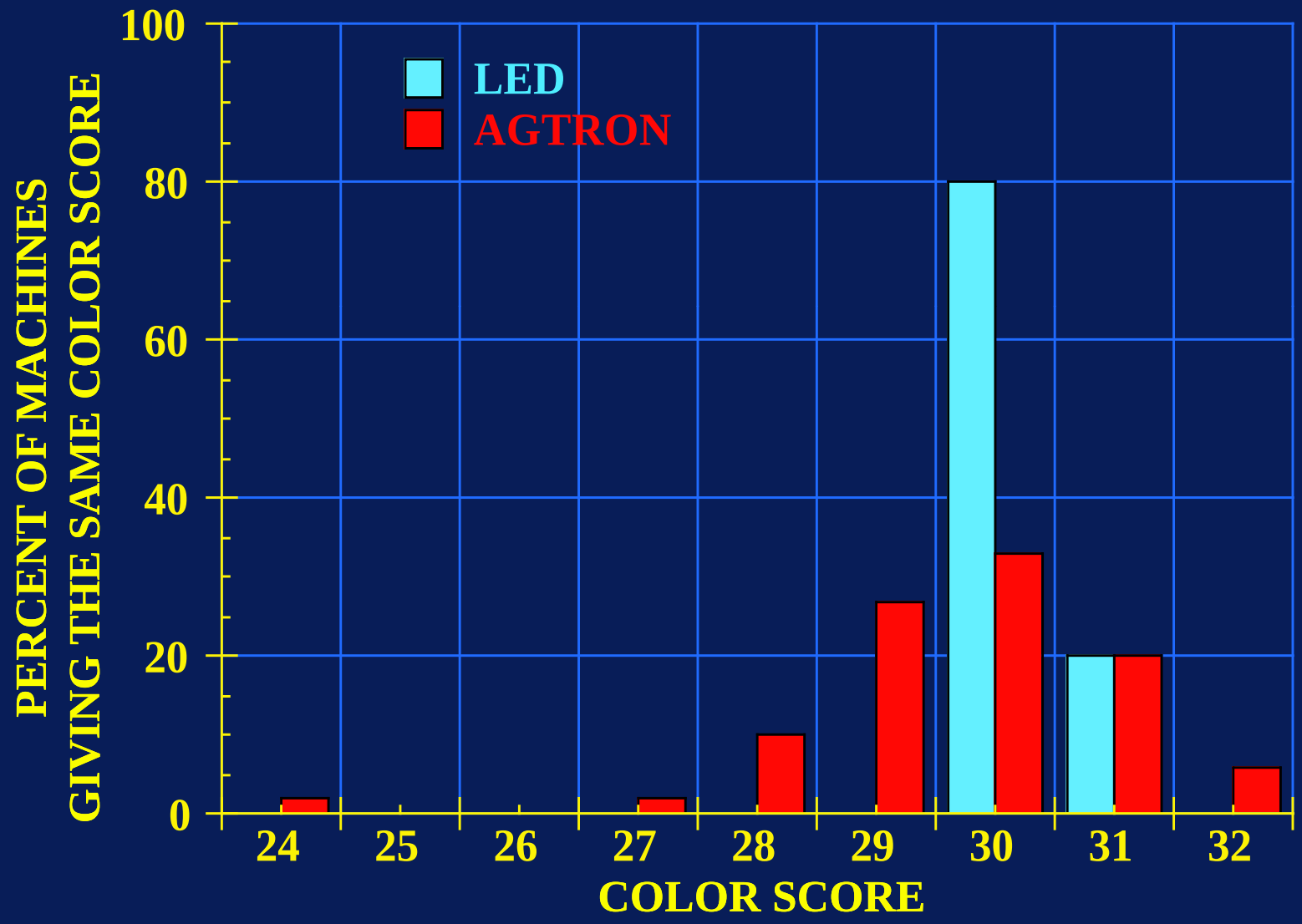
Agtron E5-M
Color in Processing Tomato Inspection



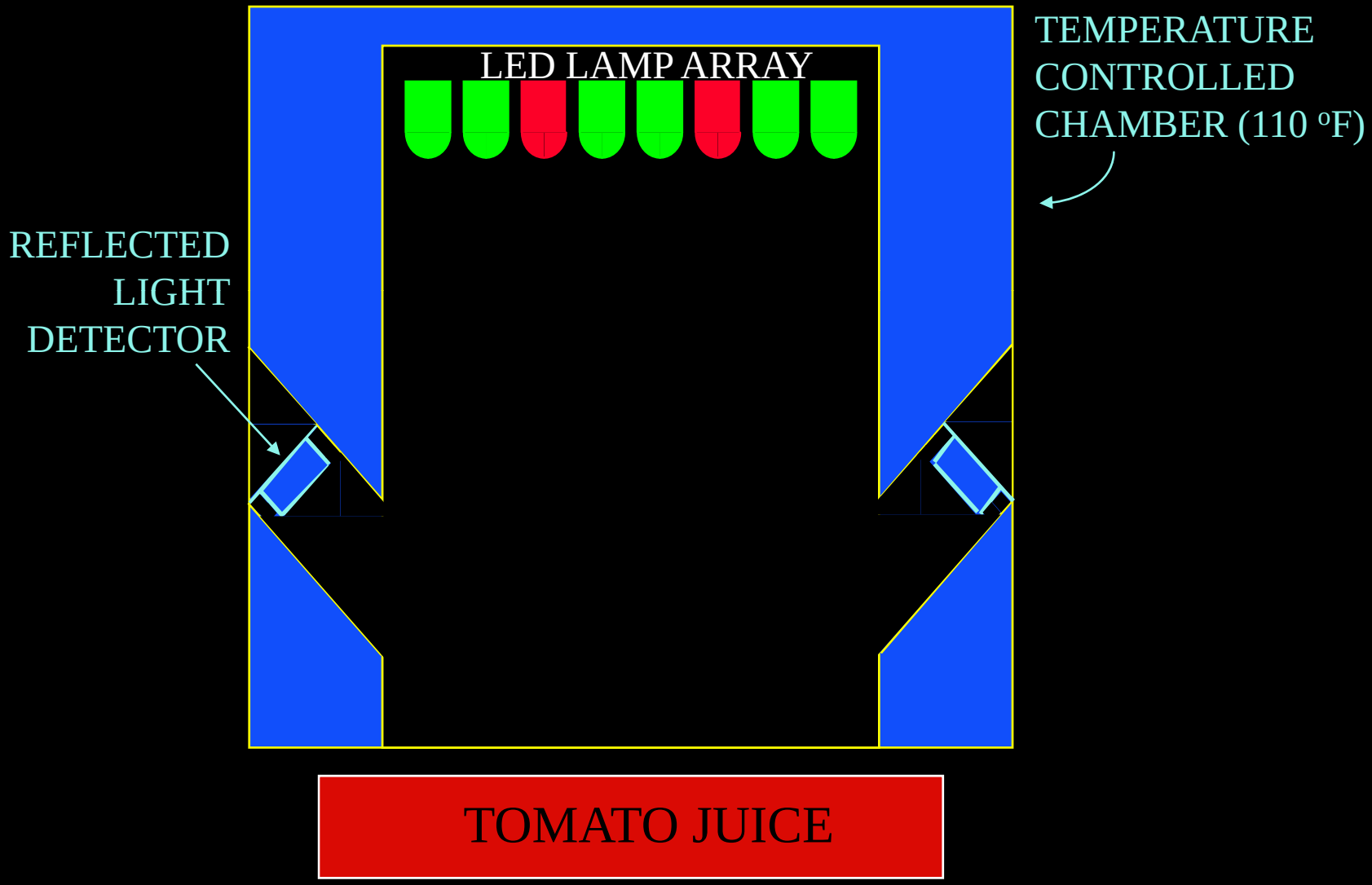
Red Neon &
Green Mercury
Lamps


Tomato Juice Reflectance
PTAB Color
20
26
31
33
35
43
Lycopene Absorbance (502 nm)
Chlorophyll Absorbance (670 nm)
Reflectance (%)
Wavelength (nm)
0
5
10
15
20
25
30
35
400
450
500
550
600
650
700

INTER-INSTRUMENT AGREEMENT OF AGTRON & LED MACHINES READING A SINGLE TOMATO JUICE SAMPLE

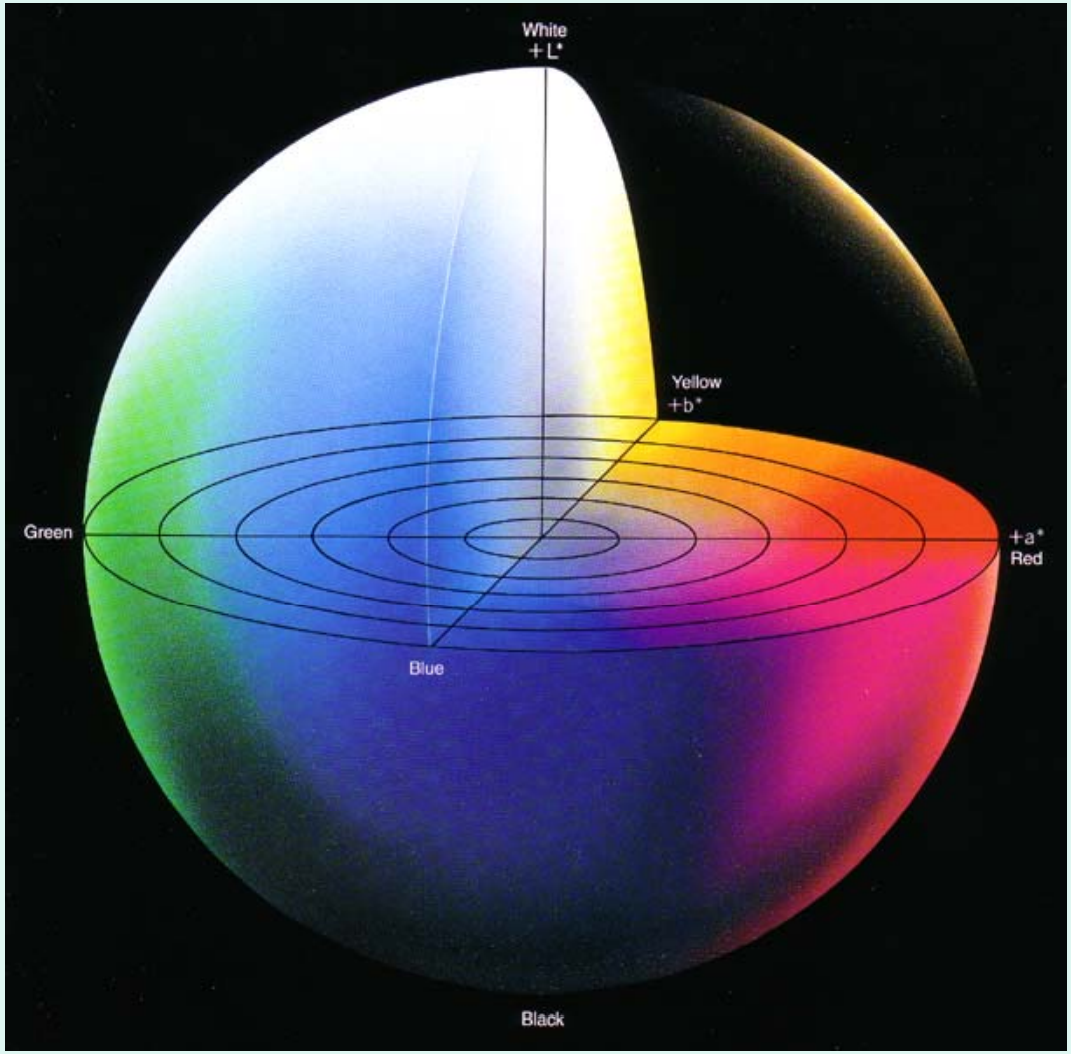


UC Davis LED Tomato Color Meter



CIE L*, a*, b* color system

- "Uniform" color system
  - Developed in 1976 by the International Commission on Illumination
  - "Improved" version of Hunter L, a, b color space



Hunter L,a,b vs. CIE L*, a*, b*

HUNTER

$$L = 10\sqrt{Y}$$

$$a = \frac{17.5 * (1.02X - Y)}{\sqrt{Y}}$$

$$b = \frac{7 * (Y - 0.85Z)}{\sqrt{Y}}$$

CIE

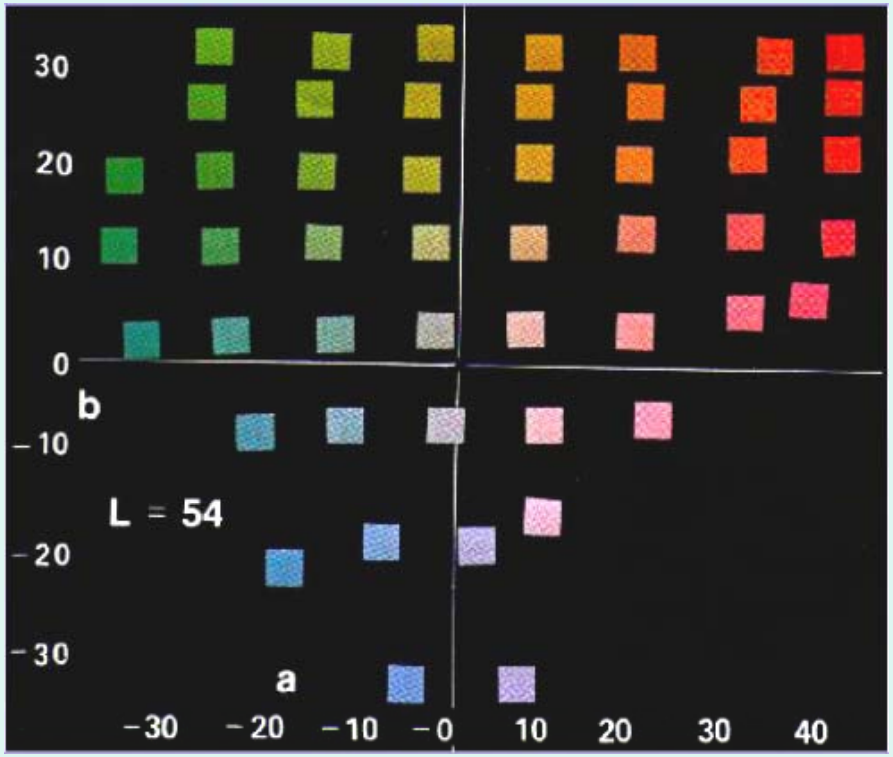
$$L^* = 116 * \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16$$

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

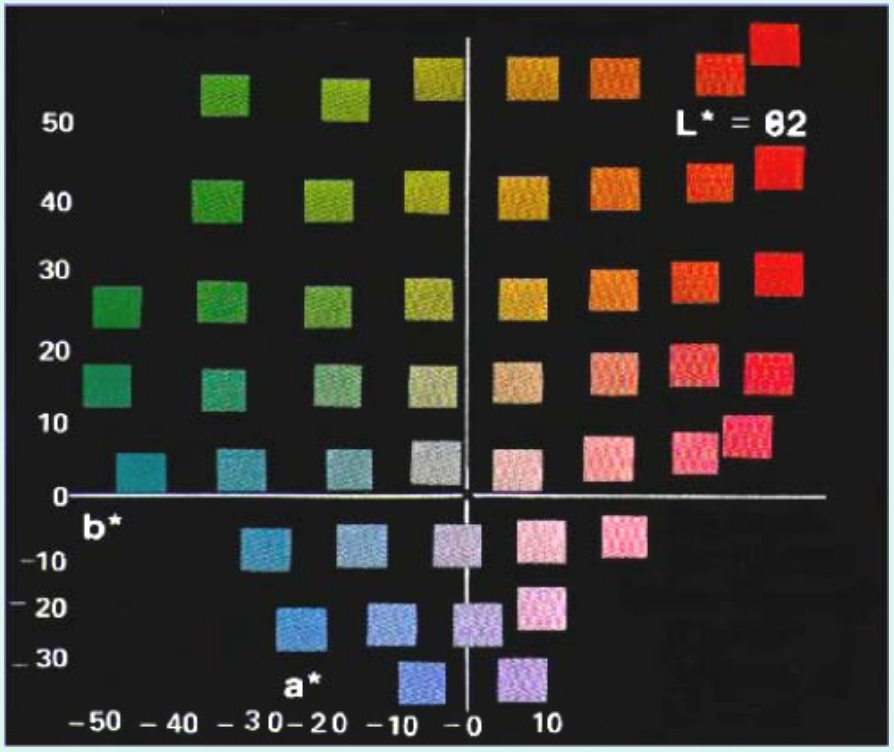
$$b^* = 200 * \left[\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right]$$

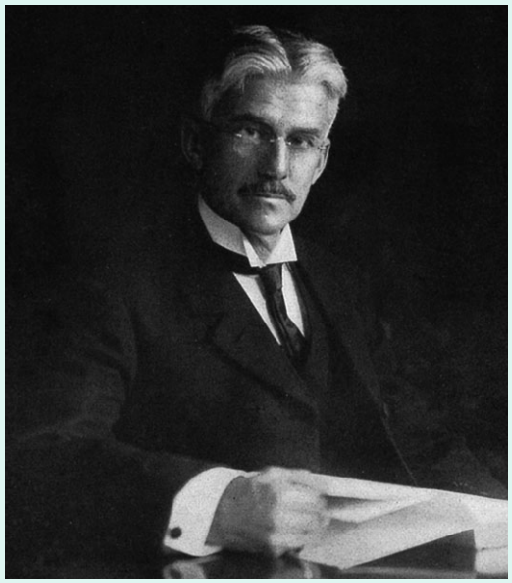
Comparison of Color Space Uniformity

Hunter Lab



CIE L*a* b*

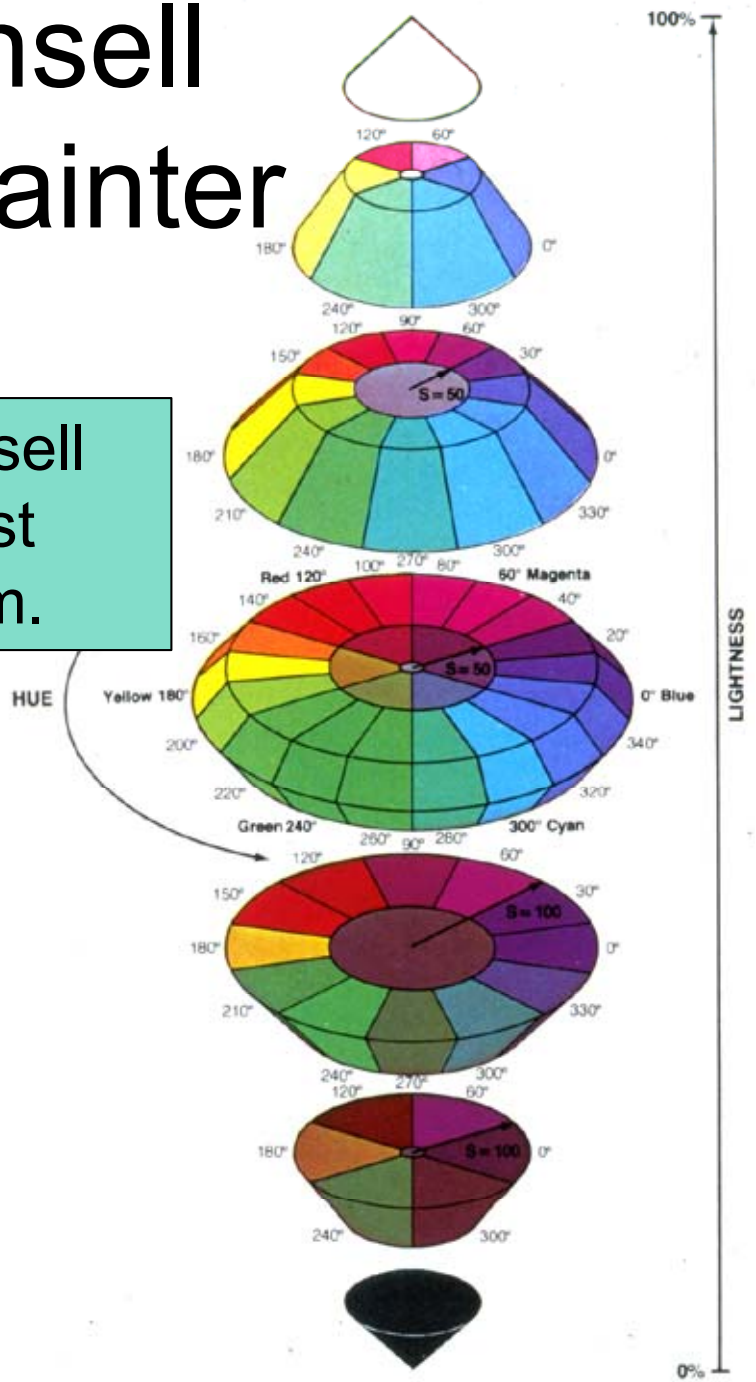




Albert Munsell American Painter 1915

The original Munsell system is almost perfectly uniform.

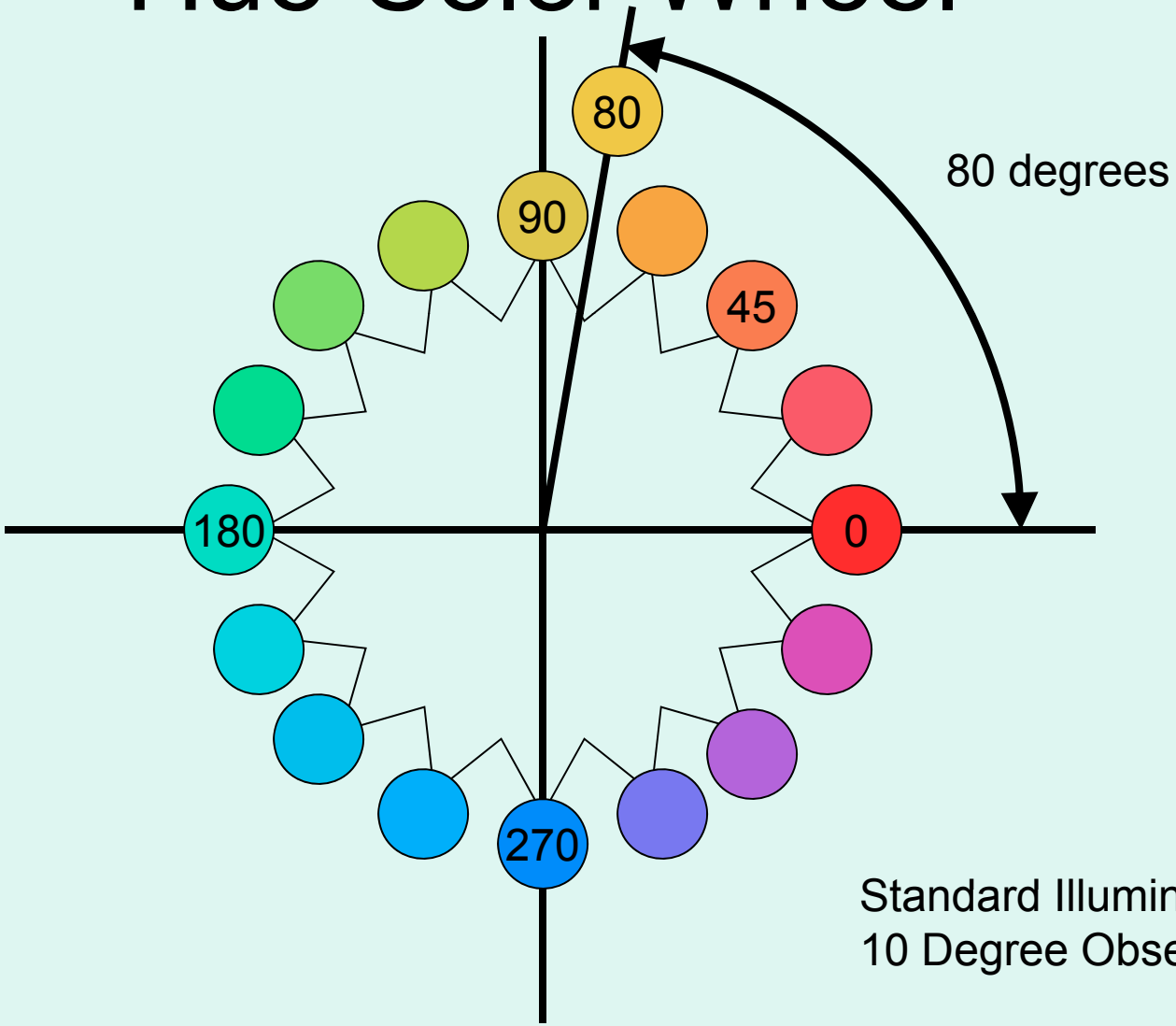
- Hue = name of color
  - (e.g., purple, green, yellow)
- Value, (or lightness)
  - Divided into 11 equal steps
    - (black=0, white = 10)
  - Value ~ √ave. reflectance
- Chroma, purity, or saturation



Konica Minolta CR-10 CIE L*,C* H* Color Meter

- Over 13,000 peaches evaluated for maturity with the CR-10 in 2006.
- Operated by SPI inspectors in 2006.

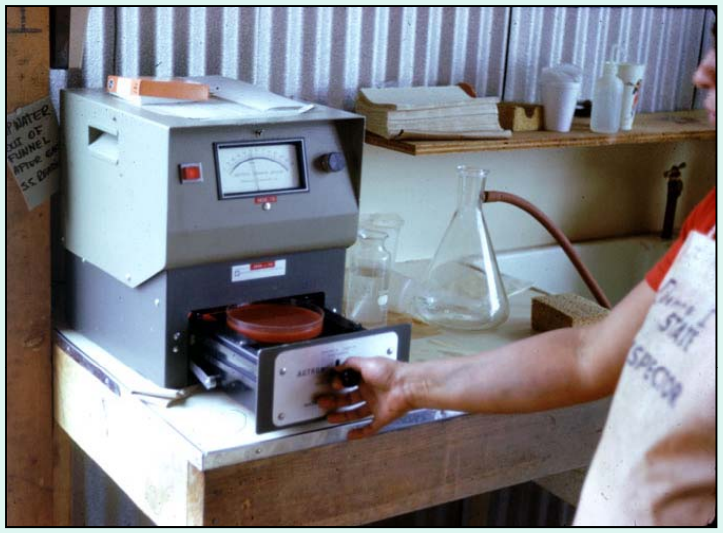
Hue Color Wheel



Standard Illuminant: D65
10 Degree Observer

UC Davis

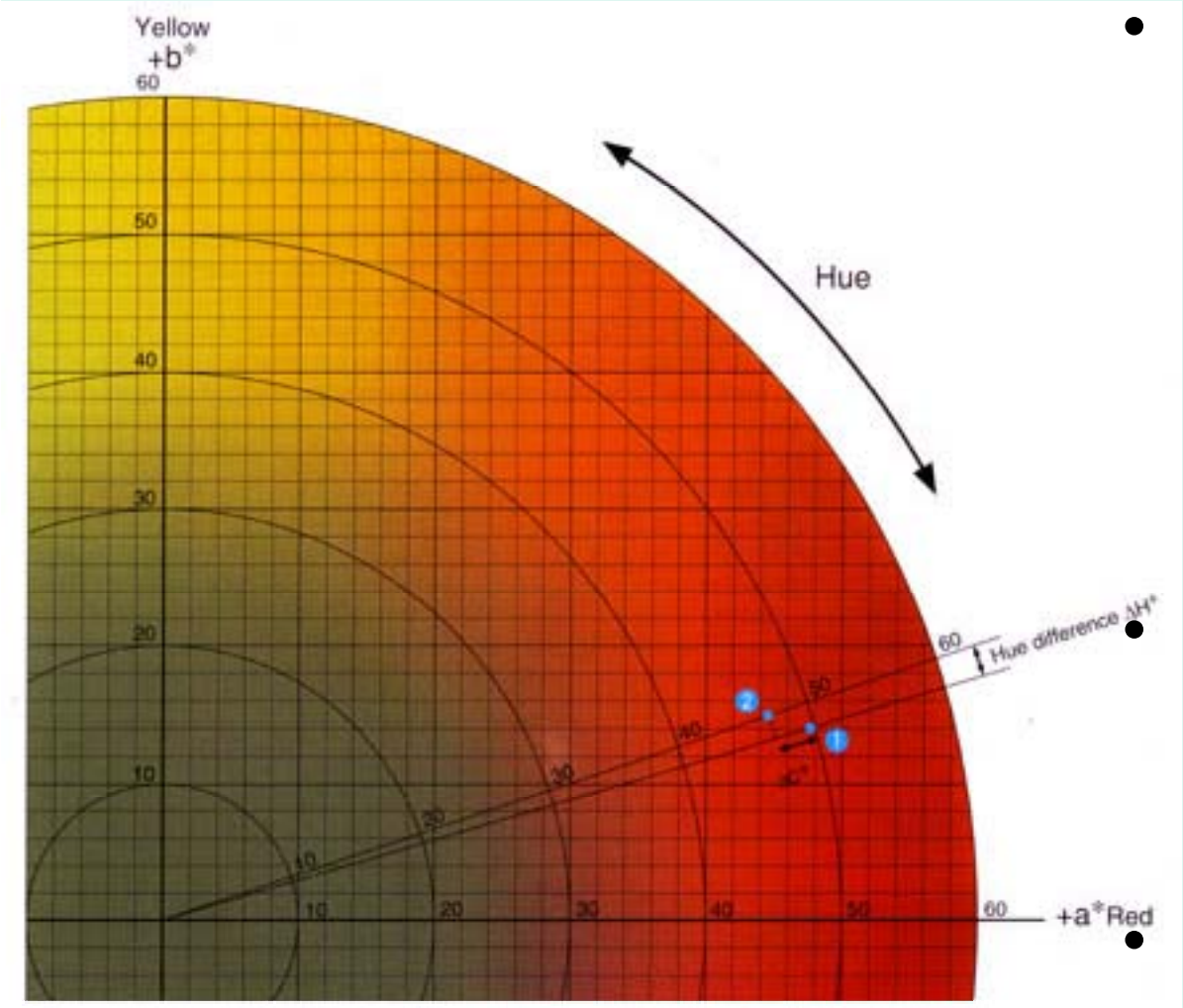
PTAB Color Situation



- The current LED technology is beginning to require increased maintenance and will require replacement.

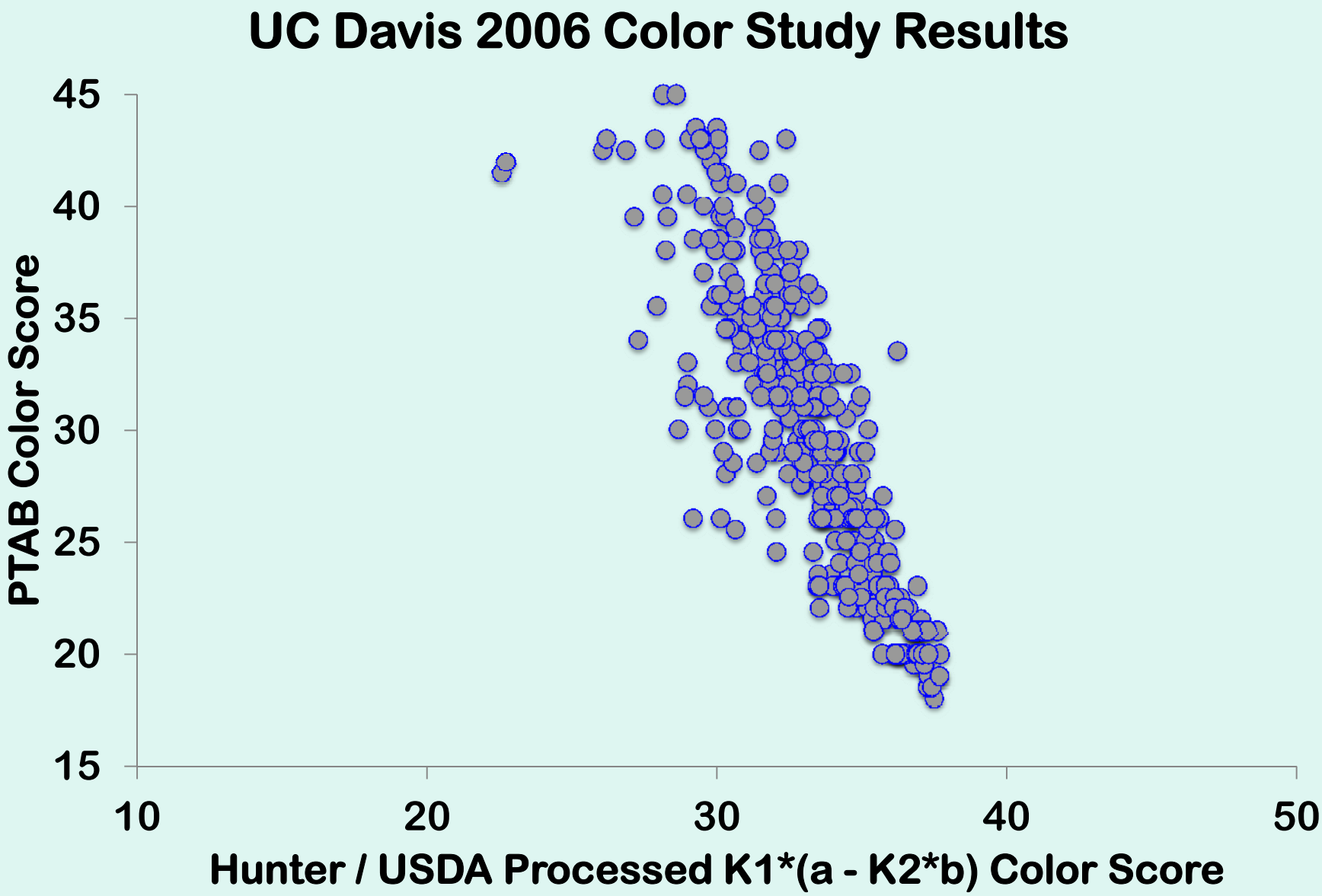
- The opportunity exists to make a significant change in how maturity/color is determined at harvest.

PTAB Color Proposal for 2012

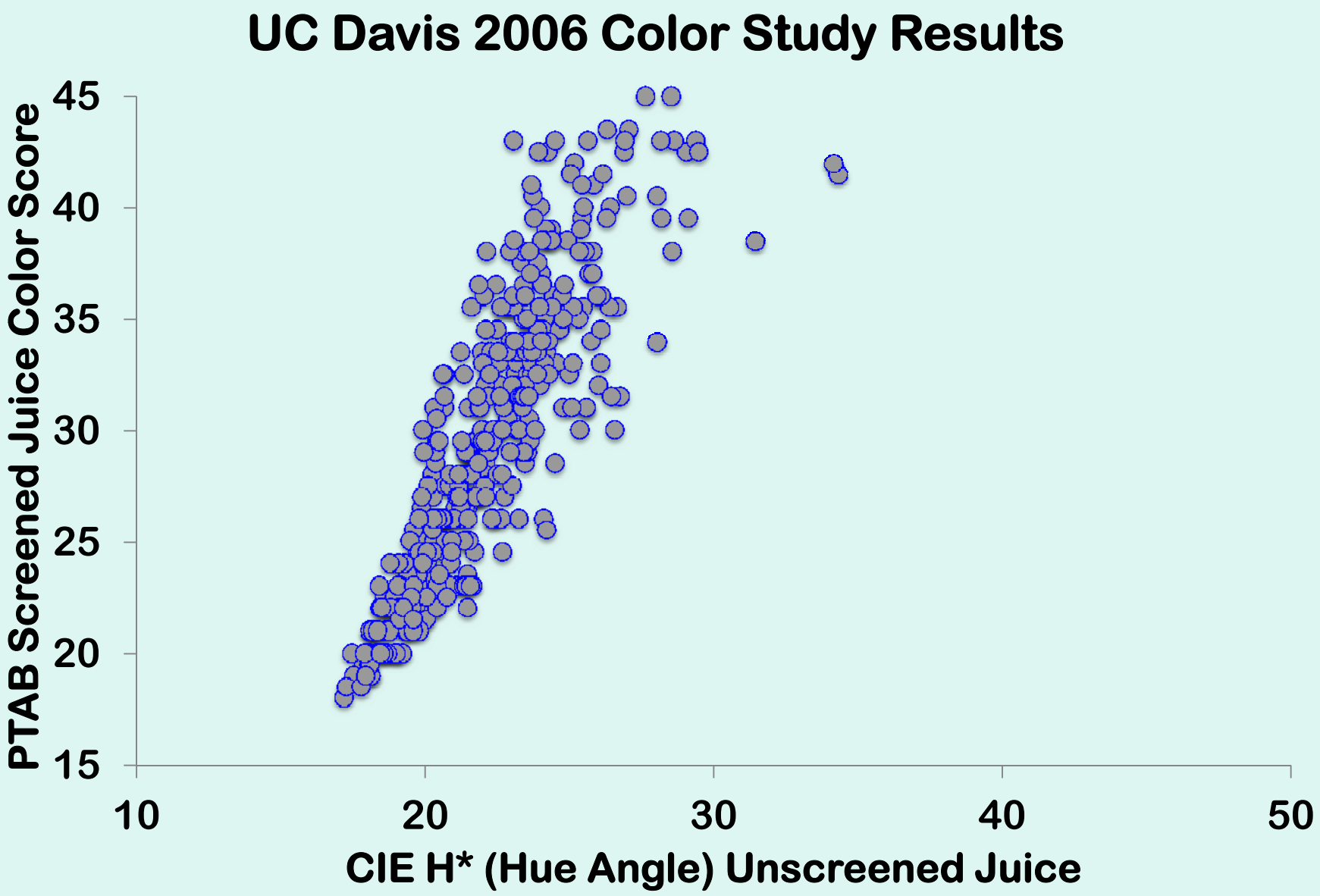


- PTAB would start using the Minolta CR-410 Colorimeter for color inspection in 2012.
- CIE H* (Hue Angle) would become the official grade.
- Hunter L, a, b, and
- CIE L*, a*, b* could be provided at no

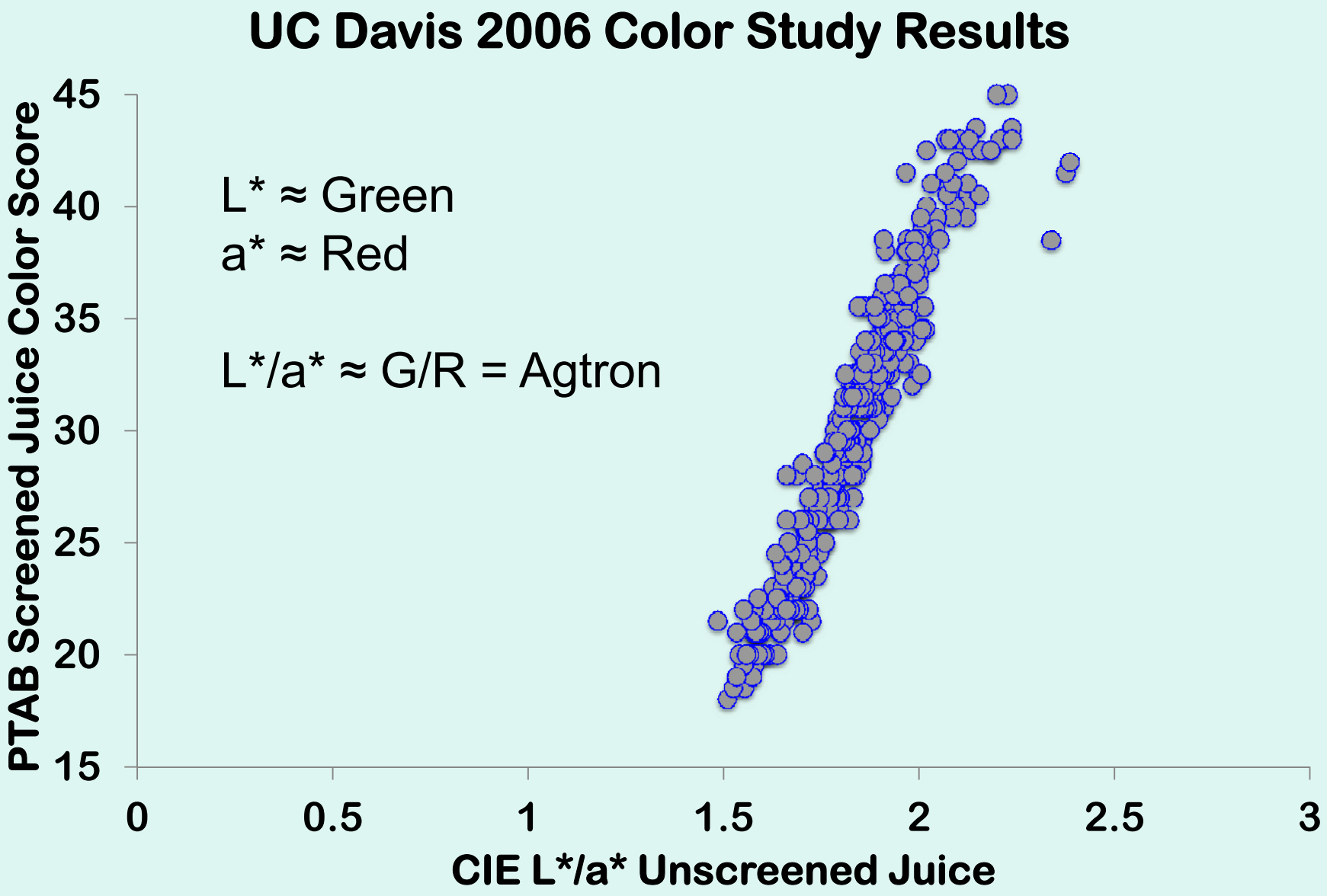
PTAB Color vs. USDA Color



PTAB Color vs. Hue Angle



PTAB Color vs. L*/a* Ratio



2011 Prototype Flow-Through Color Grading System

- Blends juice sample,
- Measures Color, pH, and Soluble Solids,
- Self-cleaning.