CS294-164 Computational Color
Instructor: Ren Ng

Computational Color
UC Berkeley CS294-164, Fall 2020

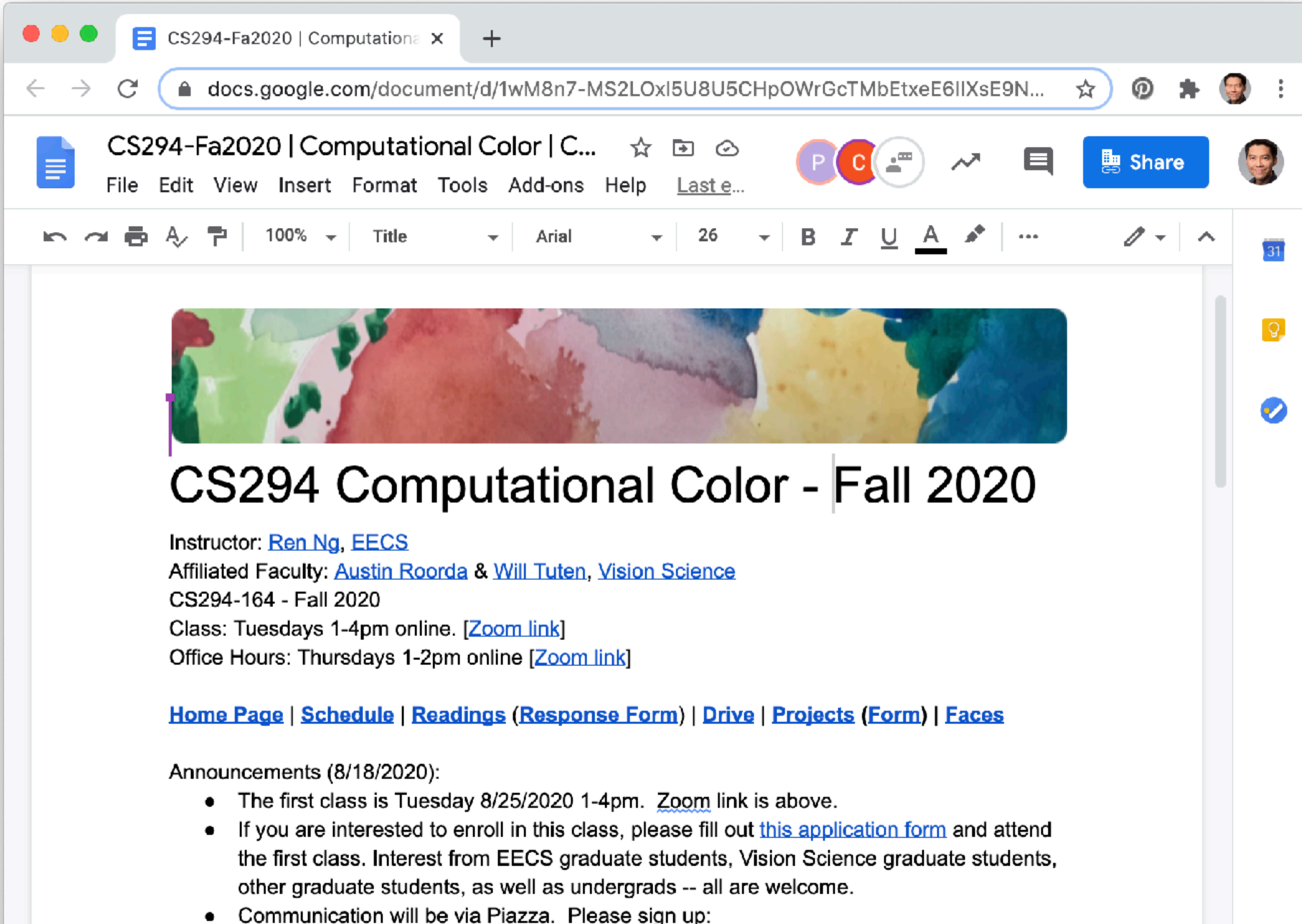
Welcome to CS294-164 Computational Color!

Today's agenda

- Course basics; introductions
- Why study color?
- Instructor background
- Overview of course topics
- Course logistics, deliverables, project

  << Break - Mingling in Ohyay >>
- Lecture 1: Tristimulus Theory and Colorimetry

Course Website: http://tinyurl.com/cs294-164-fa20



Course Info

- Instructor: Ren Ng (ren@berkeley.edu)
- Tuesday, 1-4pm, online, synchronous
- Class Website: http://tinyurl.com/cs294-164-fa20 (Berkeley login)
- Zoom links: see website
- Class Communication: Piazza (Berkeley CS294-164)
- Office Hours: Thu 1-2 or by appointment
- Assumed knowledge: CS184 (Graphics) OR VS260A+260D

Class Format

Weekly 3 Hour Class Meetings on Tuesday

- 1:10 – 2:20pm, student-led discussions on readings
  - Each reading:
    - 15 min discussion leader presentation
    - 20 min leader-facilitated group discussion
- << Break >>
- 2:30 – 4:00pm: lecture preparing for next readings

Enrollment Information

- Application google form (on class website)
  - Many of you have applied already
  - Deadline: Today, Tuesday 9/1 at 9:00pm
- Enrollment will be decided before next class
  - Will do my best to be inclusive
  - Online format provides some flexibility
  - But some finite resources to consider

Code of Conduct

We are all here to learn!

- discussion-based class
- seeking an intellectually diverse quorum
- everyone has different backgrounds
- engage intellectually in class!
- be respectful; be curious; seek to learn

Class Video Participation Etiquette

Zoom

- Request you enable your video + use your name
- Use zoom “hand up” feature
- Be an active participant. Verbalize as if you are in class, if at all possible. Use chat as second option.
- Class will be recorded as a resource, not as alternative to attendance and participation

Ohyay

- We’ll test drive a different virtual class space today
- Respectful and friendly engagement as in real life

Introductions - Groups of 3 for 3 minutes

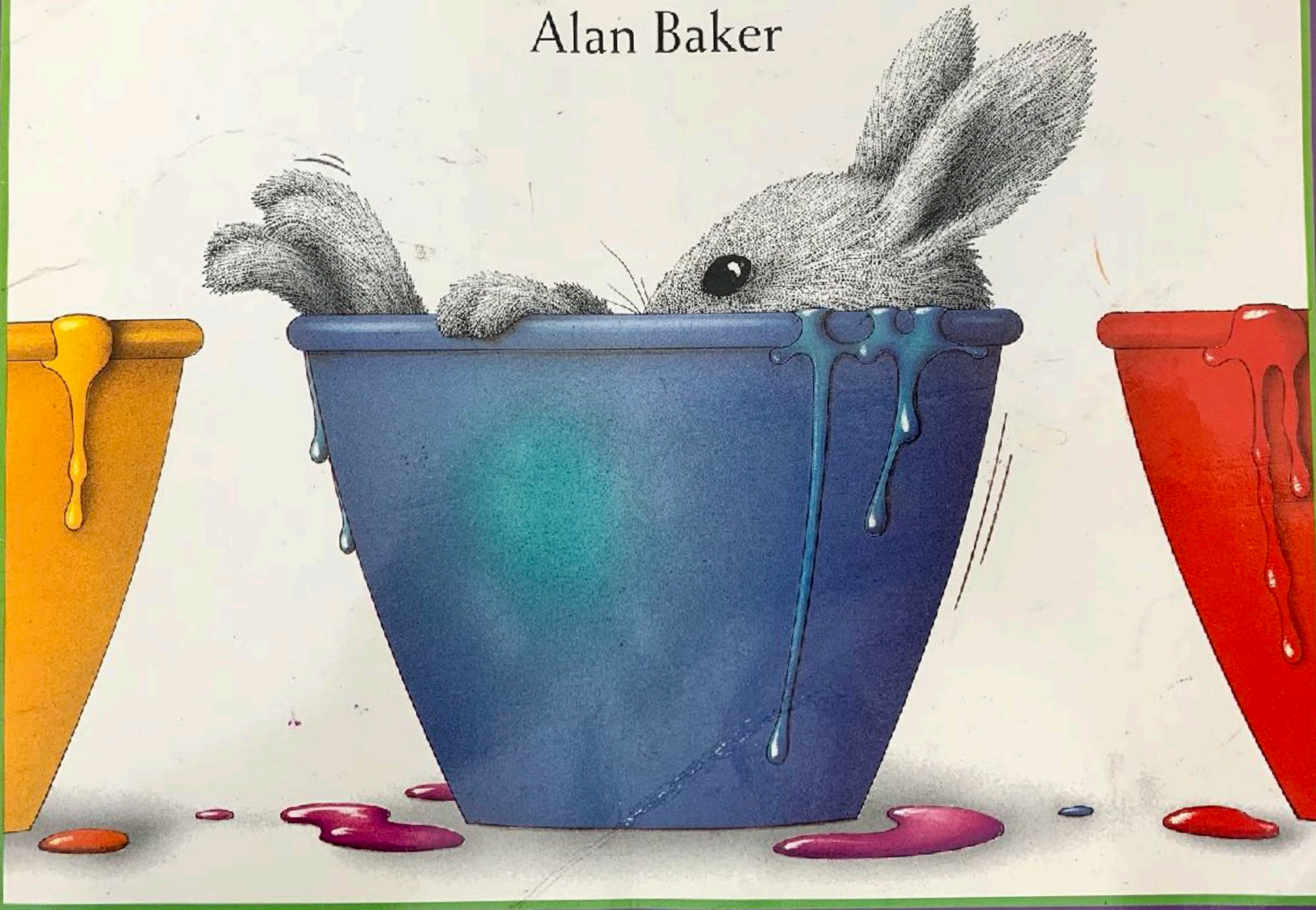
Share your department and interest in computational color.
Speculate: will there ever be new colors that we can see?

- CS184 backgrounds
- Graphics interest led to comp color
- Weili M.Eng, web dev + graphics background
- Janaki, hybrid ecology lab.
- Yiyang and Shm; joined for research reasons. Jason has CVD and is interested in learning more.
- Navneedh, Rishi (ugrad in 184 prior), Vishal (Masters in robotics). Interest in simulation to real synthesis. 5th Year masters, in cog-sci and CS
- Nithin (4th year), James (MS) and Angela (3rd year) — new colors? and how to be applied to graphics
- Yin, Sun, Suzie, 184, graphics, more about color.

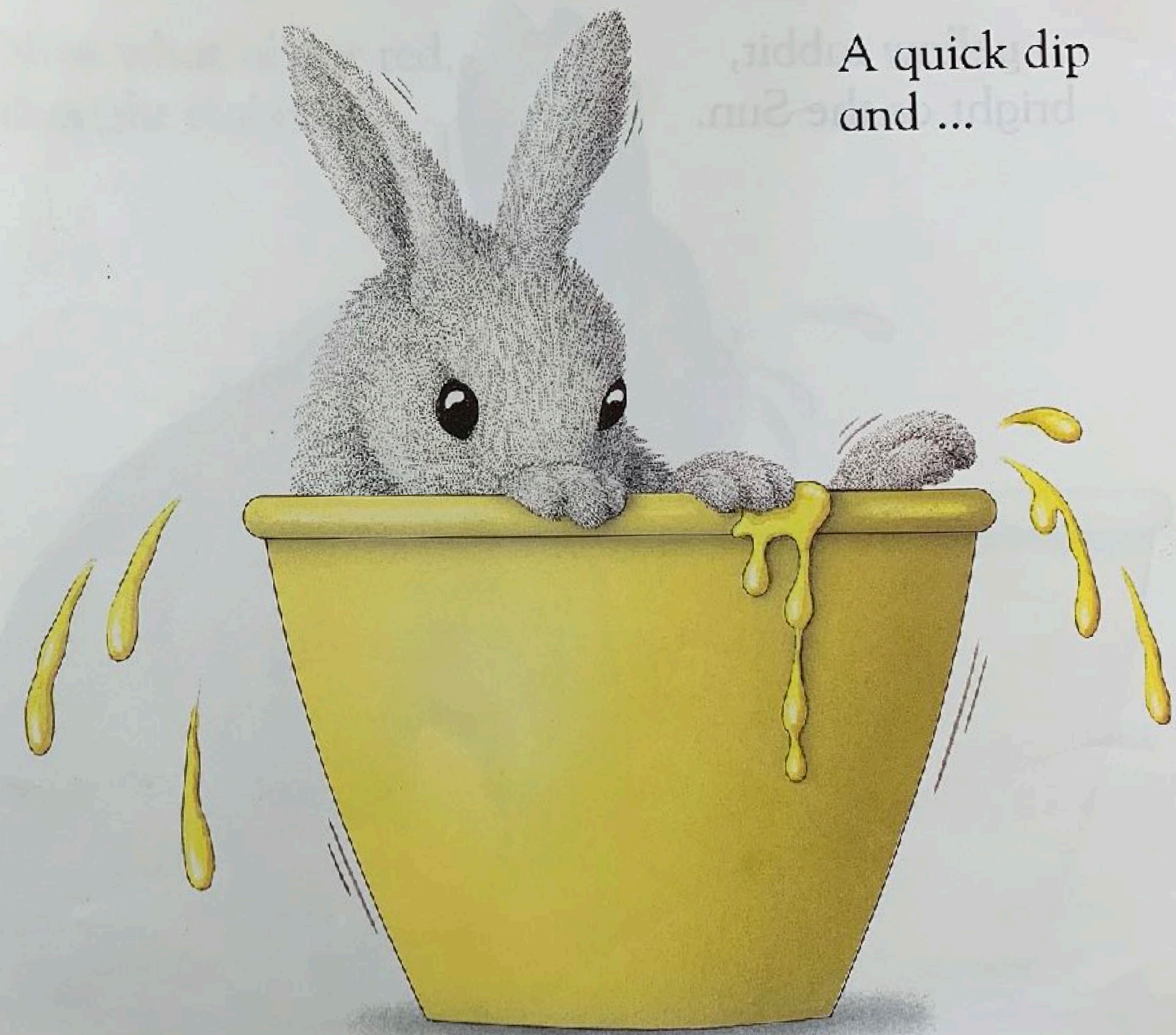
Why Study Color?

White Rabbit's Color Book

Alan Baker



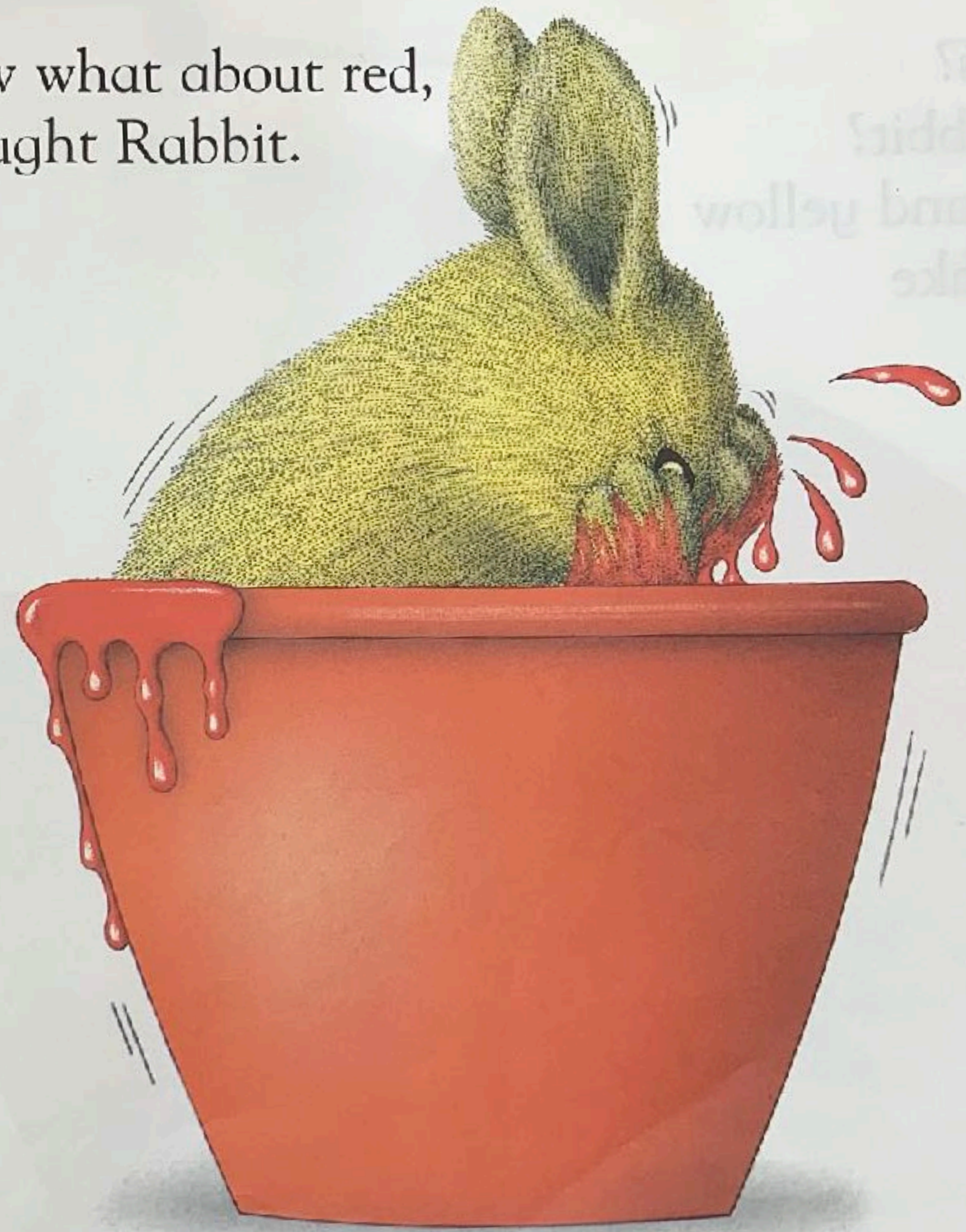
A quick dip
and ...



... yellow rabbit,
bright as the Sun.

Now what
thought R

Now what about red,
thought Rabbit.



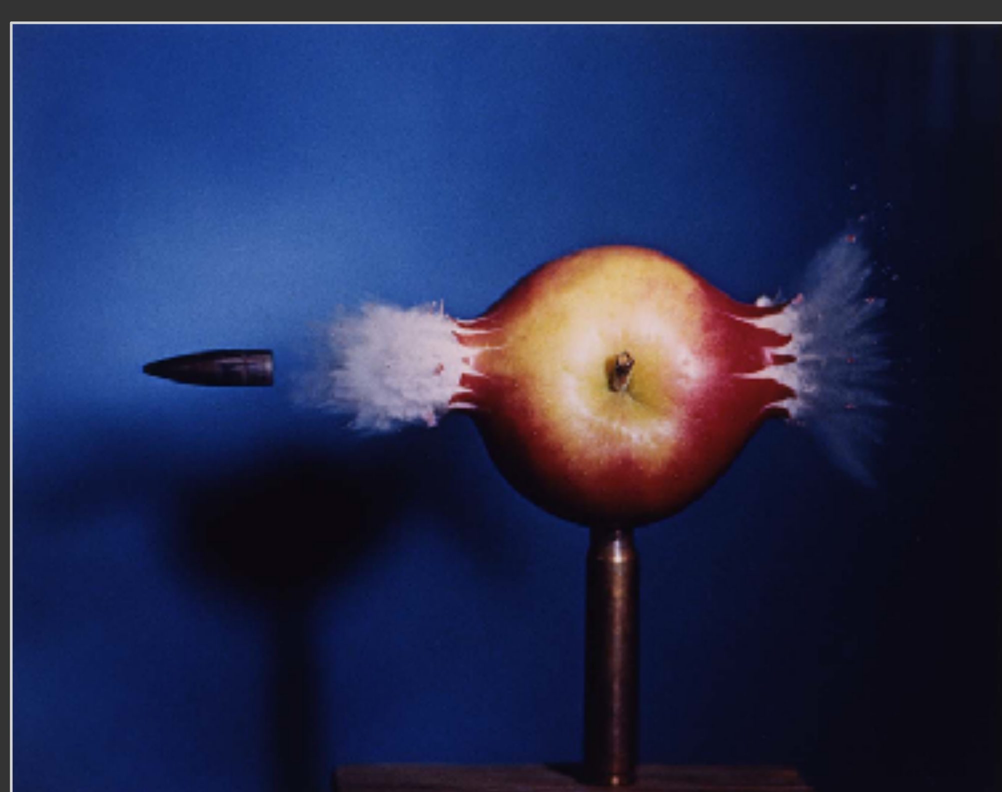
What's this?
Orange Rabbit?
Look. Red and yellow
together make
orange!


We Humans Are Visual Animals
Petr Novák

Color is Core to Our Human Visual Sense

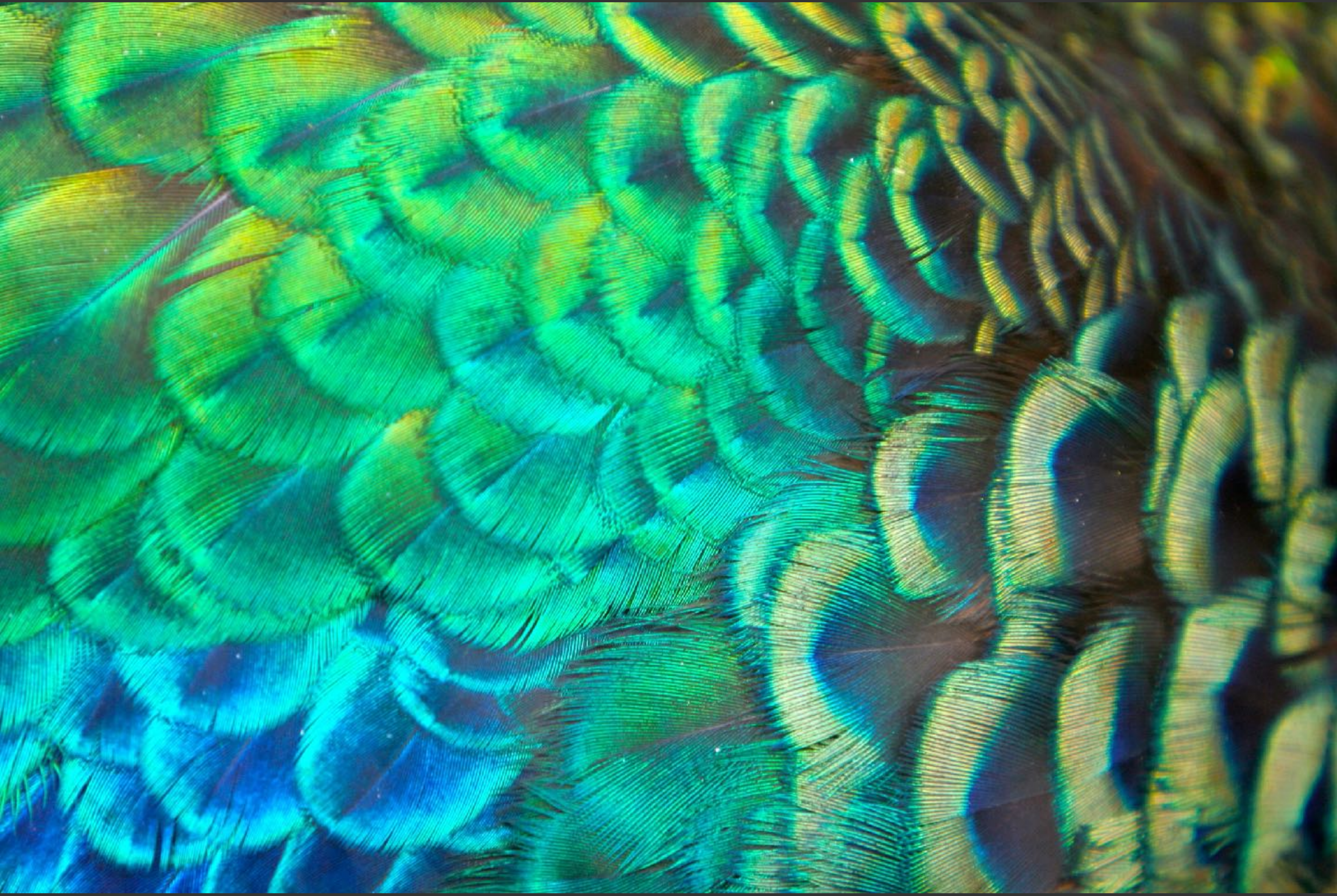






Steve McCurry | Reza | Walter Iooss | Steve McCurry
Harold Edgerton | NASA | National Geographic


本頭公巷
10200 P. PINANG




FIRE ENGINE

Color is a power which directly influences the soul.

Wassily Kandinsky

Wassily Kandinsky, Color Study. Squares with Concentric Circles, 1913
Munich, The Städtische Galerie im Lenbachhaus

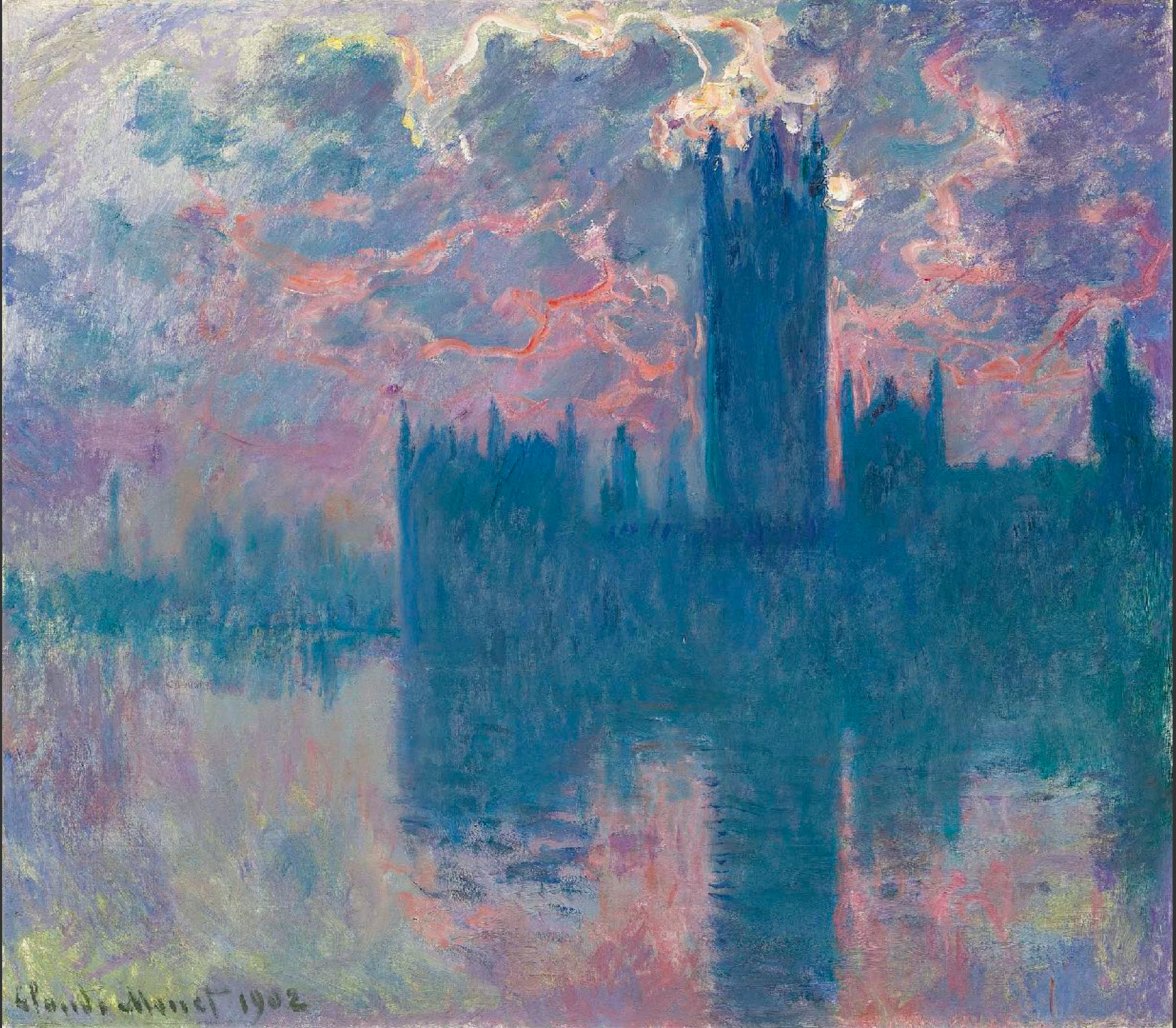
Wassily Kandinsky, 1913 - Composition 7

Wassily Kandinsky, Improvisation 31 (Sea Battle), 1913, National Gallery of Art

Color is my day-long obsession, joy and torment.

Claude Monet

Houses of Parliament, London, 1900–1901 The Art Institute of Chicago



Parlement, coucher du soleil (sunset), 1902, private collection

The Houses of Parliament, Sunset, 1903, National Gallery of Art Washington, DC.

Trouée de soleil dans le brouillard (Sun Breaking Through the Fog) Houses of Parliament, 1904. London, Sun Breaking Through the Fog, 1904 Musée d'Orsay, Paris

Houses of Parliament, stormy sky, 1904, Palais des Beaux-Arts de Lille, Lille, France

Seagulls, the River Thames and the Houses of Parliament, 1904, Pushkin Museum

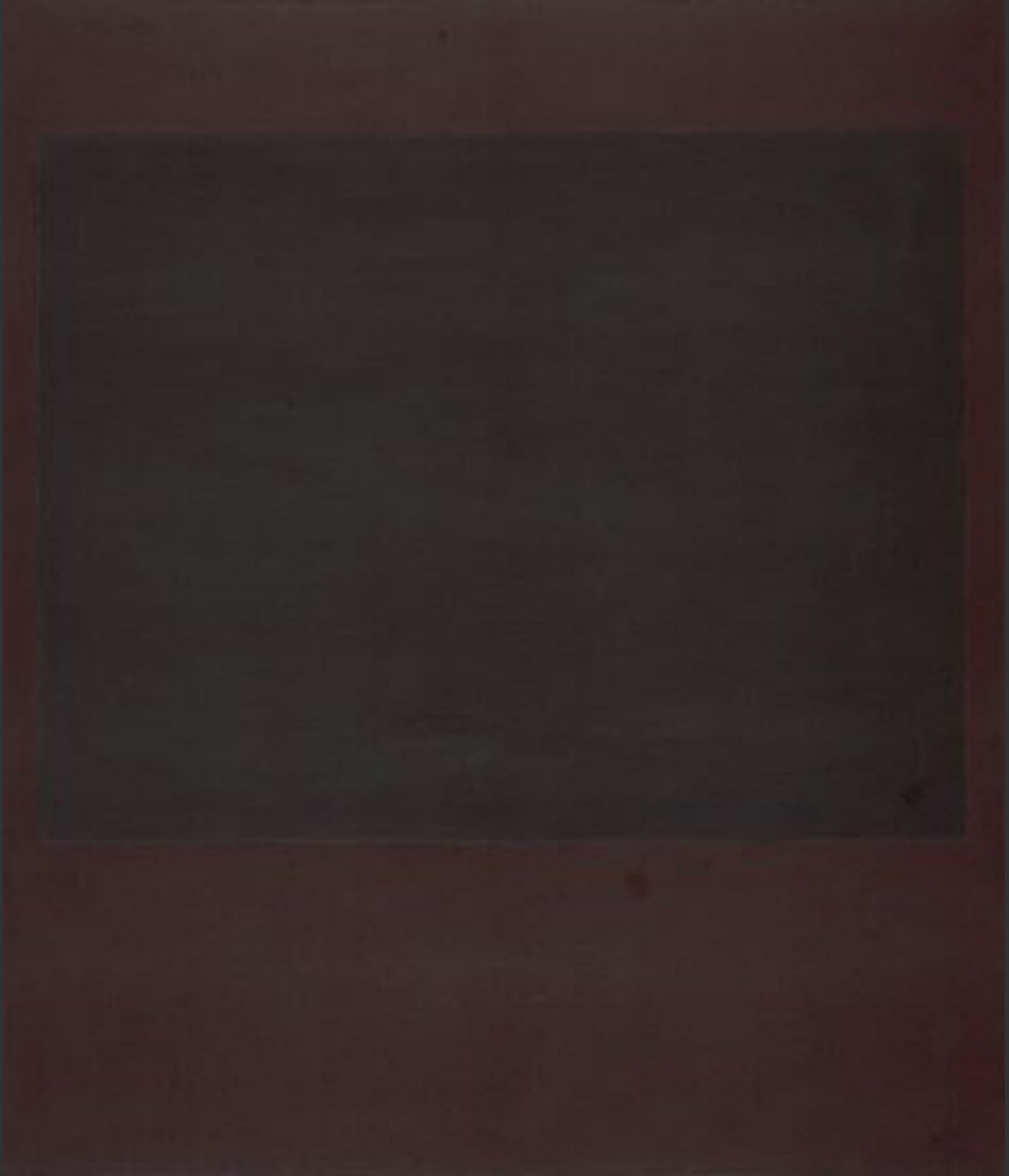
I am interested in expressing the big emotions – tragedy, ecstasy, doom.... If you are only moved by color relationships, you are missing the point.

Mark Rothko

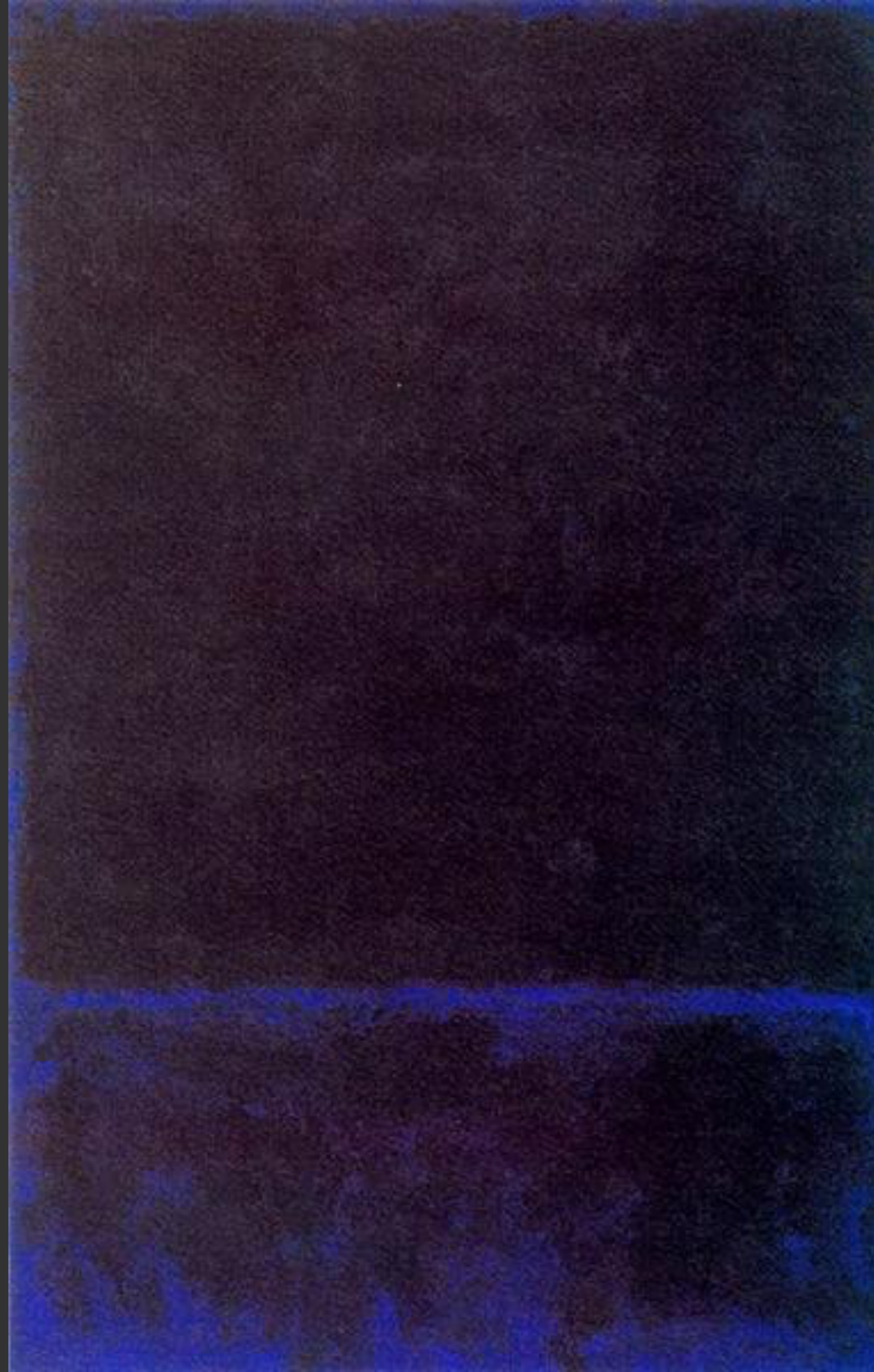
Mark Rothko, 1953, No. 61, Rust and Blue, Museum of Contermporary Art, Los Angeles

Mark Rothko, Orange and Tan, 1954, National Gallery of Art

Mark Rothko, No. 10, 1950, MOMA | Rothko, White Center, 1950, Private Collector



Mark Rothko, No. 4, 1964, National Gallery of Art



Mark Rothko, *Untitled*, 1968, Private Collection

Why Study Color?

Why Study Color?

Color is intertwined with the history of science. E.g.

- Isaac Newton's Experimentum Crucis - near the birth of the scientific method
- Thomas Young’s intuition about the trichromatic nature of human vision
- James Clerk Maxwell's foundations of colorimetry - before his equations unifying electricity and magnetism
- Erwin Schrödiner's theories of the color solid, which he considered his best work

Isaac Newton's Experimentum Crucis

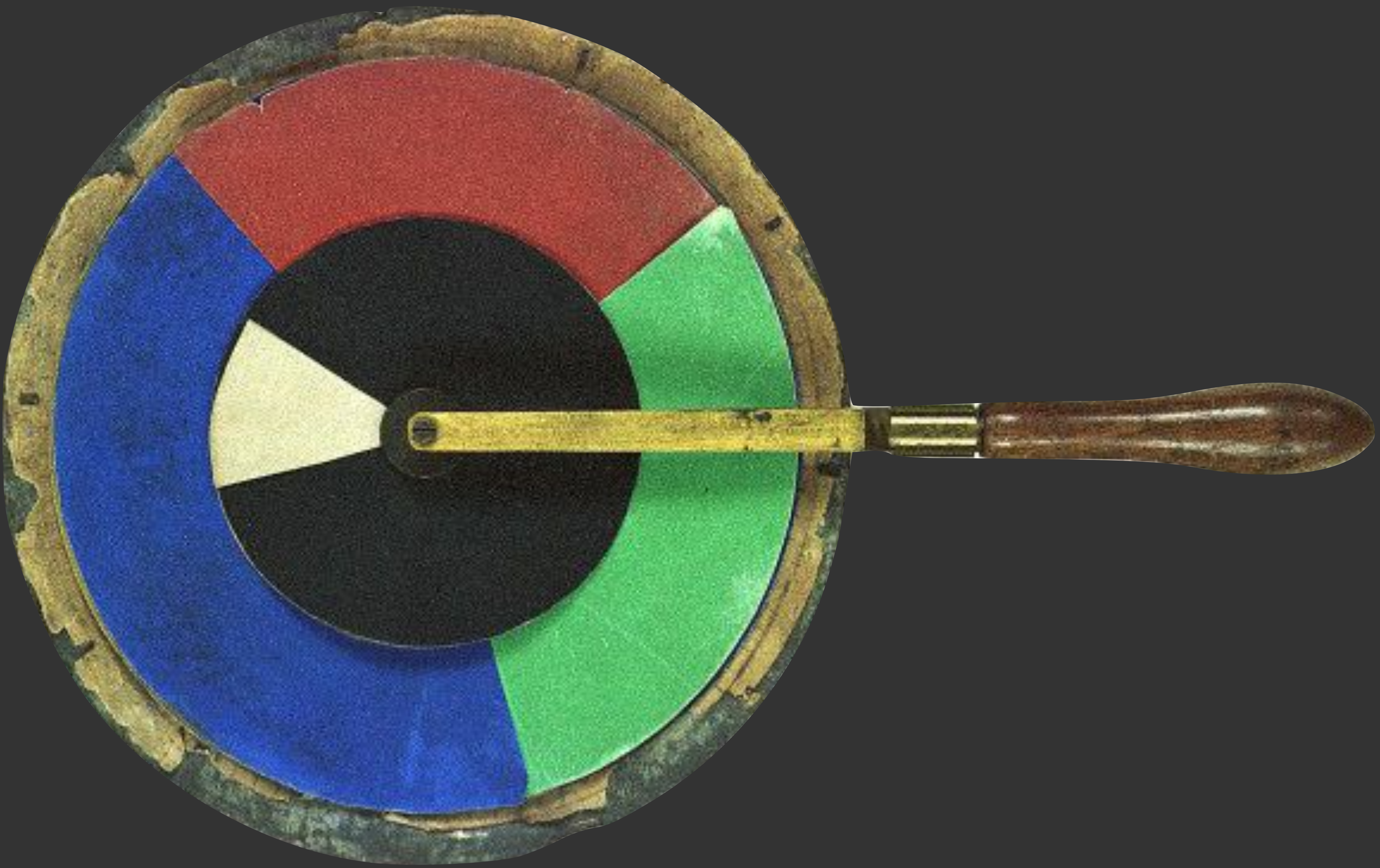
Isaac Newton performing his crucial prism experiment – the 'experimentum crucis' – in his Woolsthorpe Manor bedroom.
Acrylic painting by Sascha Grusche (17 Dec 2015)

Thomas Young - Trichromacy of Human Vision

"In 1802, Young proposed that there might exist three types of retinal particles, each associated with one of the principal colors red, yellow, and blue, in his 1803 paper changed to red, green, and violet."

- Jan Koenderink, 2010.

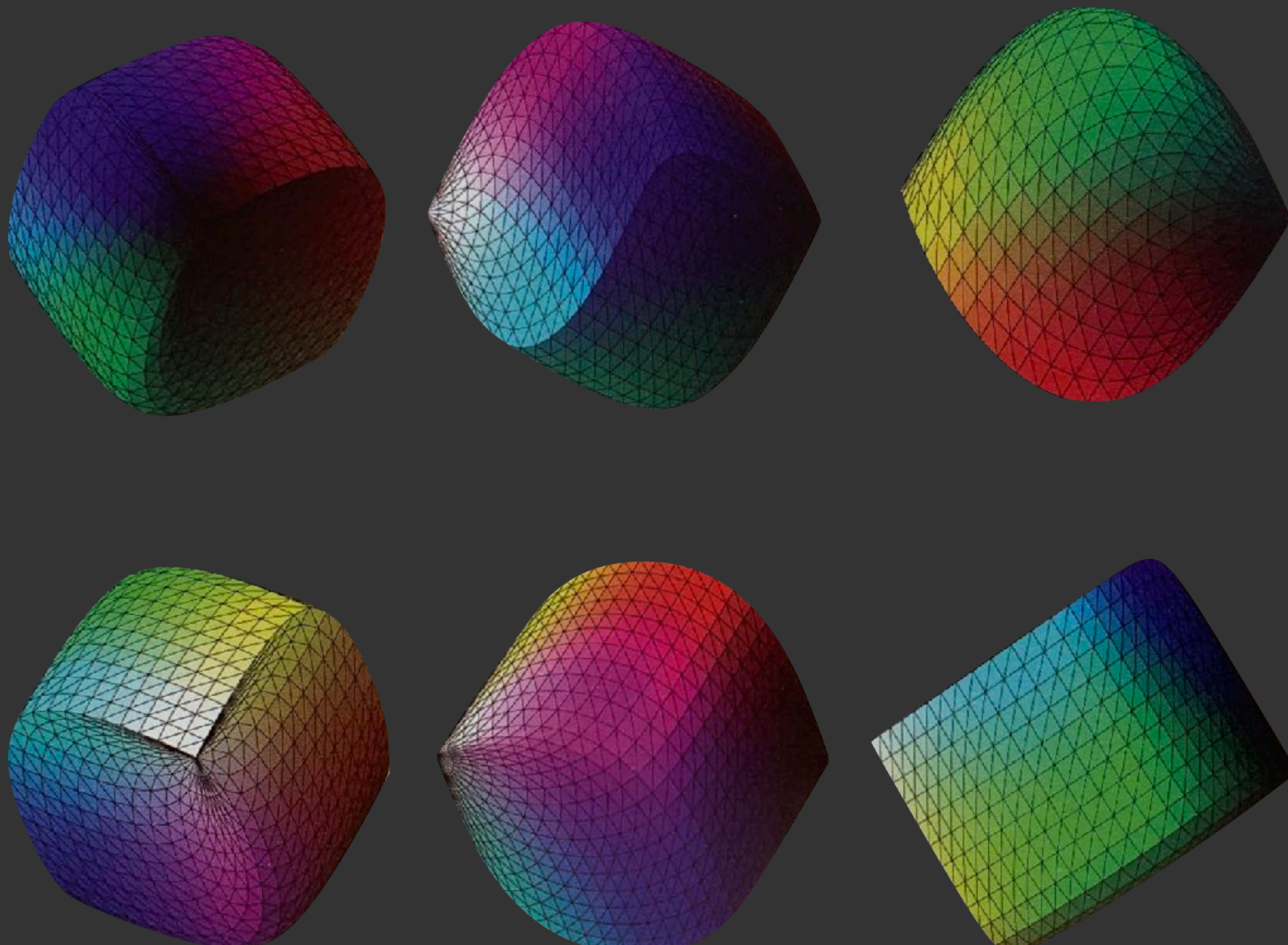
James Clerk Maxwell's Foundations of Colorimetry



http://designblog.rietveldacademie.nl/?p=68422

Portrait: http://rsta.royalsocietypublishing.org/content/366/1871/1685

Erwin Schrödinger's Optimal Colors

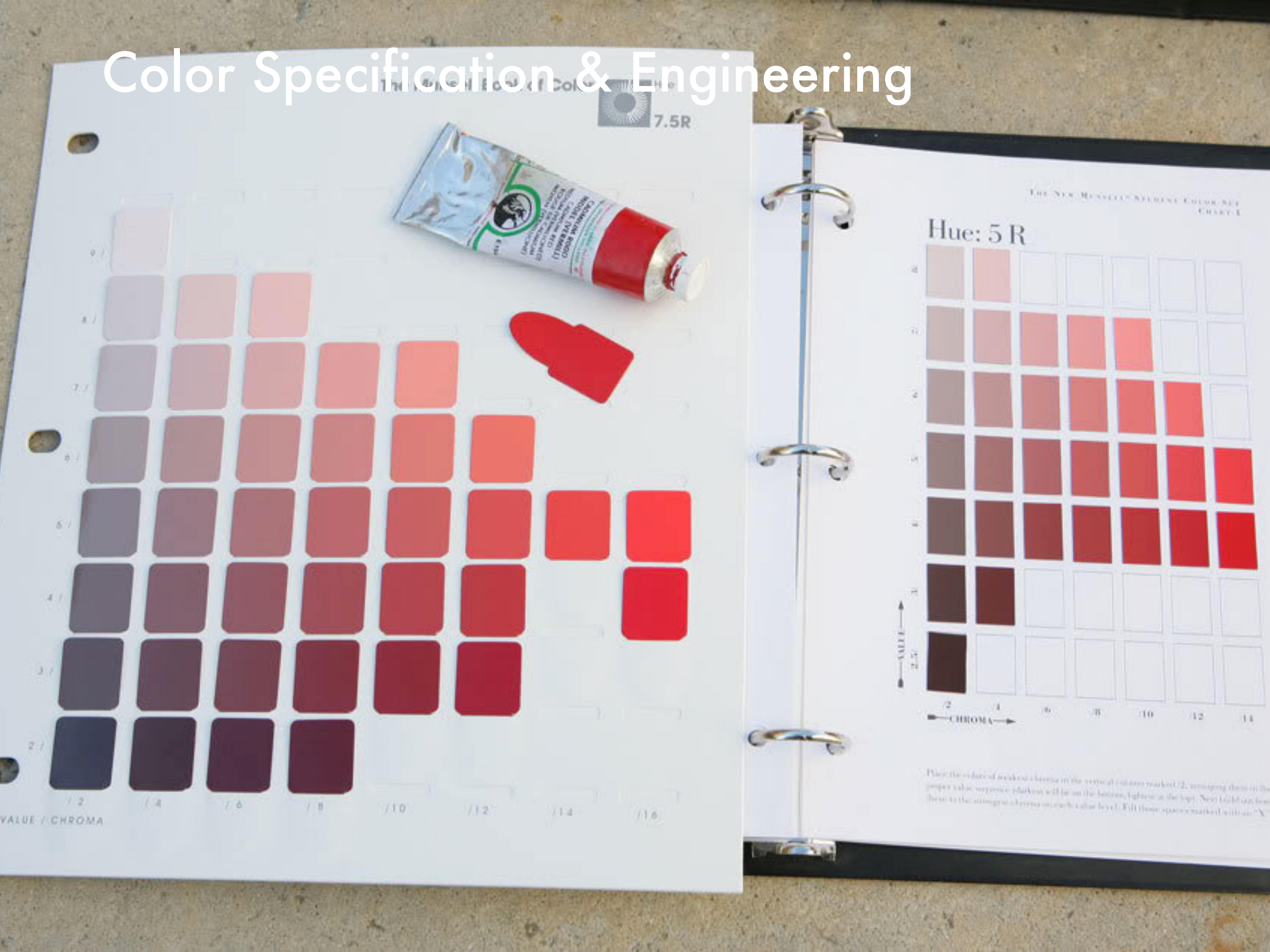


Koenderink, Color for the Sciences, 2010

Why Study Color?

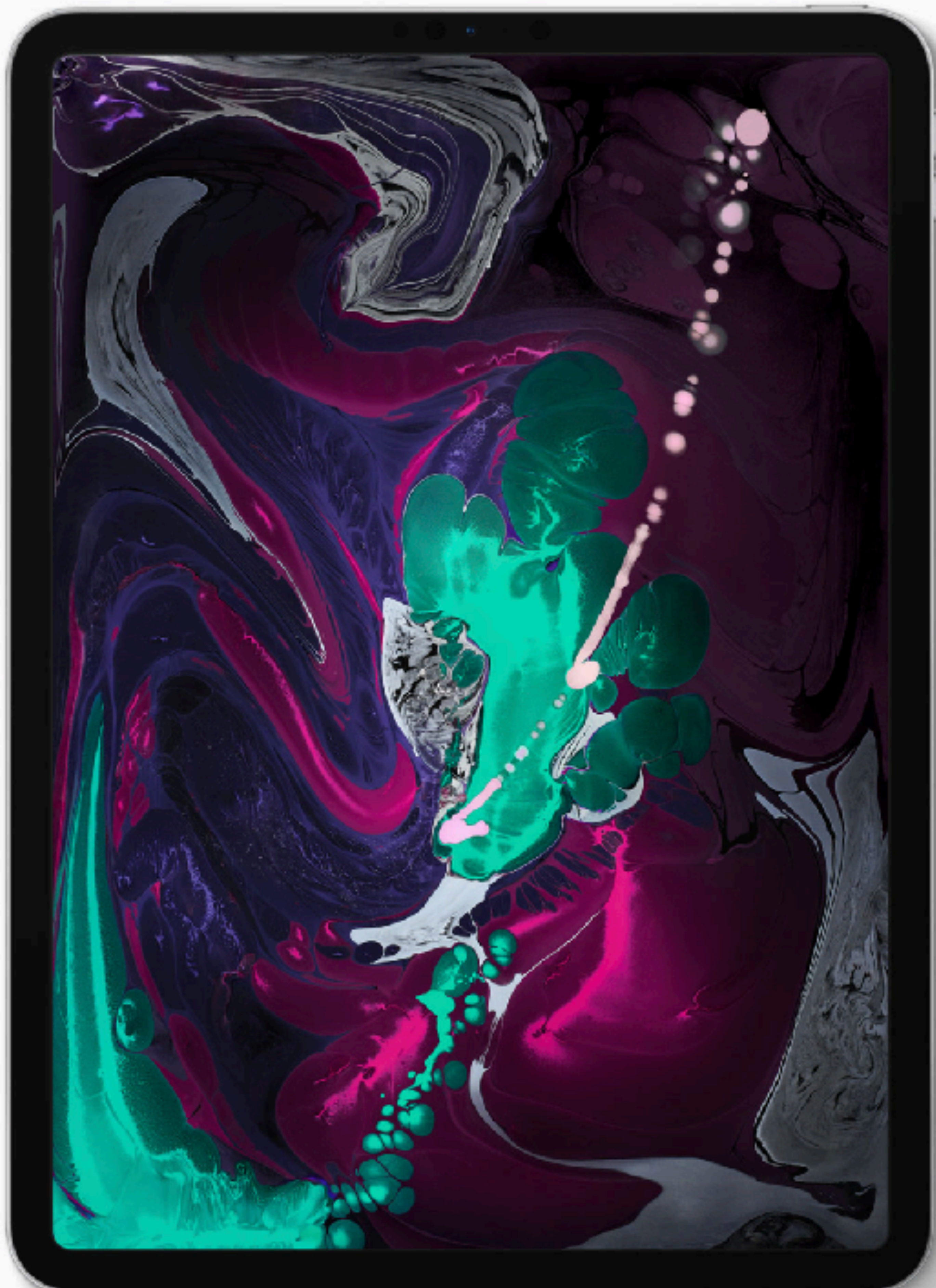
Color Specification & Engineering

Color Specification & Engineering



Color Specification & Engineering

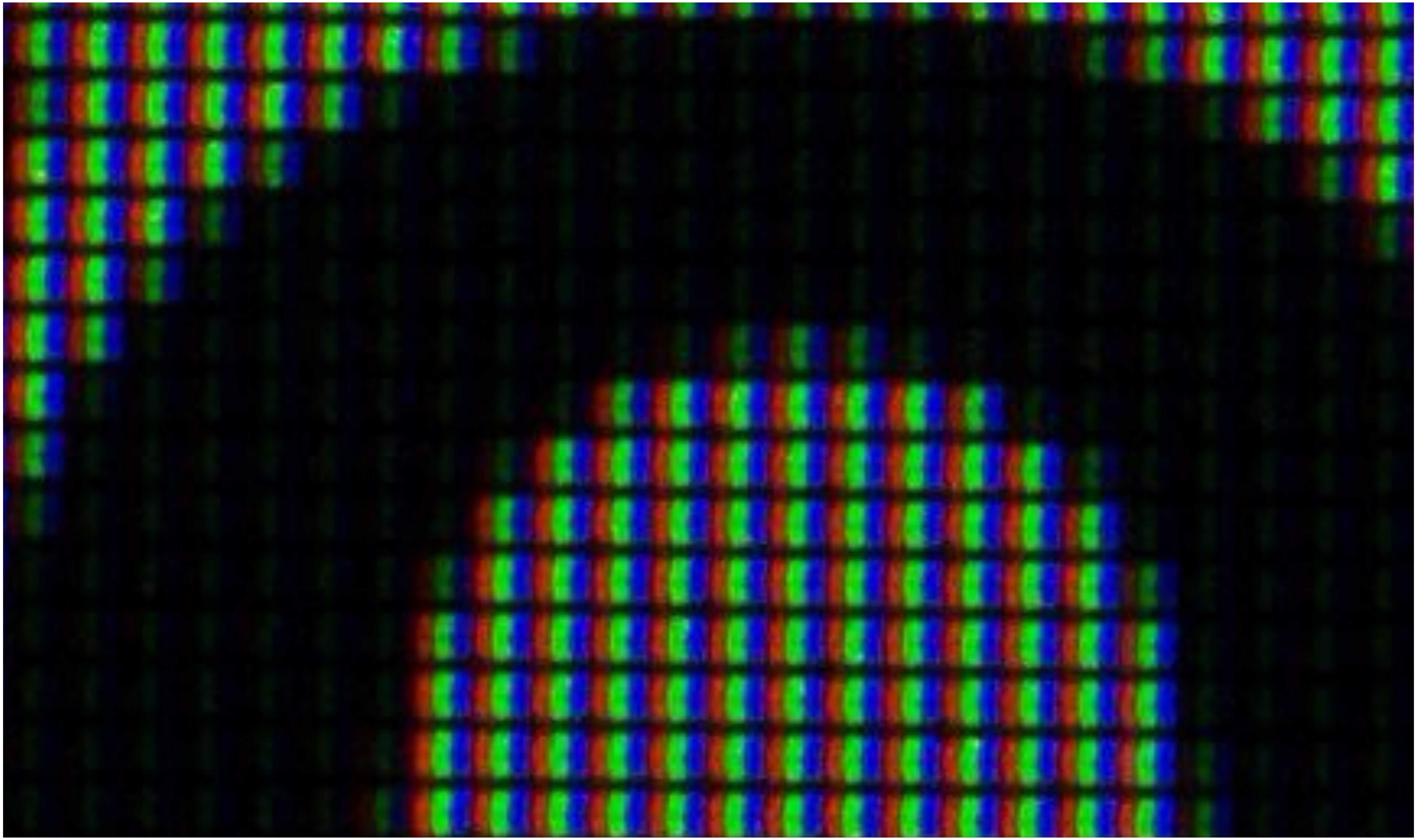
Displays Demand Color Engineering



11"

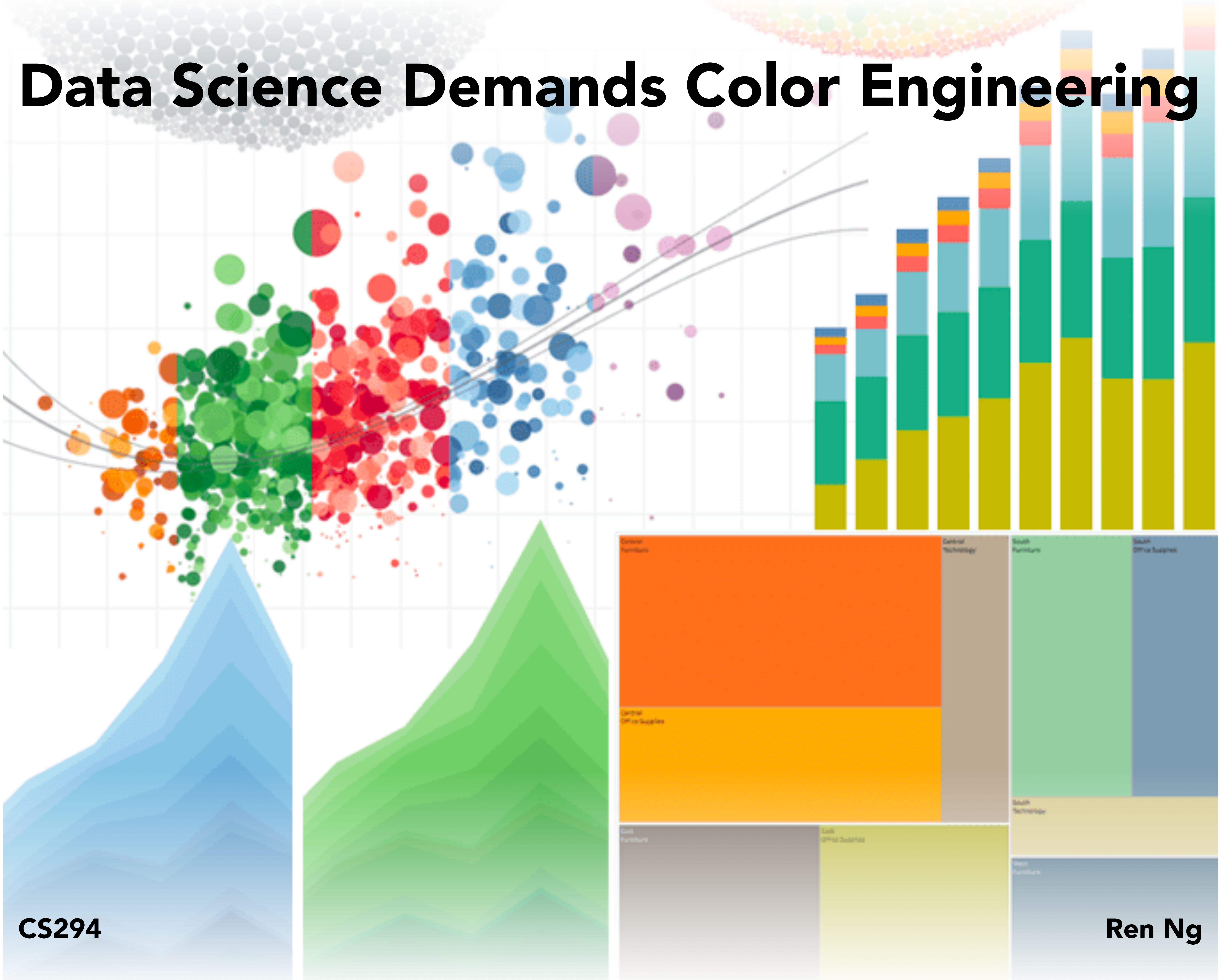
12.9"

Displays Demand Color Engineering



Camera Pipelines Demand Color Engineering

Data Science Demands Color Engineering



M. Stone, Tableau

CS294

Ren Ng

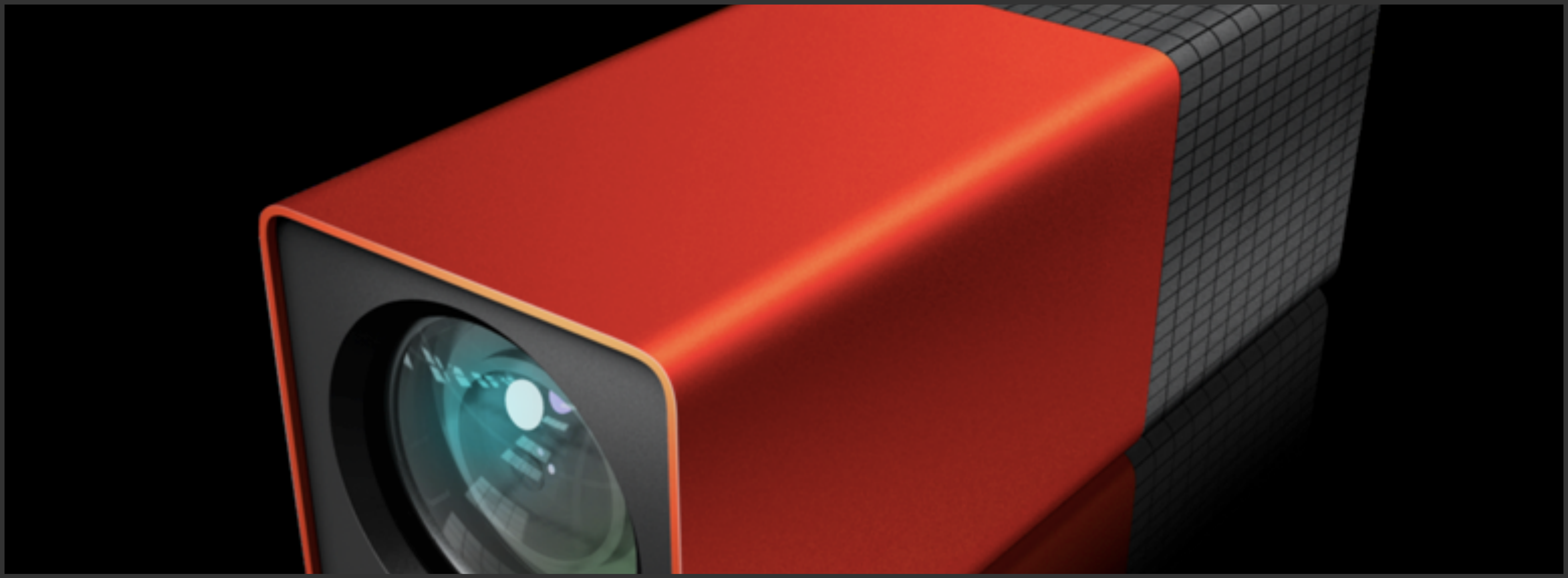
Instructor Background

Ren Ng

Background:

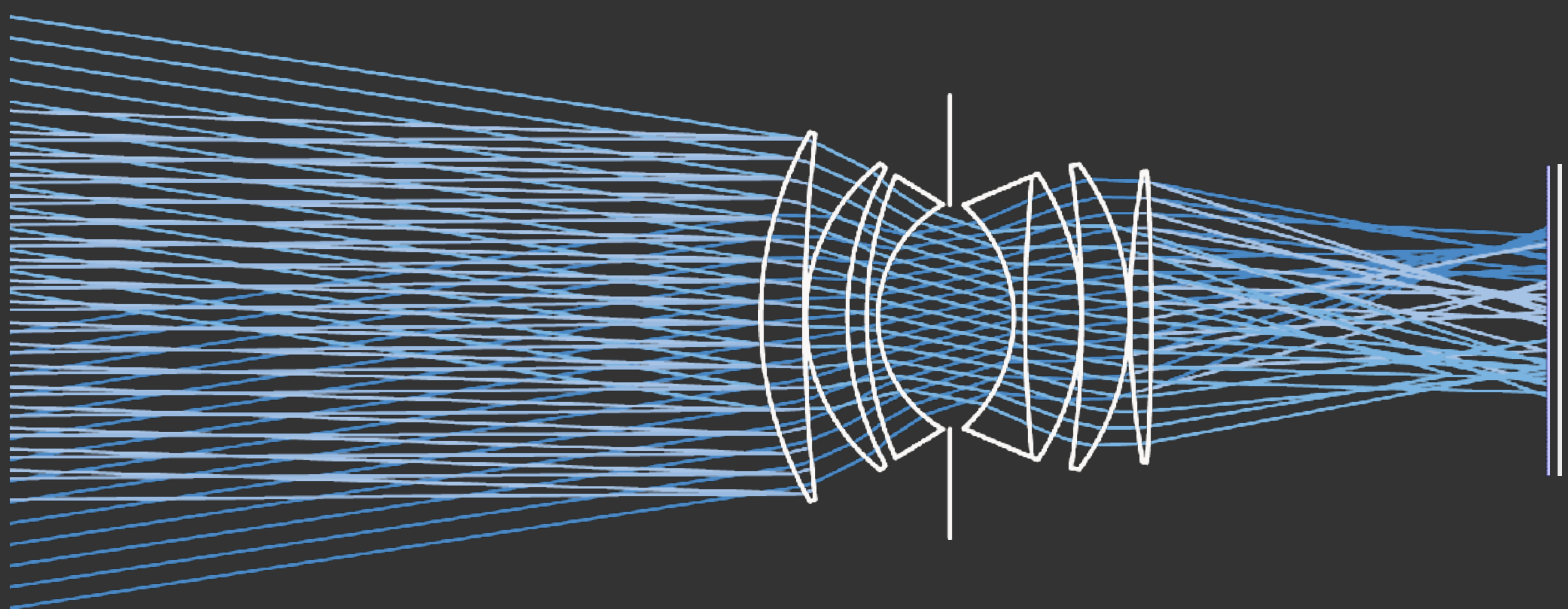
- Born in Malaysia
- Migrated to Australia
- Migrated to America
- Stanford BS, MS, PhD
- Founder & CEO of Lytro, Inc.
- Berkeley professor

PhD & Entrepreneurship: Light Field Photography



Why do we have to focus
before taking a photograph?

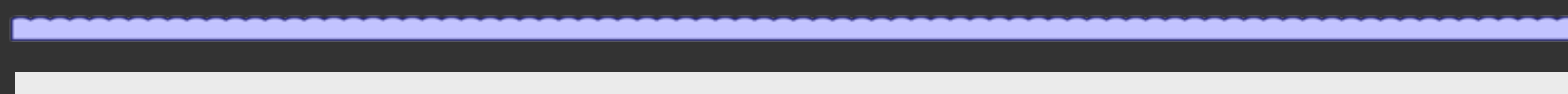
Light Field Photography



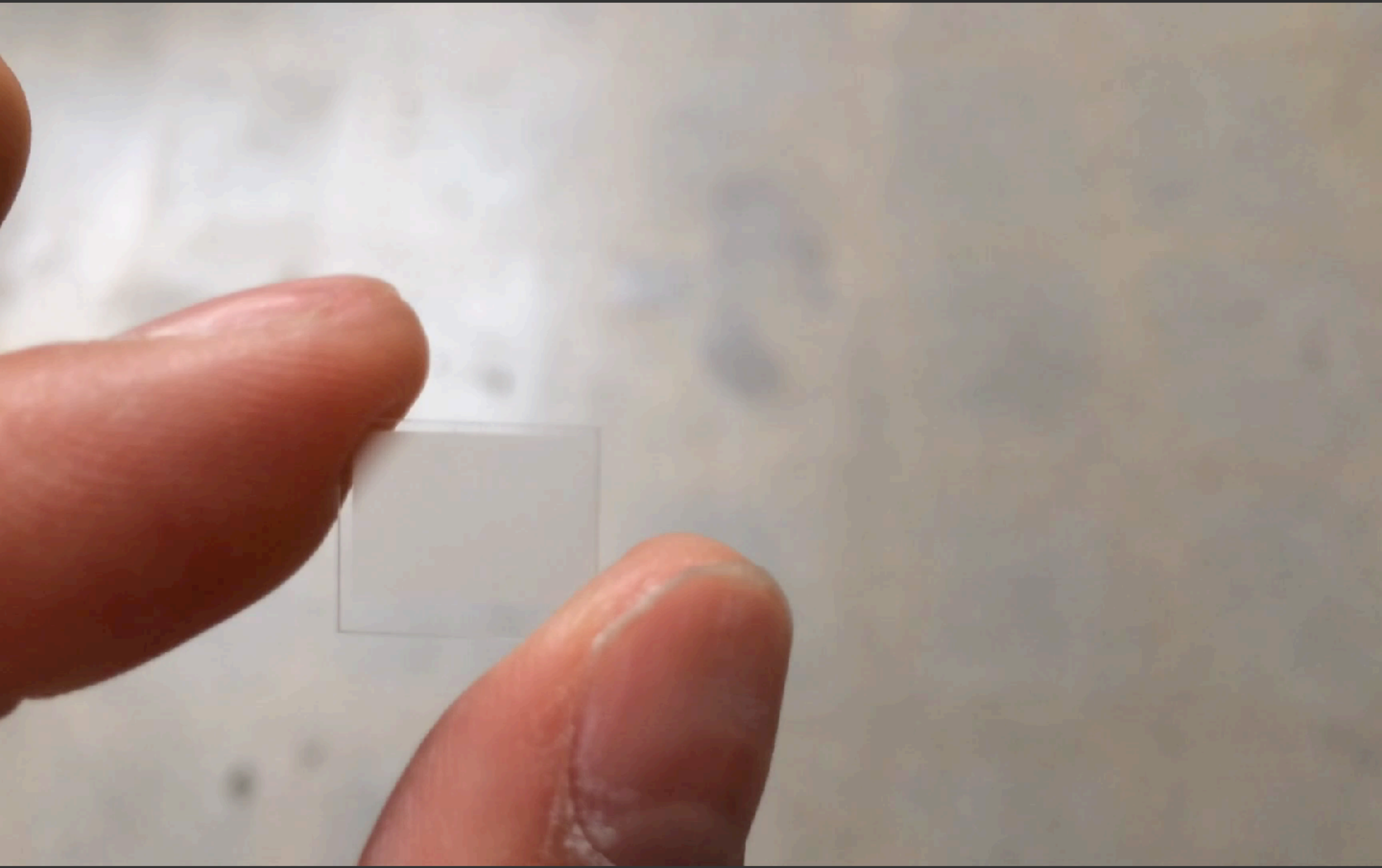
Photograph = light at every pixel on plane (2D)
Light field = light along every ray (4D)
Compute final images with ray-tracing

Light Field Photography

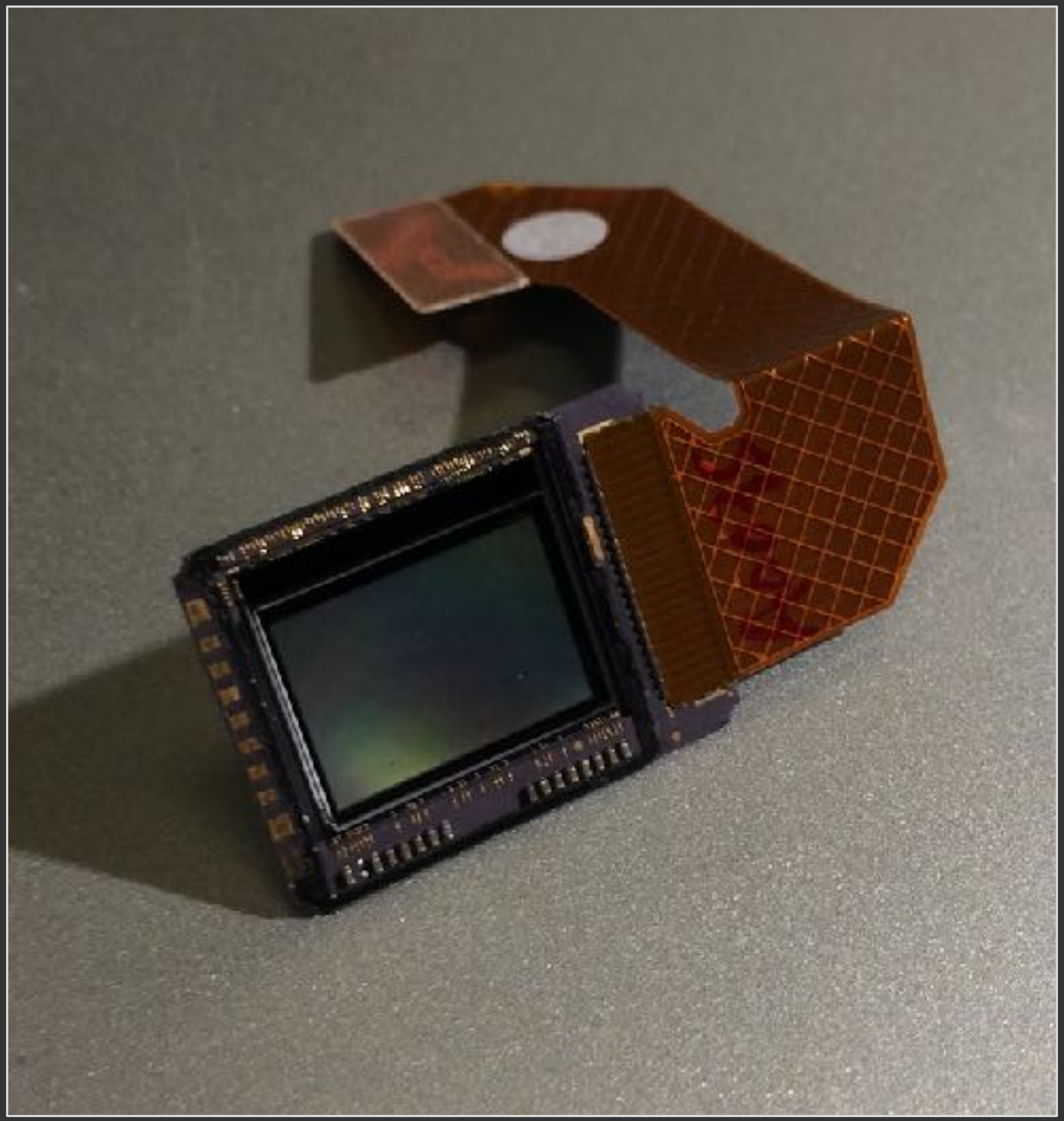
Microlens Array



Standard CMOS Sensor



Computational Photography



Light Field Sensor

Light Field Camera

Ren Ng Research Areas

- Imaging Systems
- Computer Vision
- Computer Graphics
- Machine Learning
- Human Vision

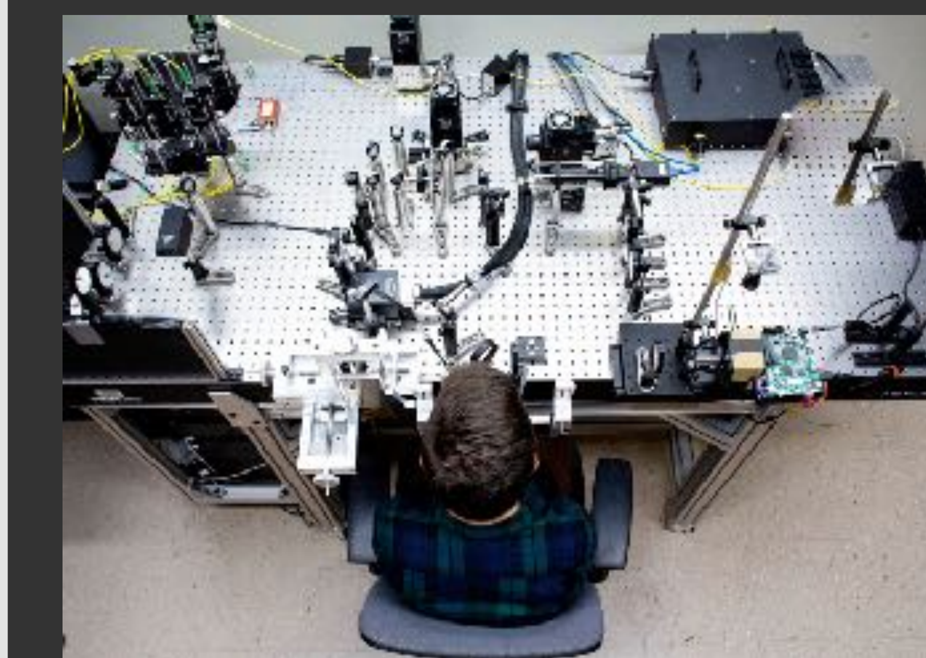
Ren Ng Research - Project Sampling

Thin cameras / microscopes

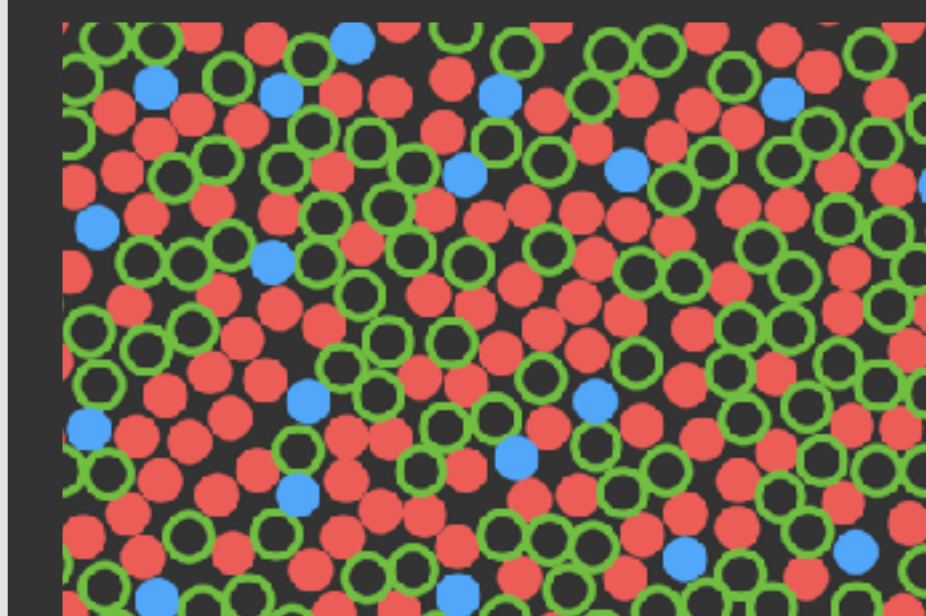
Superhuman vision for cars

3D photography

Look-ahead video autofocus



Vision science experiments



Oz Vision & Coretsumo

Imaging Systems

Computational Photography

Color Science & Display

Course Topics

Course Organization

Two organizational "cores"

- Current research on the perceptual limits of color
  - Oz Vision project (overview next week)
  - Aim: perception of fundamentally new colors
  - Join us in exploring a living research project
- Color in practice and in processing pipelines
  - Color in data science, photography
  - Camera reproduction in processing pipelines
  - Color appearance models

Course Speakers

Ren Ng
UC Berkeley
Your Prof

Maureen Stone
Tableau
Color in practice,
data science

Ramkumar Sabesan
UW
Hacking the
visual system II

Jay Neitz
UW
Expanding
color dimension

Michael S. Brown
York Univ.
Camera pipelines

Jenny Bosten
Univ. of Sussex
Tetrachromacy

Bruno Olshausen
UC Berkeley
Neural modeling

Ming Thein
Color in practice,
photography

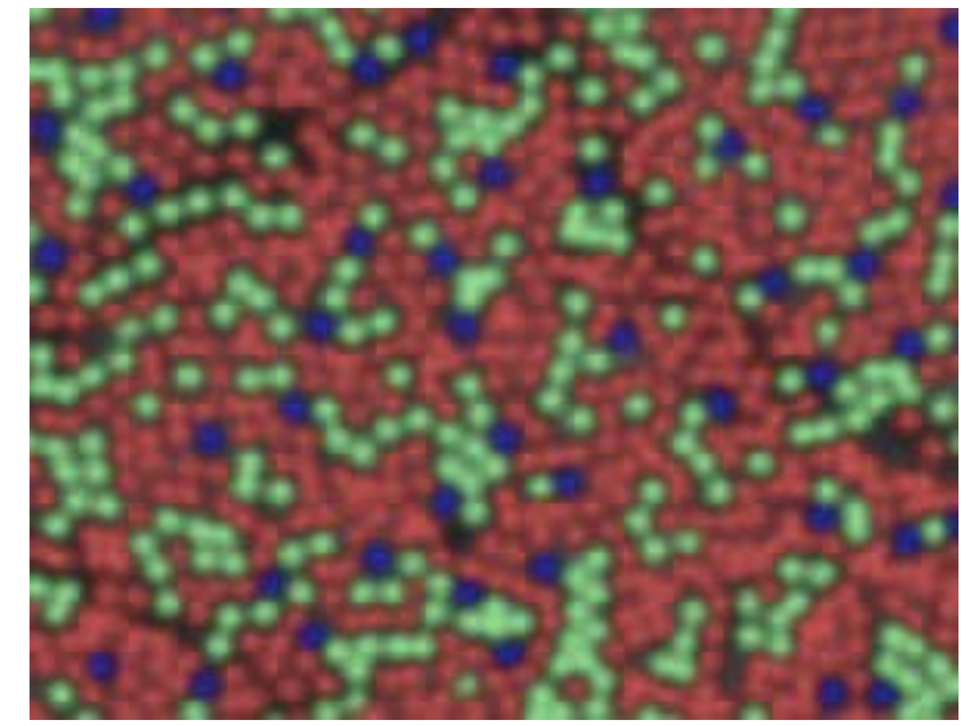
Mark Fairchild
RIT
Color appearance
models

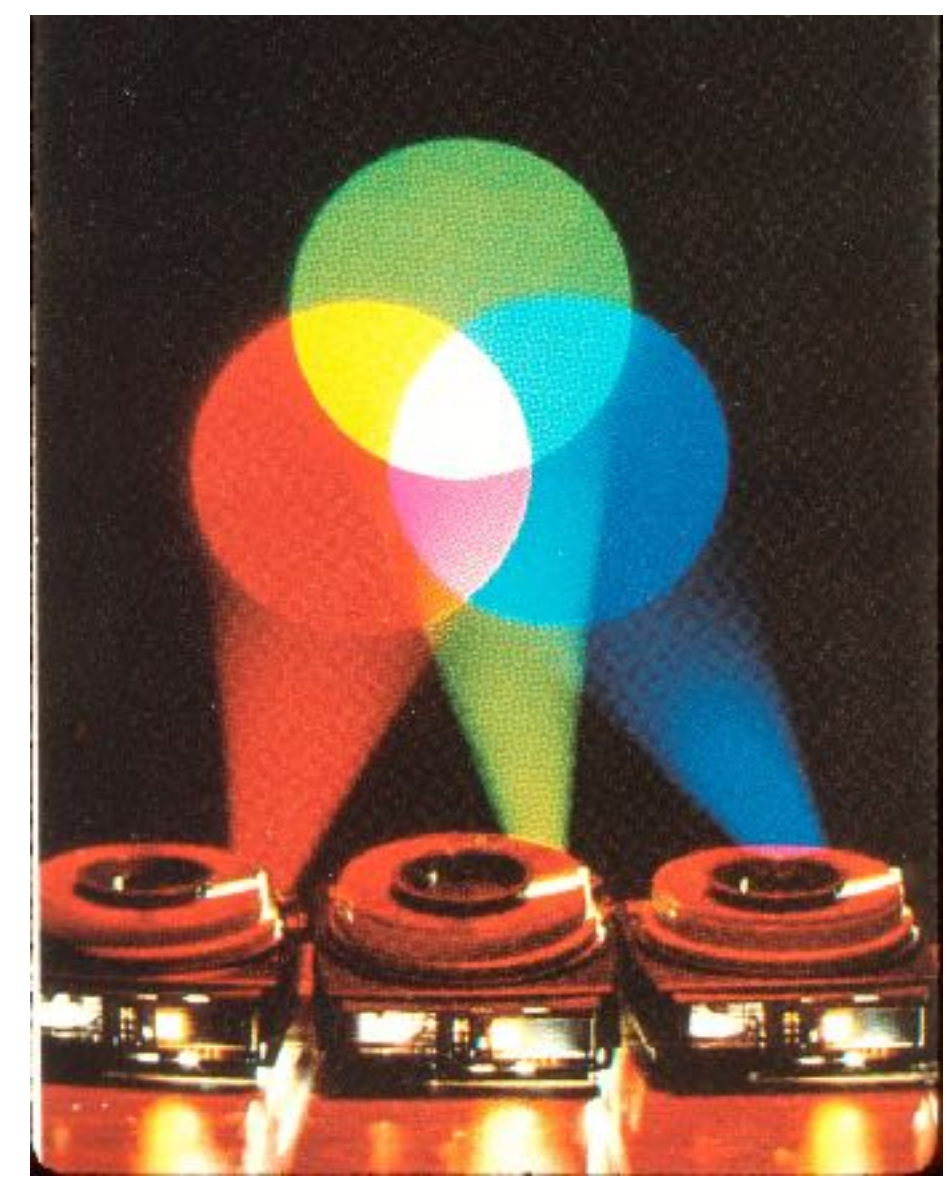
William Tuten
UC Berkeley
Visual biology
psychophysics

Austin Roorda
UC Berkeley
Hacking the
visual system

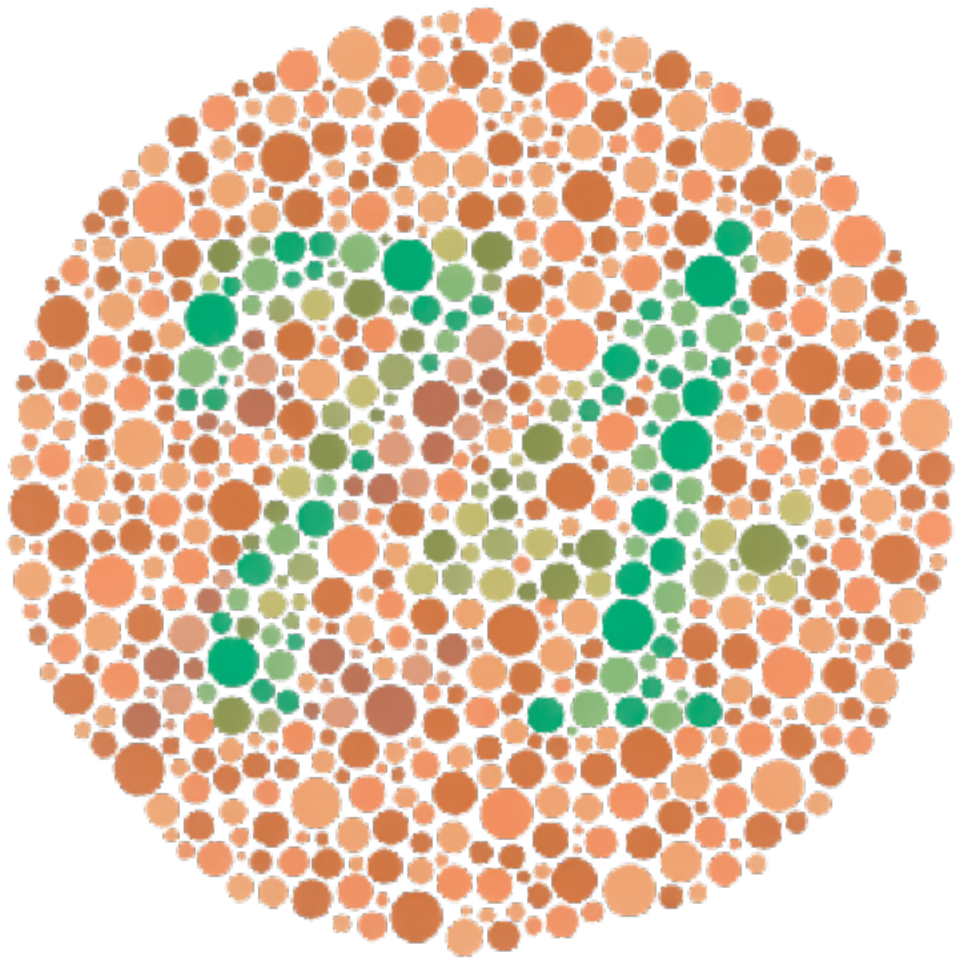
Course Topics:
Perceptual Limits of Color

Tristimulus Theory and Colorimetry





Color Blindness, Potential Treatments



Ishihara color test

Mancuso et al. 2009

Guest lecture: Jay Neitz, UW

Tetrachromacy

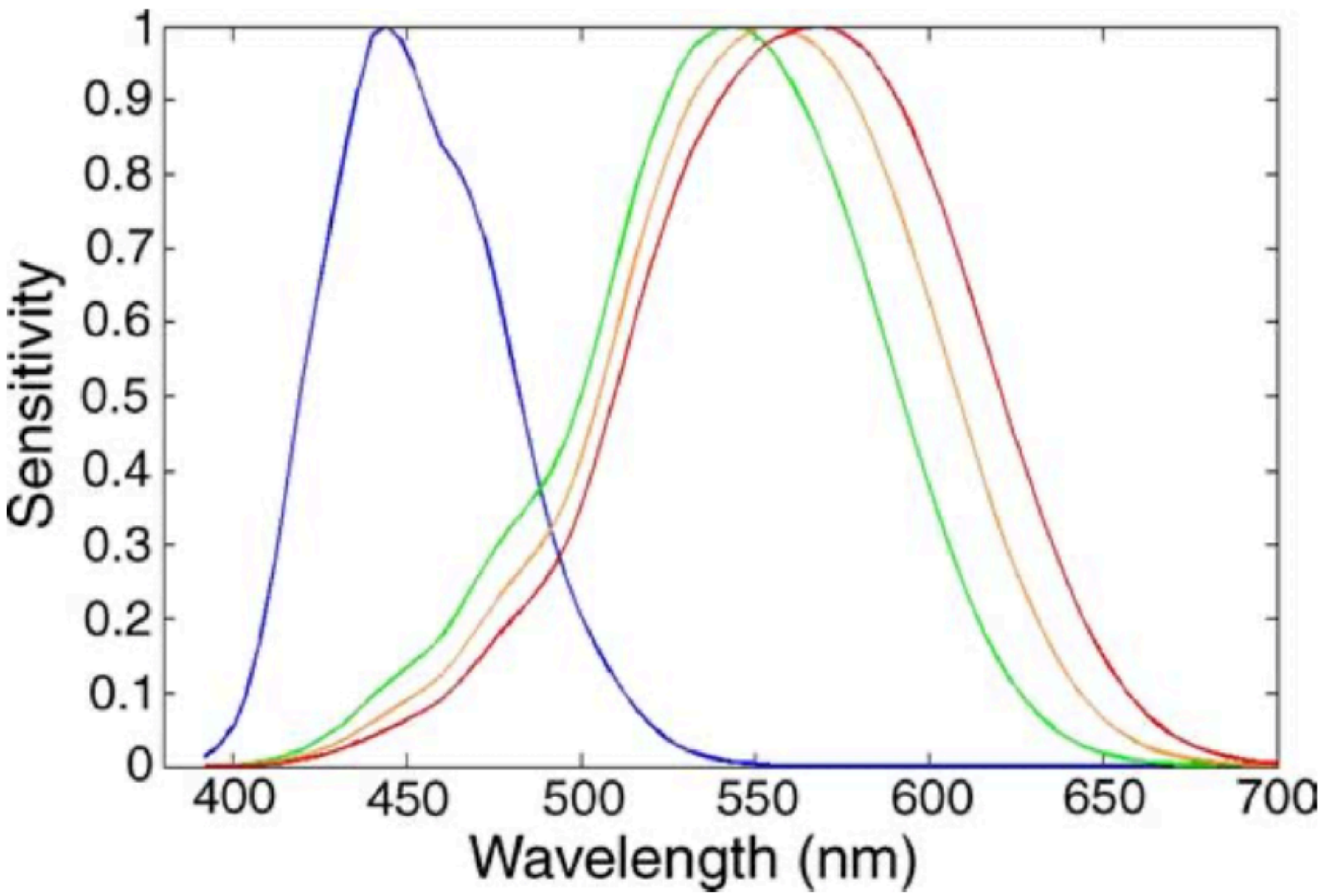
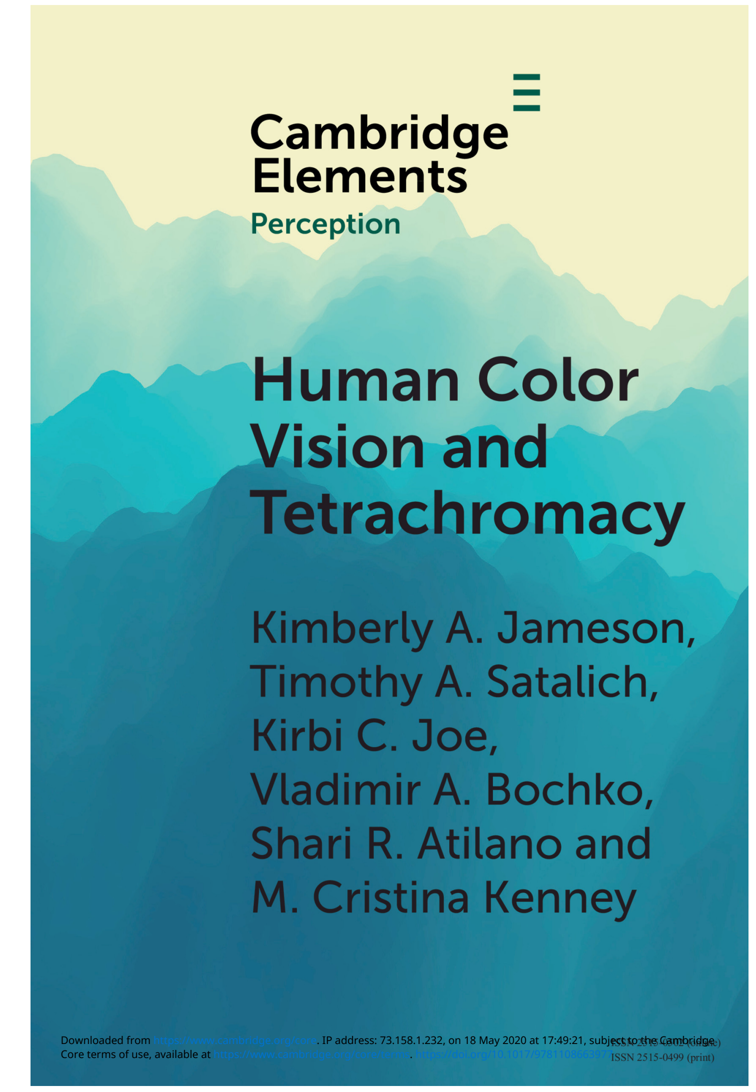


Figure A1. Simulated cone fundamentals for cDa29.

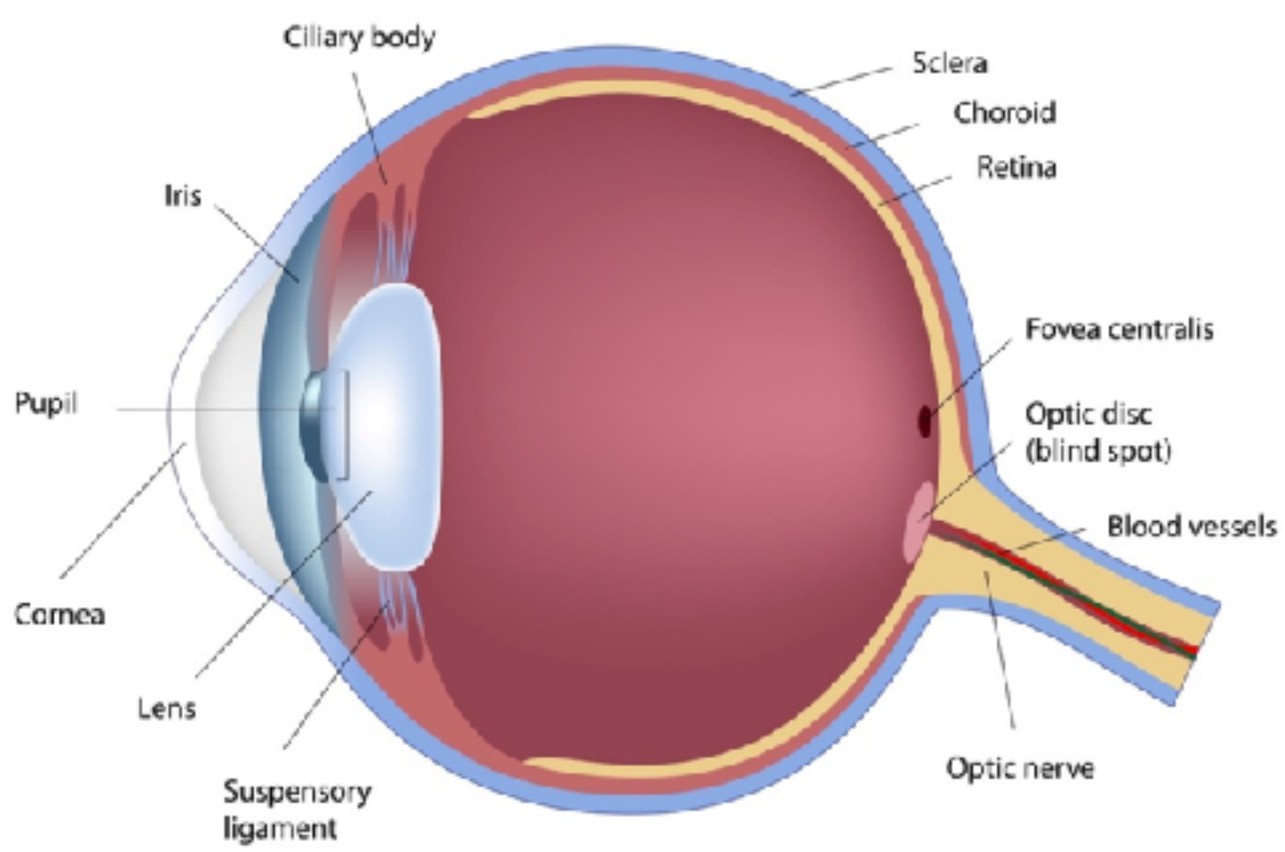
Jordan et al. 2010

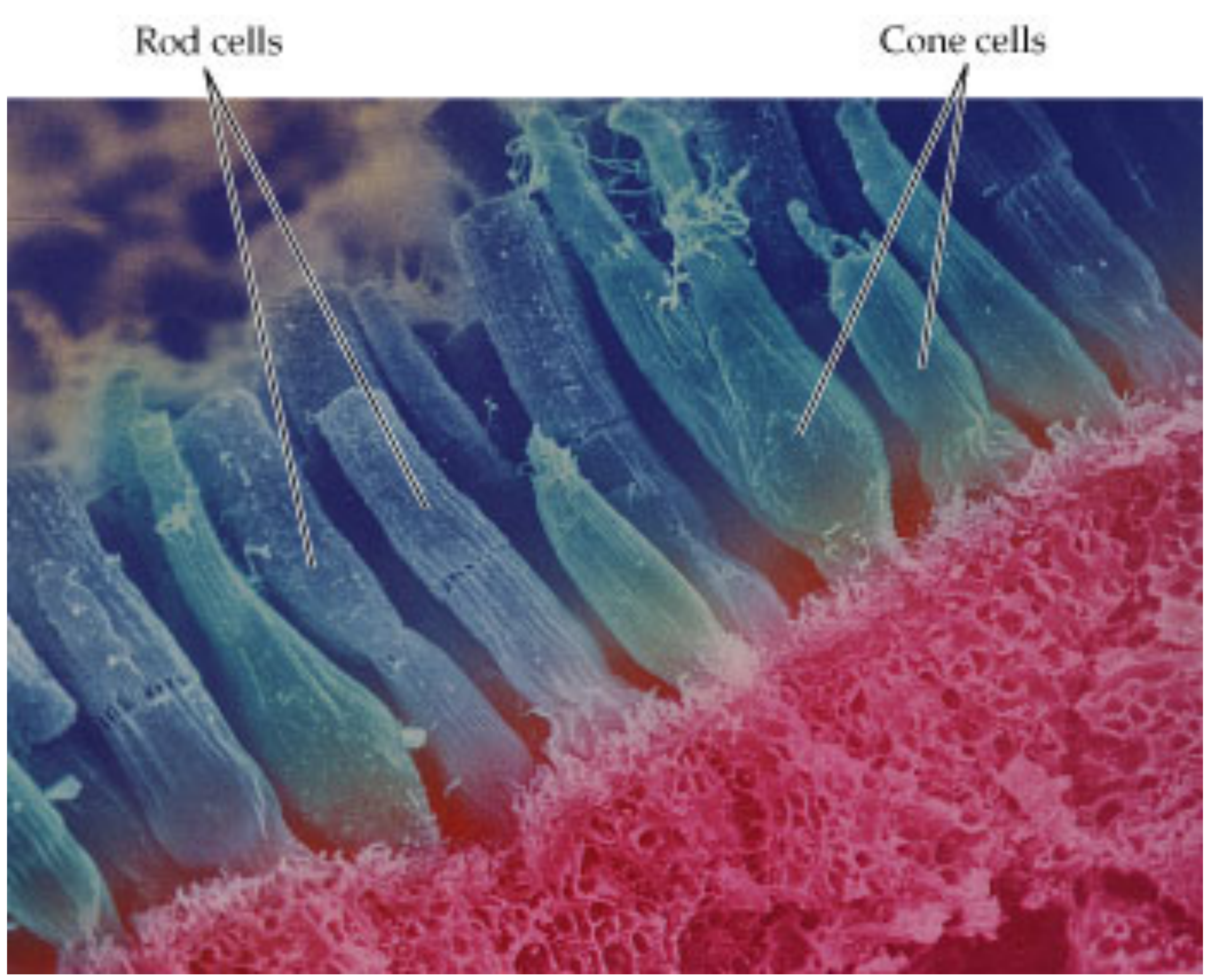


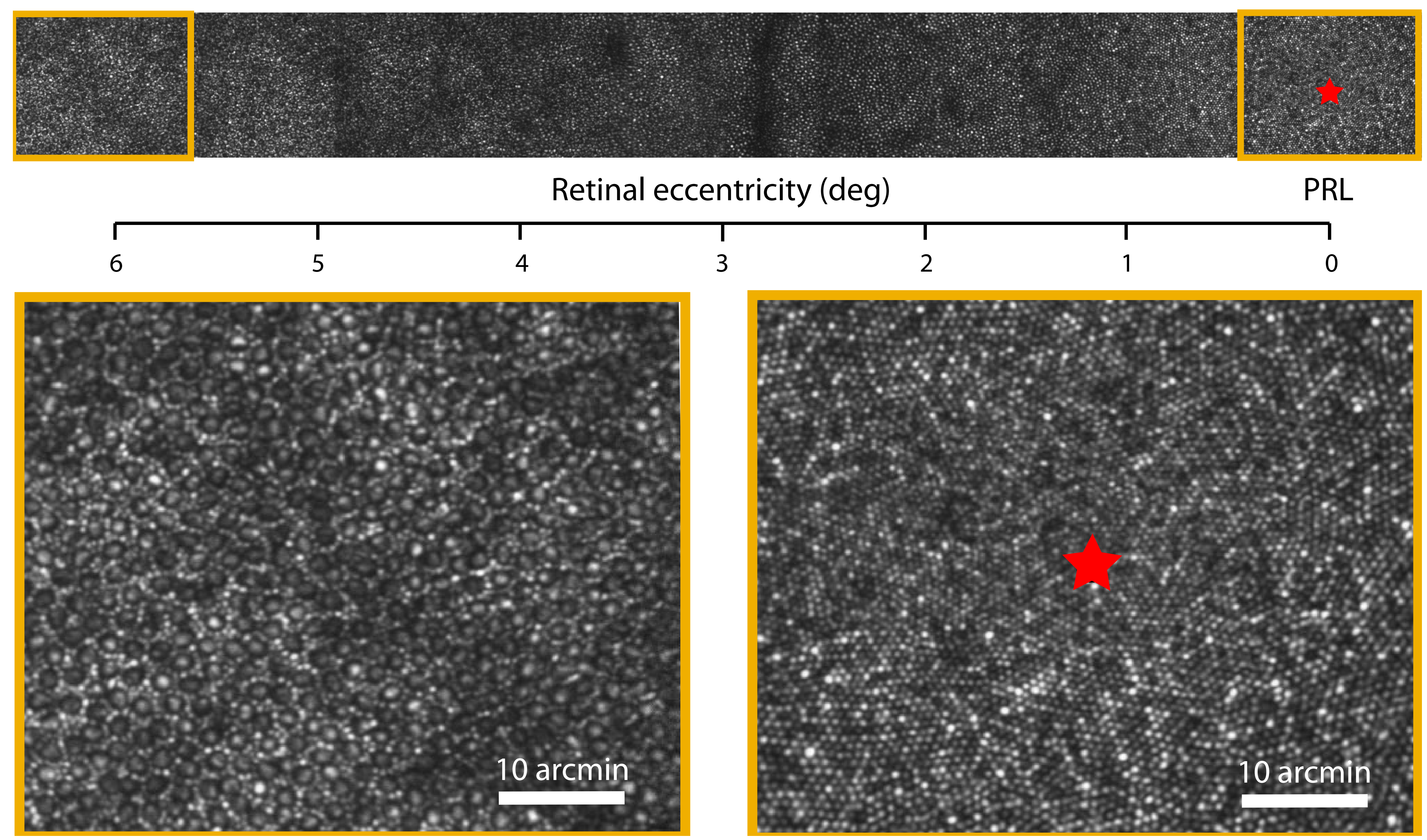
Vogue, Dec 2014

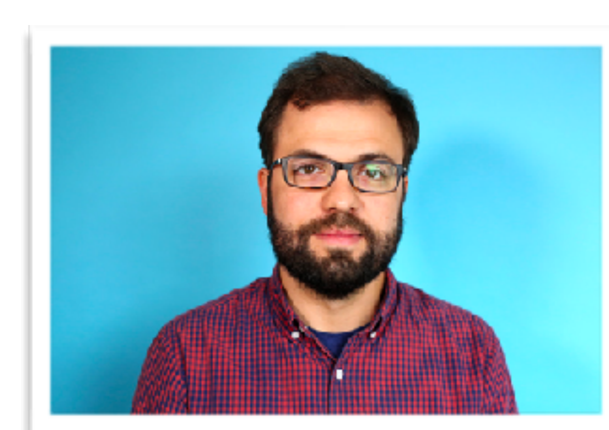
CS294 **Guest lecture: Jenny Bosten, Univ. of Sussex** **Ren Ng**

Eye Anatomy & Vision Neurobiology









CS294 **Guest lecturer: William Tuten** **Ren Ng**

Neural Coding & Computational Neuroscience

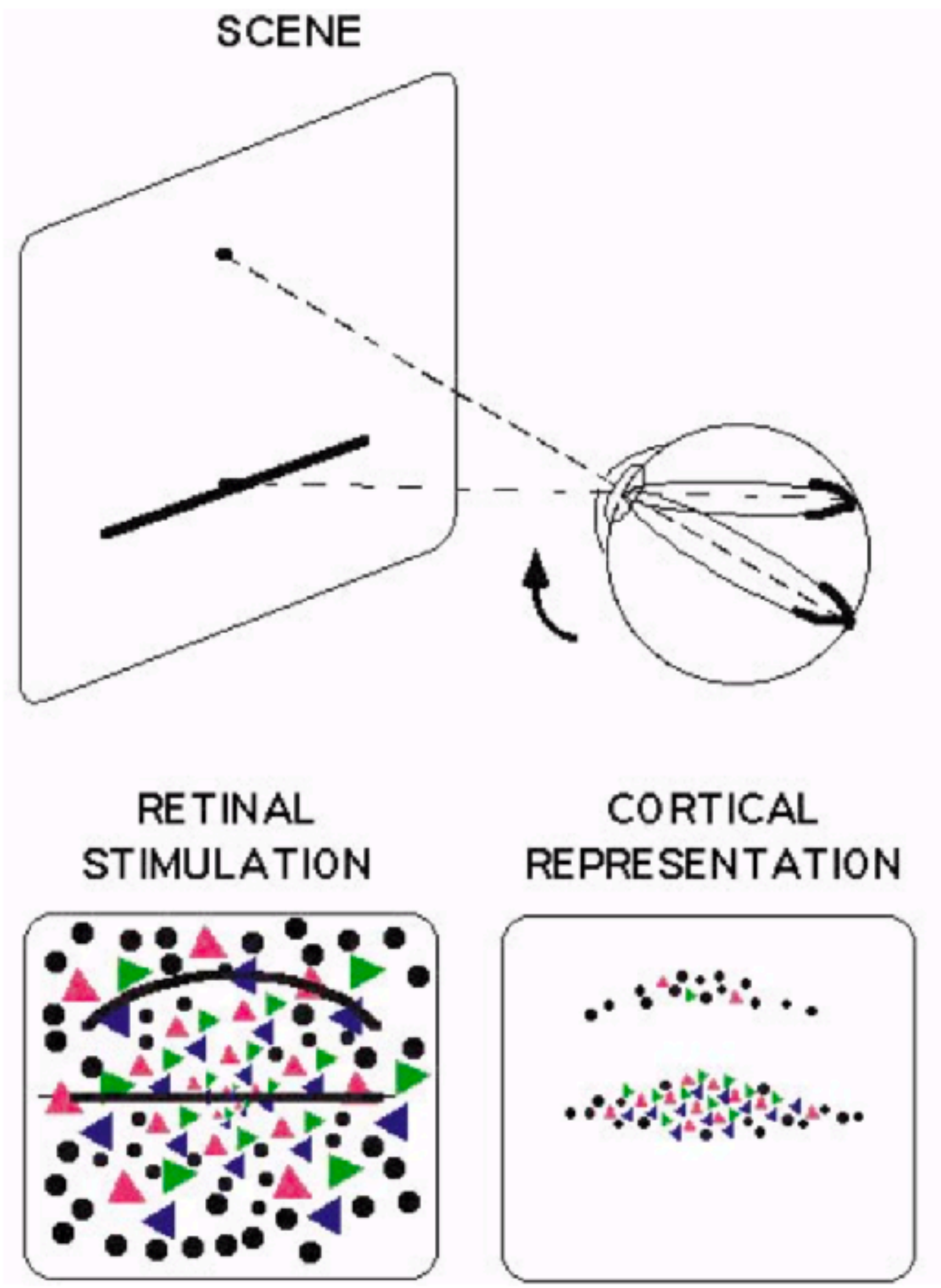


Figure 1: Oregan and Noe, 2001.

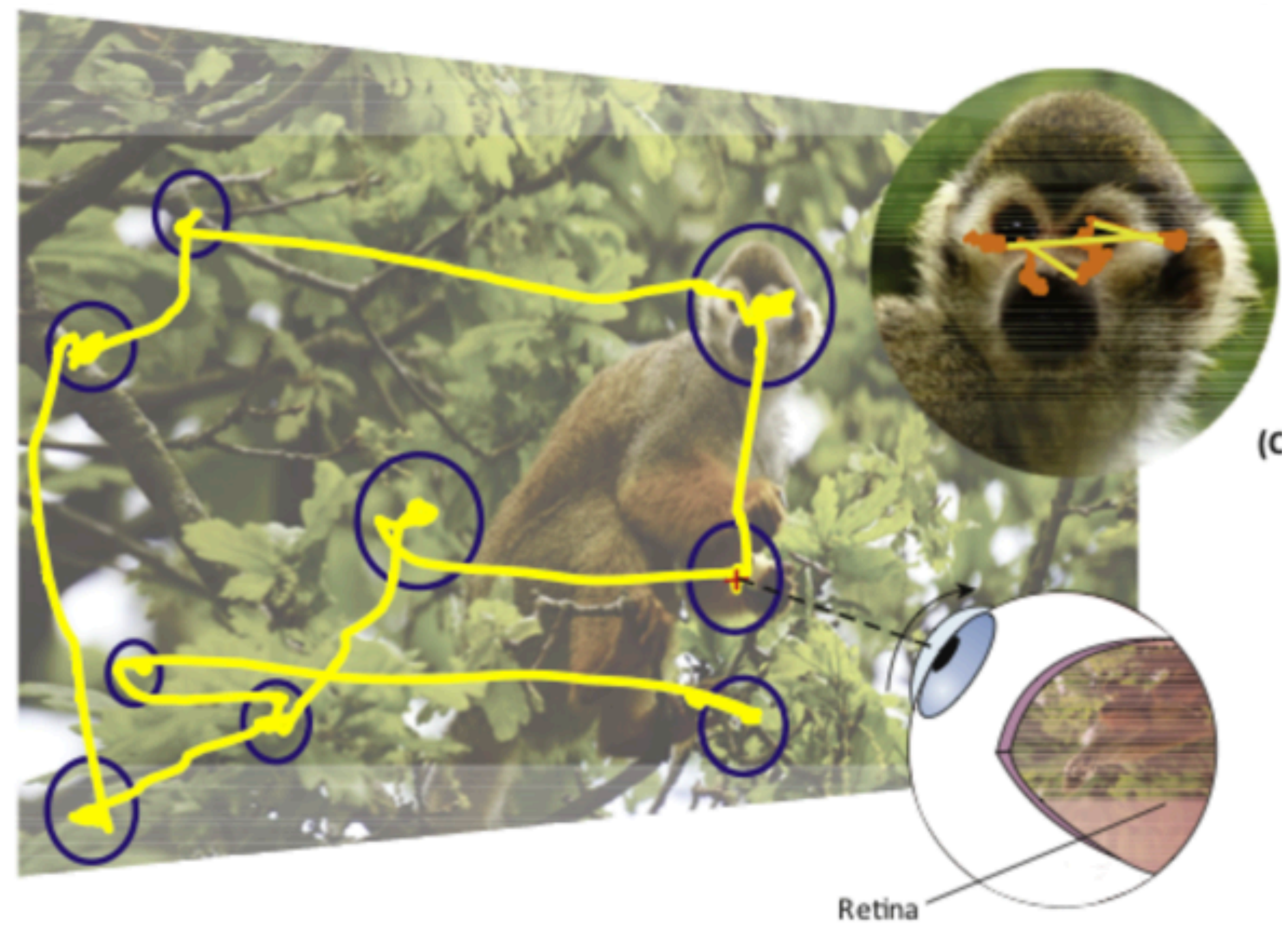
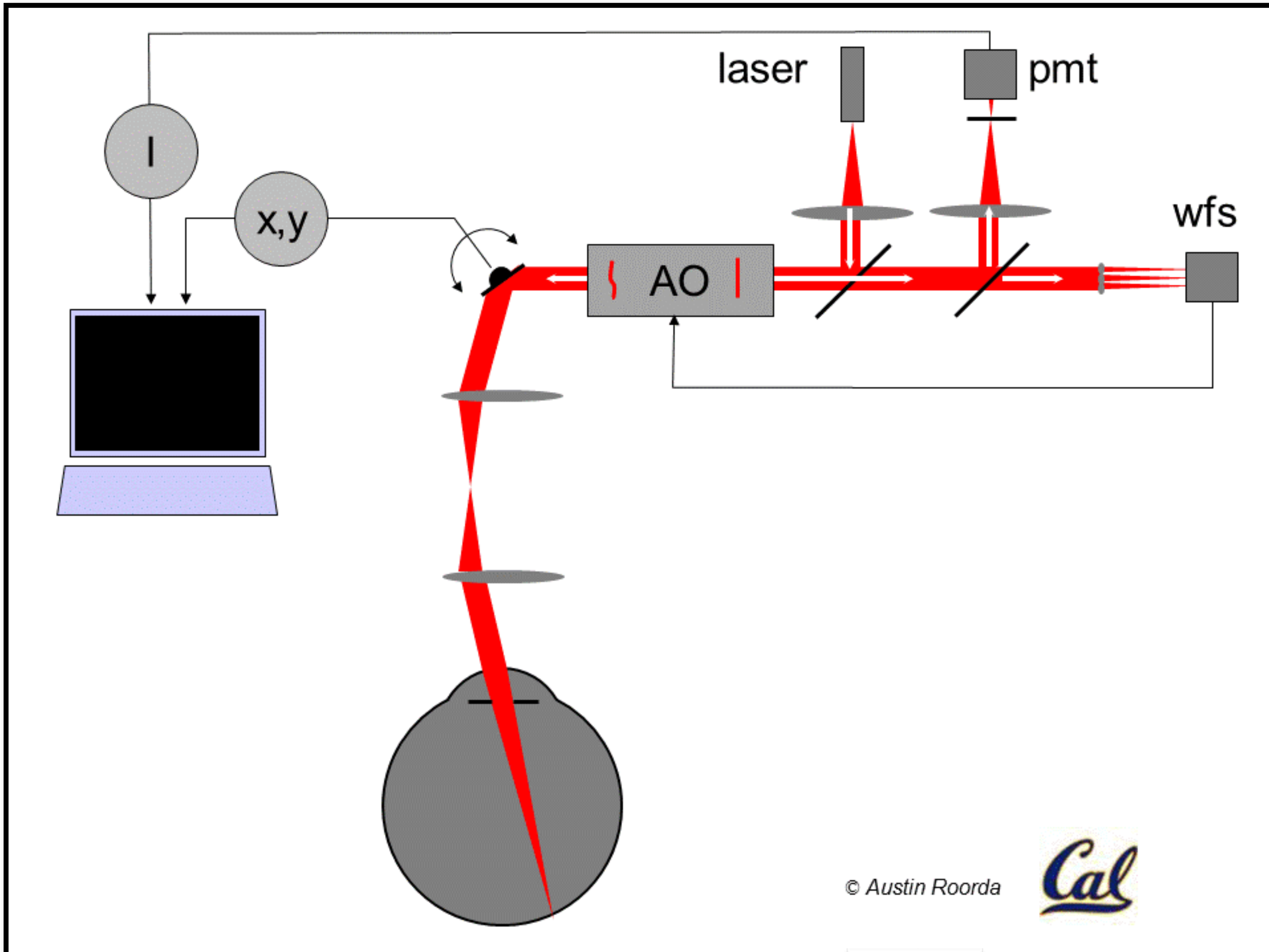
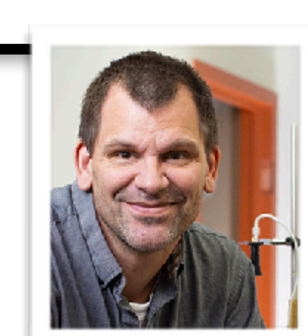


Figure 1: Rucci et al, 2018.

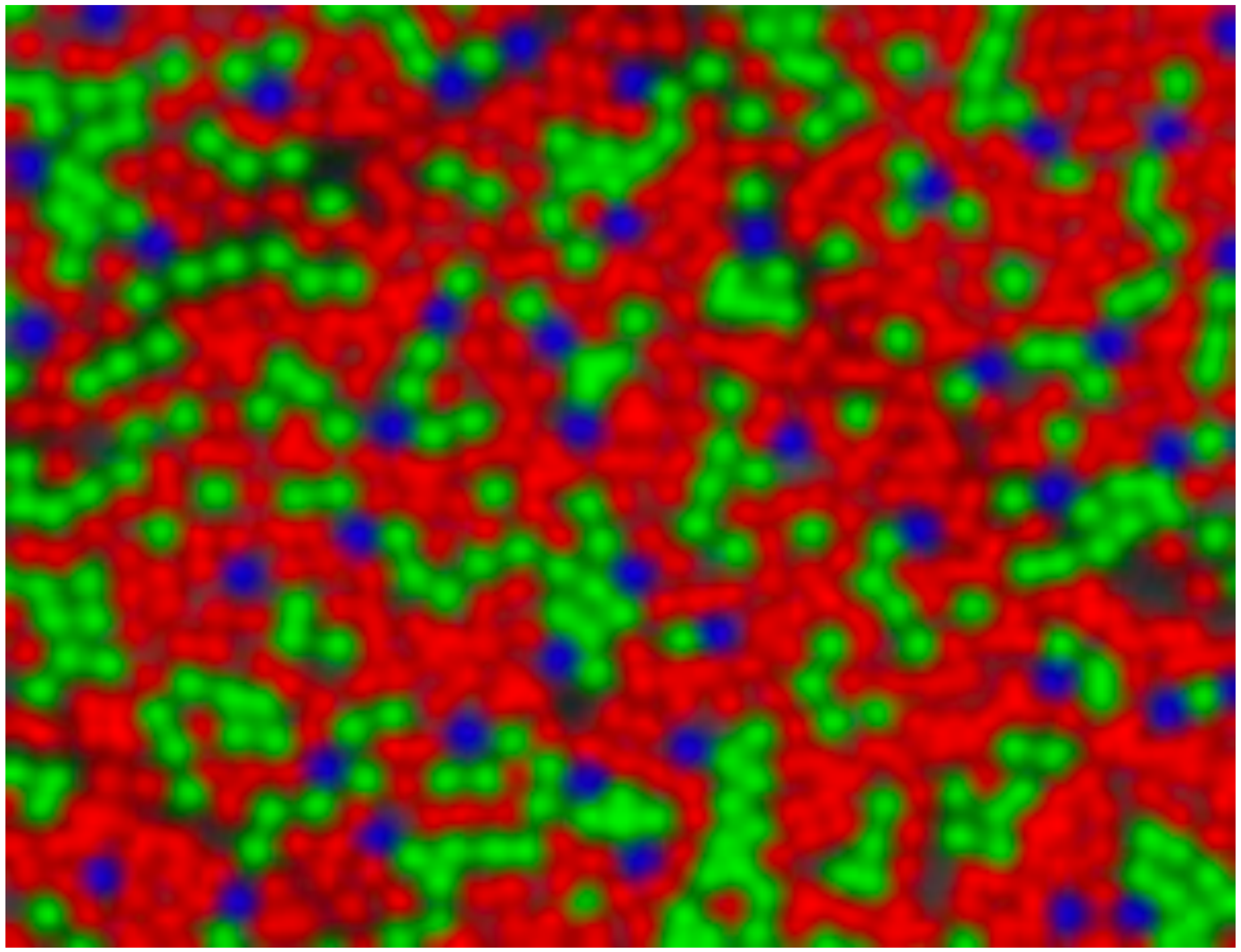
Guest lecture: Bruno Olshausen

Retinal Imaging, Tracking & Stimulation

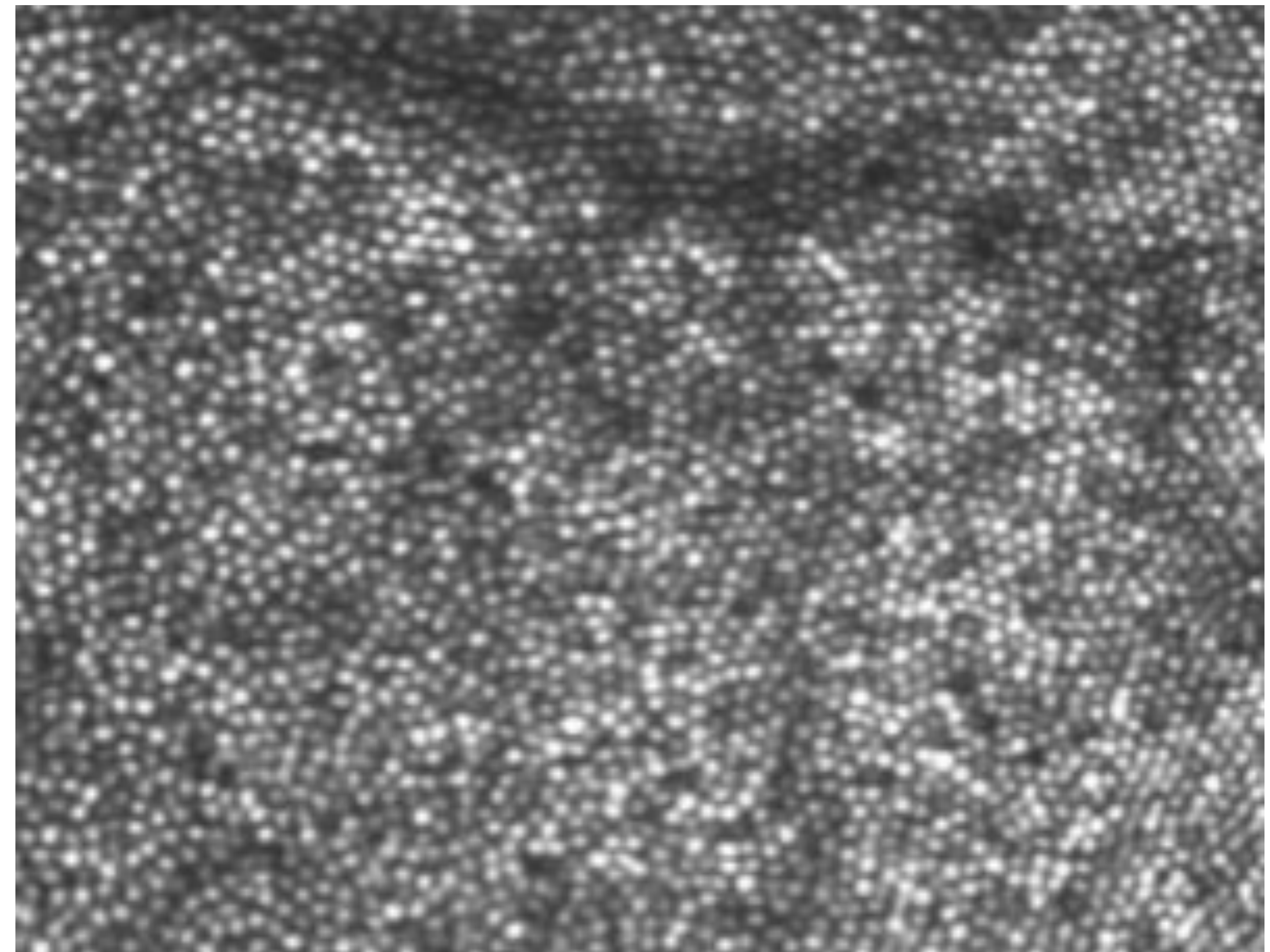




Classifying Cone Cells

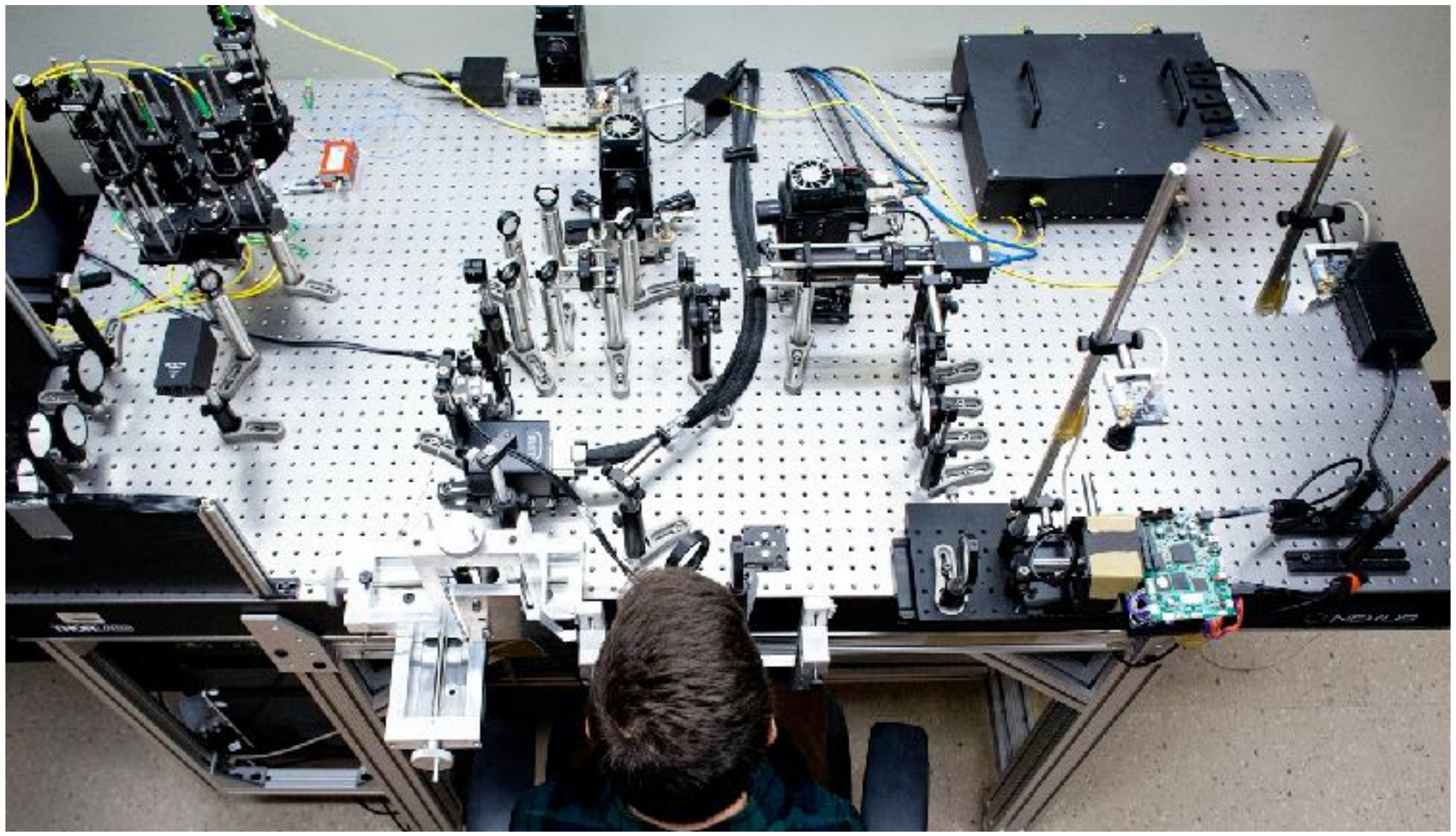


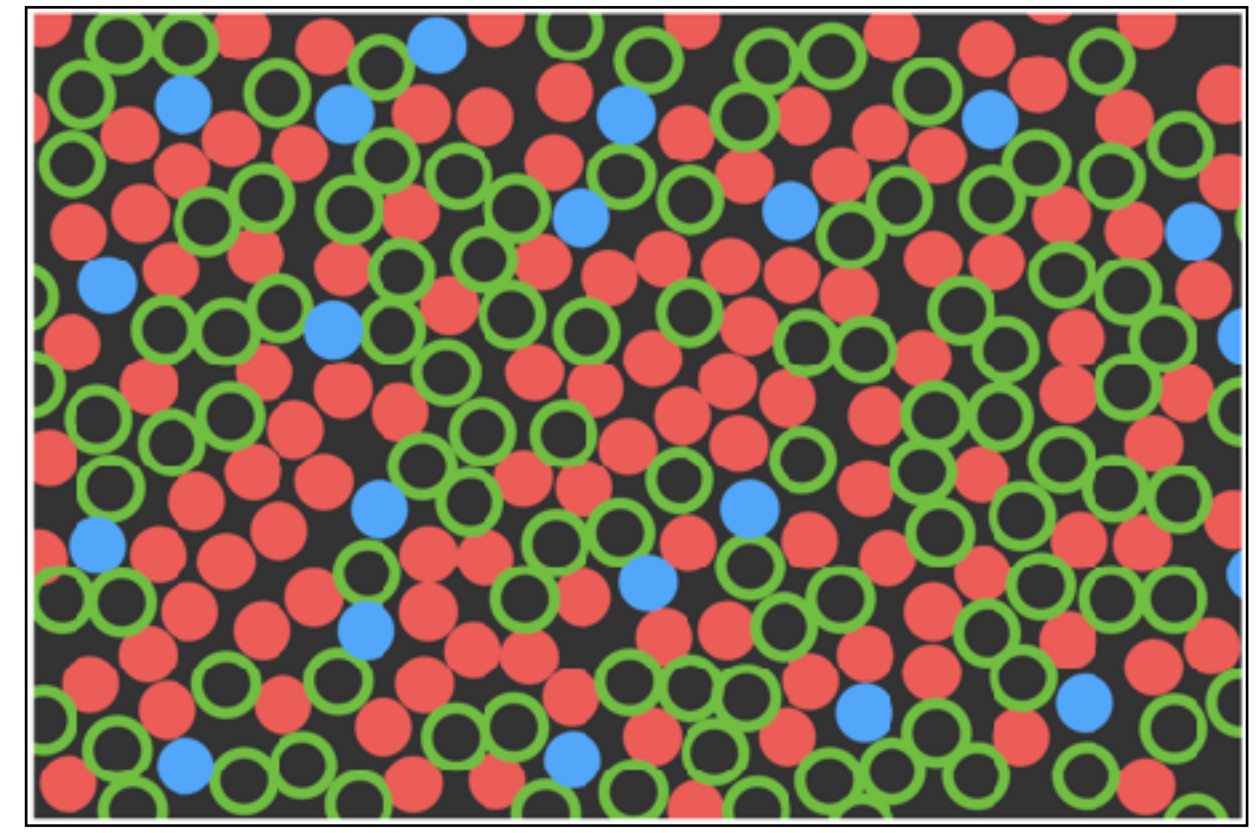
Human trichromatic cone mosaic (in pseudocolor) imaged with an adaptive optics scanning laser ophthalmoscope

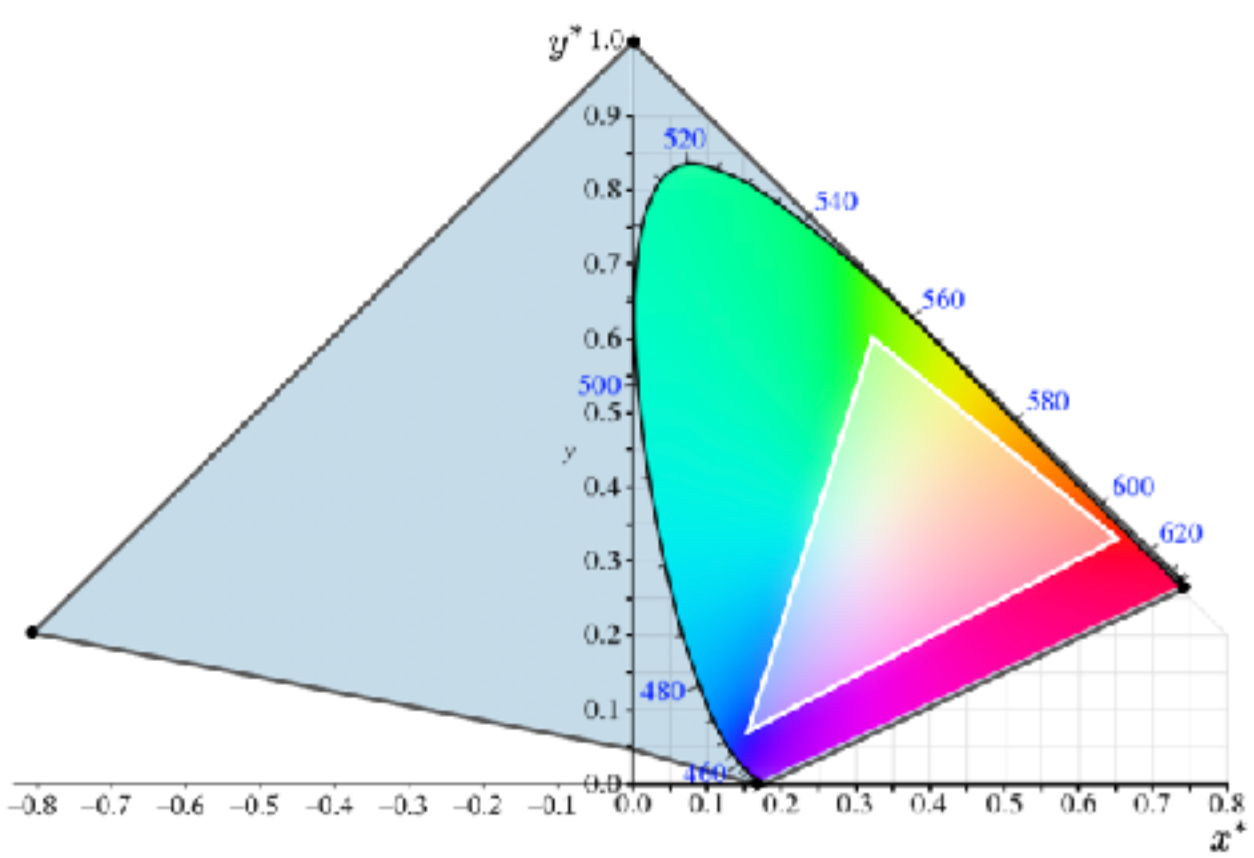


In vivo image of a human cone photoreceptor mosaic. Bright circular spots are cone photoreceptors, darker areas are shadows of blood vessels.

Oz Vision - New Principles of Color Display







Philosophically, the goal of Oz Vision is to enable a researcher to program the activity levels at every photoreceptor in the retina at every point in time. We seek to enable a person to perceive new colors beyond the natural human gamut, and to enable a color blind person to perceive normal color for the first time.

Oz Vision – New Principles for Color Display

Ren Ng, James Fong, Jay Shenoy, Varsha Ramakrishnan,
Peter Manohar, Utkarsh Singhal,
Andrew Aikawa, Jay Shenoy, Yi Zong, Rishi Uphadhyay,
Hugh Johnson, Li Yang Kat, Jesse Ku,
Arjun Sabnis, Steven Sun, Jiaqi Zhang
Emma Alexander

- Department of Electrical Engineering & Computer Sciences

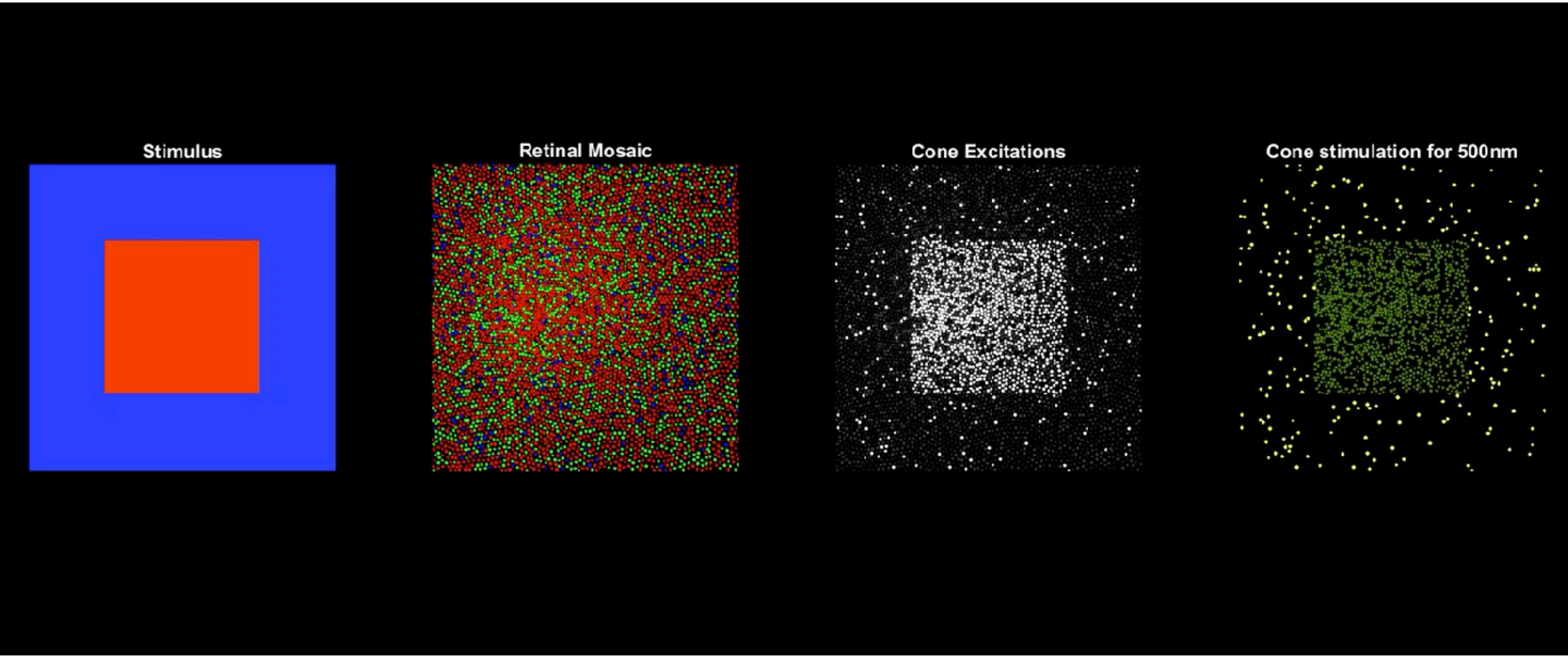
Alexandra Boehm, John Erik Vanston, Brian Schmidt,
Pavan Tiruveedhula, Will Tuten, Austin Roorda

- School of Optometry and Vision Sciences

Berkeley
UNIVERSITY OF CALIFORNIA

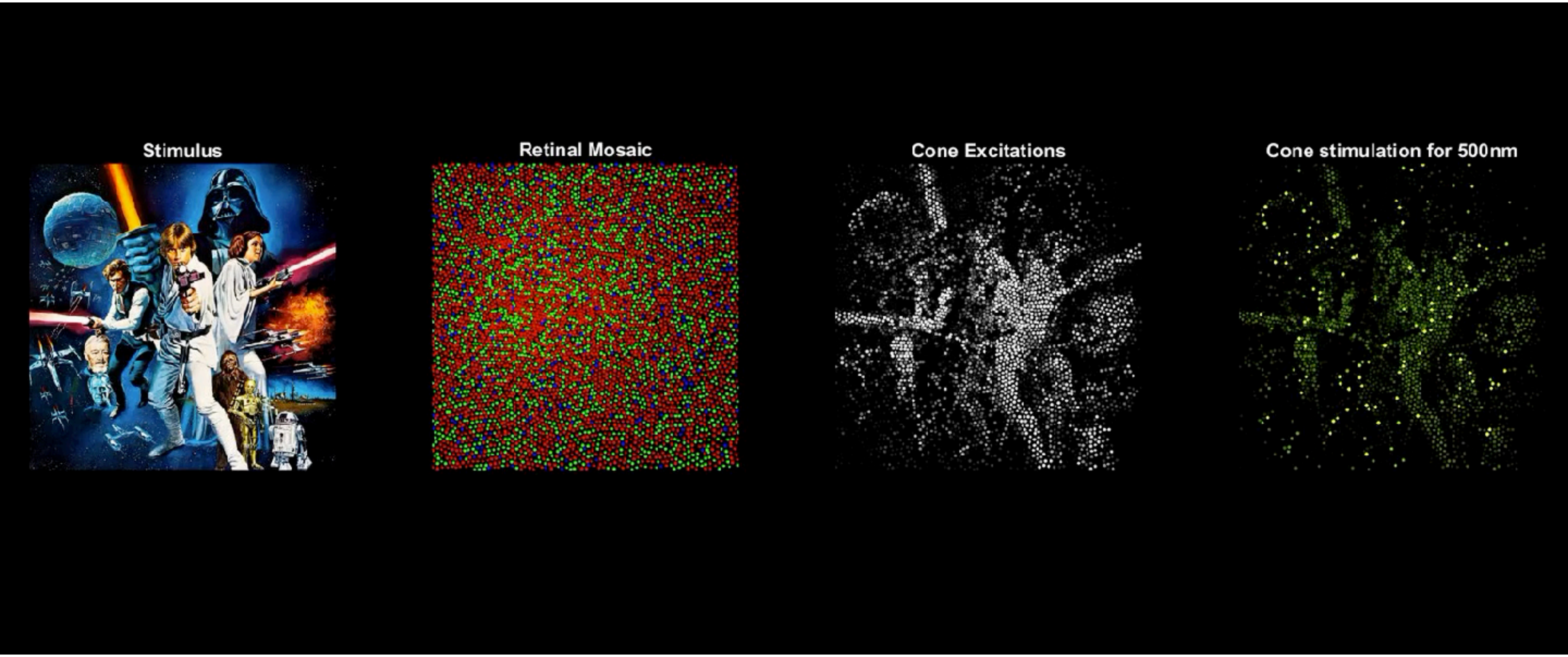
L.F. Baum
W.W. Denslow

Oz Vision - New Principles of Color Display



Courtesy A. Roorda

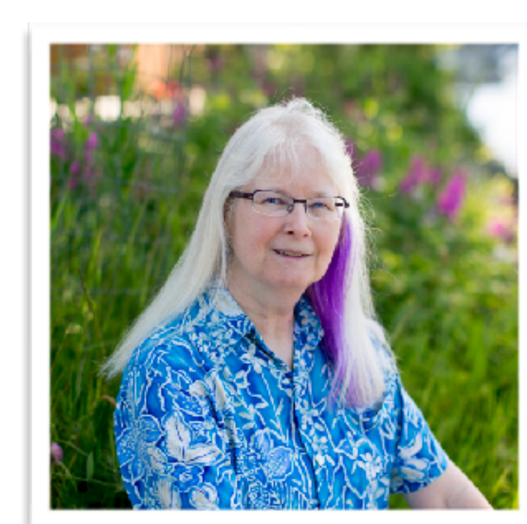
Oz Vision - New Principles of Color Display



Courtesy A. Roorda

Course Topics:
Color in Practice

Color in Practice (Data Scientist's Perspective)



CS294 Guest lecturer: Maureen Stone, Tableau **Ren Ng**

Color in Practice (Photographer's Perspective)

Guest lecturer (all photos here): Ming Thein

Color Reproduction + Camera Processing Pipelines

Real world, original light

Image recording

Input Pixels

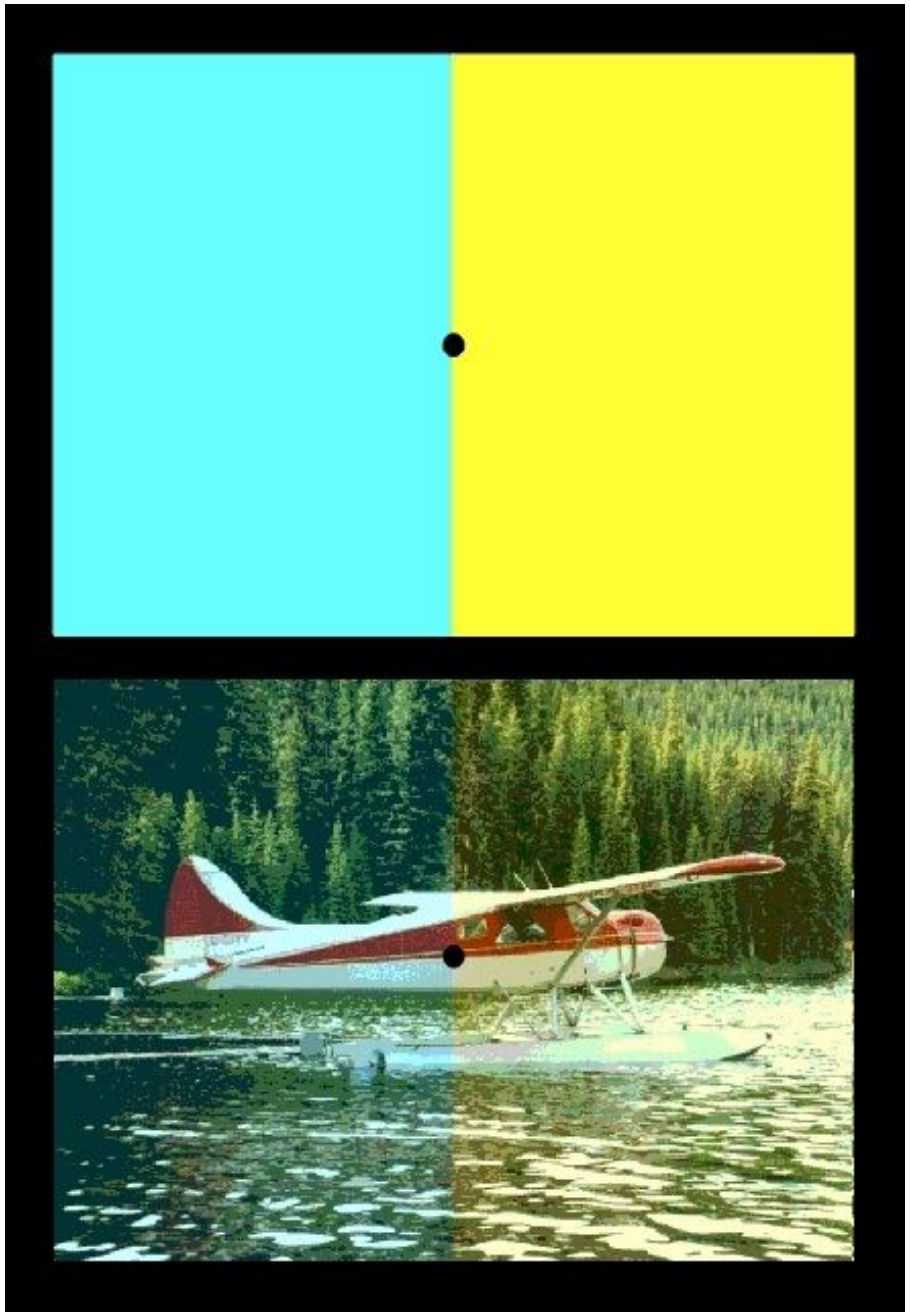
Output pixels

Physical display

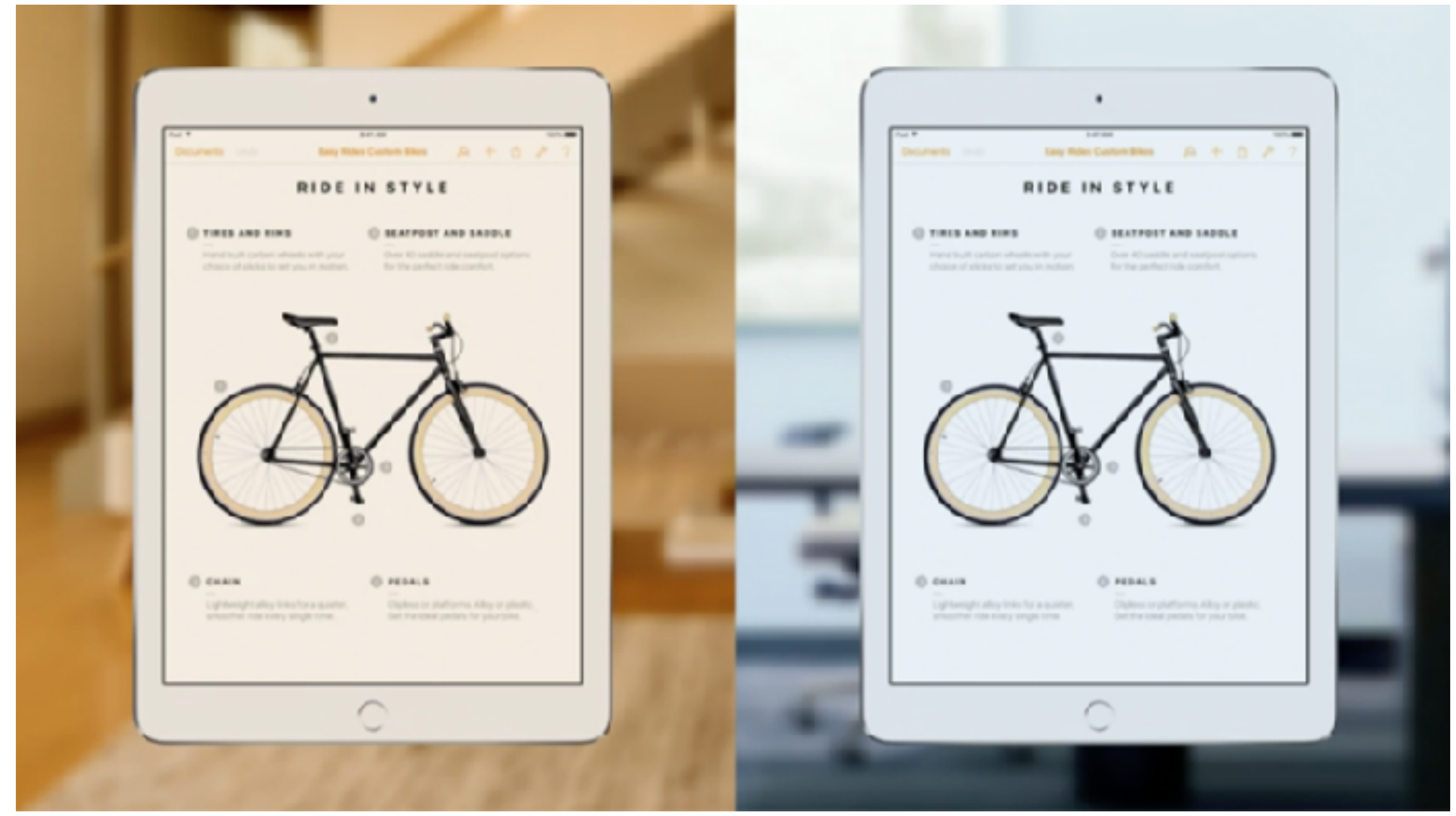
Emitted light

Guest lecturer: Michael S. Brown, York University

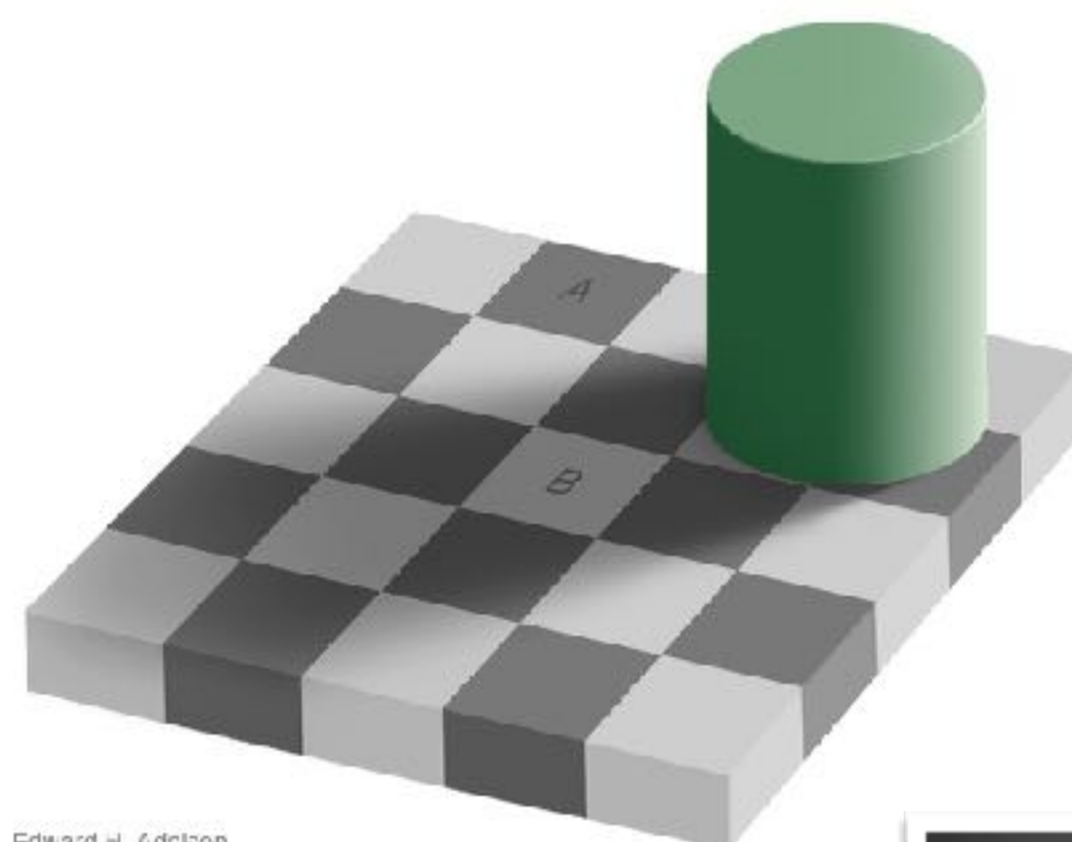
Color Appearance Models



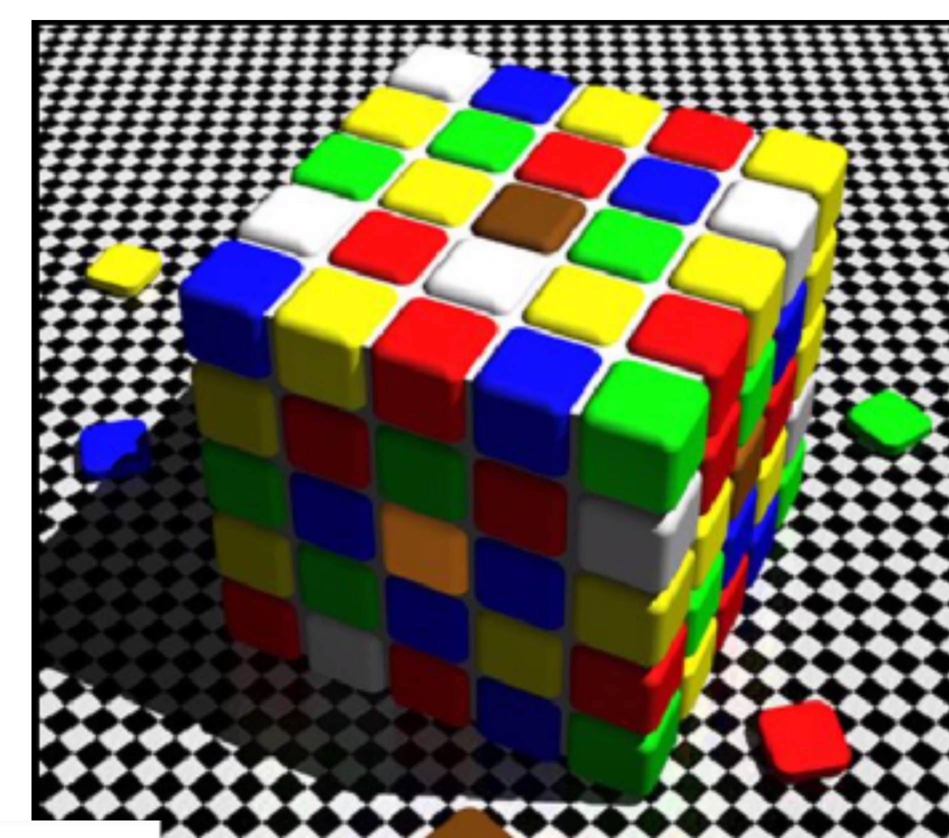
Chromatic adaptation



Apple True Tone



Adelson



Lotto

CS294 **Guest lecturer: Mark Fairchild, RIT** **Ren Ng**

Course Speakers

Ren Ng
UC Berkeley
Your Prof

Maureen Stone
Tableau
Color in practice,
data science

Ramkumar Sabesan
UW
Hacking the
visual system II

Jay Neitz
UW
Expanding
color dimension

Michael S. Brown
York Univ.
Camera pipelines

Jenny Bosten
Univ. of Sussex
Tetrachromacy

Bruno Olshausen
UC Berkeley
Neural modeling

Ming Thein
Color in practice,
photography

Mark Fairchild
RIT
Color appearance
models

William Tuten
UC Berkeley
Visual biology
psychophysics

Austin Roorda
UC Berkeley
Hacking the
visual system

Tentative Schedule (Website for Updates)

HOME		Student Disc. Topics | 1:10 - 2:20	Lecture Topic | 2:30 - 4:00	Lecturer
1	Sep-1	None - course introduction	Tristimulus theory and colorimetry	Ng
2	Sep-8	Tristimulus theory and colorimetry	On expanding the dimensionality of color vision	Jay Neitz
3	Sep-15	On expanding the dimensionality of color vision	Oz Vision overview	Ng
4	Sep-22	Oz Vision overview	Neural image coding	Bruno Olshausen
5	Sep-29	Neural image coding	Intro to eye anatomy and visual neurobiology	William Tuten
6	Oct-6	None - In-Class Pitches	Color in practice (data science perspective)	Maureen Stone
7	Oct-13	Intro to eye anatomy and visual neurobiology	Color processing in the camera pipeline	Michael Brown
8	Oct-20	Color in data science and in the camera pipeline	Color in practice (photographer perspective)	Ming Thein
9	Oct-27	Color in practice (photographer perspective)	Field guide for hacking the human visual system	Austin Roorda
10	Nov-3	None - In-class demos / midpoint presentations	Next-gen single-photoreceptor imaging	Ramkumar Sabesan
11	Nov-10	Single-photoreceptor stimulation hardware	Color dimensionality and tetrachromacy	Jenny Bosten
12	Nov-17	Color dimensionality and tetrachromacy	Color appearance models	Mark Fairchild
13	Nov-24	Color Appearance Models	Wrap up	Ng
14	Dec-1	**Final Presentations**		
	Dec-8			
		No Final Exam		

Questions?

Course Logistics

Student Deliverables, Grading

1. Preparation & Participation (25%)
2. Lead a Class Discussion (25%)
3. Final Project (50%)

1. Preparation & Participation (25%)

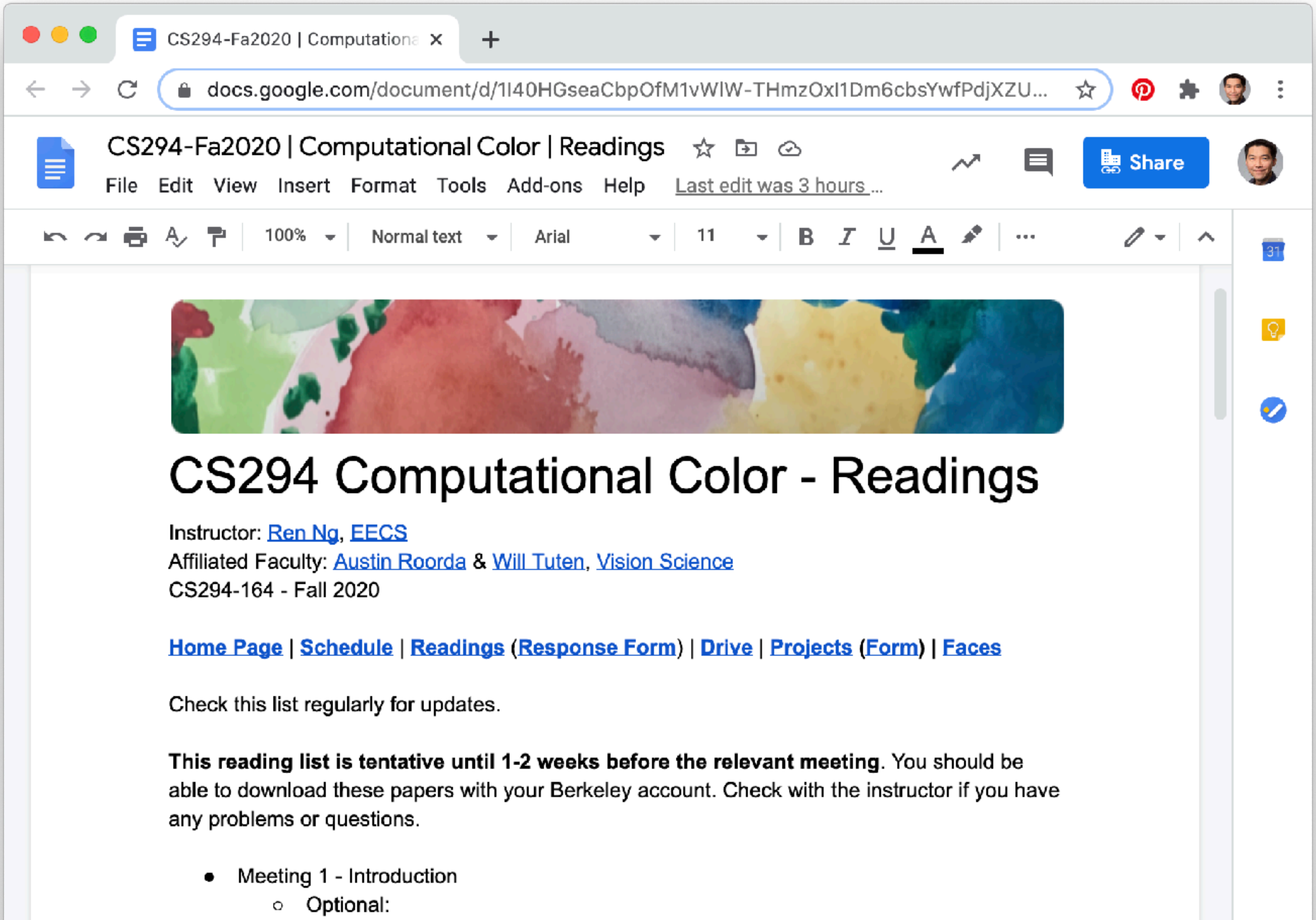
Basics: attend all classes and engage

Prepare to participate in paper discussions

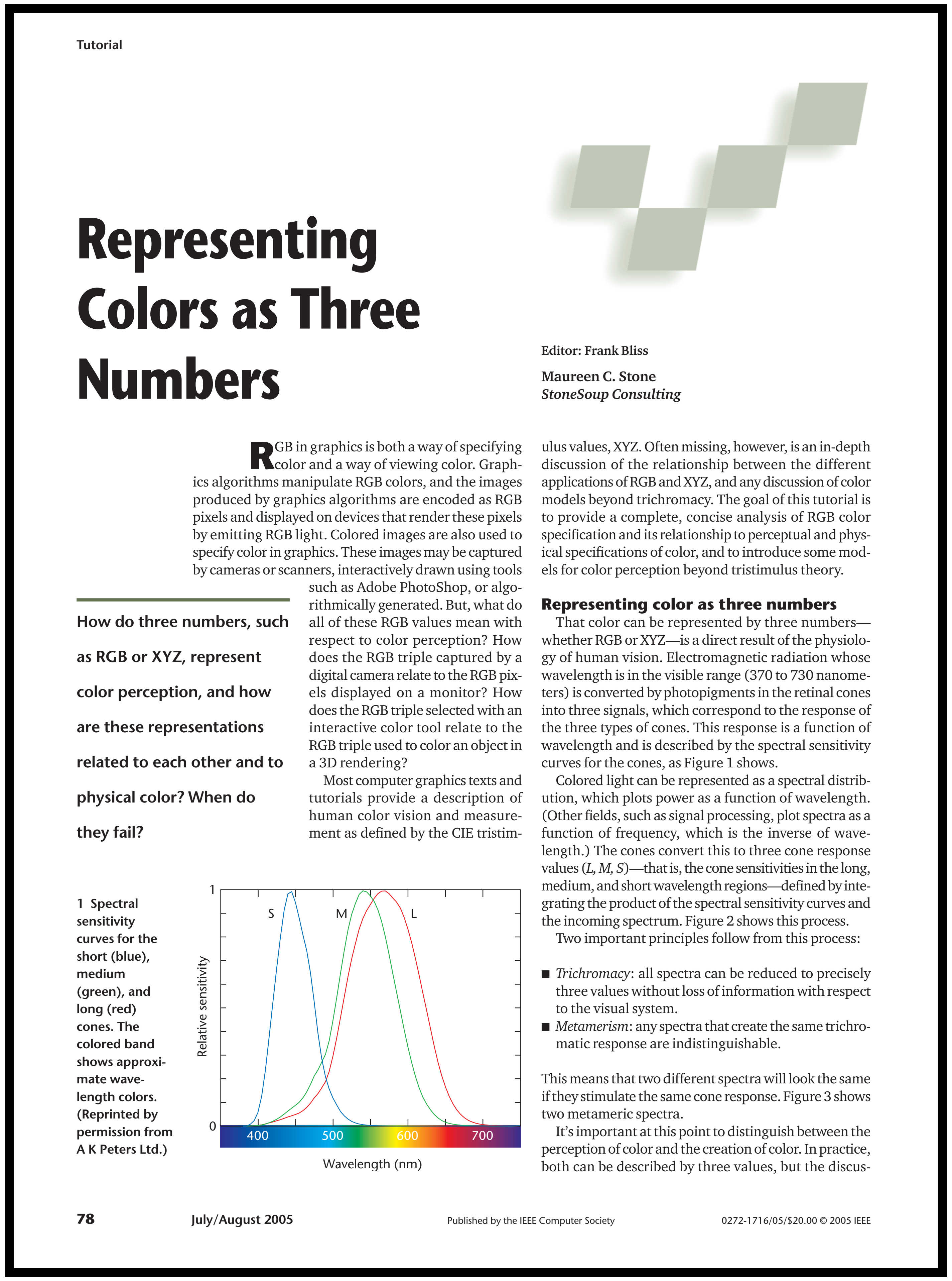
- Read all assigned papers; reading groups fine and encouraged!
- Submit a short response to readings before each class
  - Explain main idea in the paper, in your own words
  - Write up one new idea based on your reading
- Bring your ideas to class, and actively discuss them!

Submit: Reading response form; link on class website

Readings


CS294-Fa2020 | Computationa
docs.google.com/document/d/1I40HGseaCbpOfM1vWIW-THmzOxI1Dm6cbsYwfPdjXZU...
CS294-Fa2020 | Computational Color | Readings
File Edit View Insert Format Tools Add-ons Help
Last edit was 3 hours ...
Share
100%
Normal text
Arial
11
CS294 Computational Color - Readings
Instructor: Ren Ng, EECS
Affiliated Faculty: Austin Roorda & Will Tuten, Vision Science
CS294-164 - Fall 2020
Home Page | Schedule | Readings (Response Form) | Drive | Projects (Form) | Faces
Check this list regularly for updates.
This reading list is tentative until 1-2 weeks before the relevant meeting. You should be able to download these papers with your Berkeley account. Check with the instructor if you have any problems or questions.
Meeting 1 - Introduction
Optional:

Assigned Reading for Next Class (9/8)



Tutorial

Representing Colors as Three Numbers

Editor: Frank Bliss

Maureen C. Stone
StoneSoup Consulting

How do three numbers, such as RGB or XYZ, represent color perception, and how are these representations related to each other and to physical color? When do they fail?

RGB in graphics is both a way of specifying color and a way of viewing color. Graphics algorithms manipulate RGB colors, and the images produced by graphics algorithms are encoded as RGB pixels and displayed on devices that render these pixels by emitting RGB light. Colored images are also used to specify color in graphics. These images may be captured by cameras or scanners, interactively drawn using tools such as Adobe PhotoShop, or algorithmically generated. But, what do all of these RGB values mean with respect to color perception? How does the RGB triple captured by a digital camera relate to the RGB pixels displayed on a monitor? How does the RGB triple selected with an interactive color tool relate to the RGB triple used to color an object in a 3D rendering?

Most computer graphics texts and tutorials provide a description of human color vision and measurement as defined by the CIE tristimulus values, XYZ. Often missing, however, is an in-depth discussion of the relationship between the different applications of RGB and XYZ, and any discussion of color models beyond trichromacy. The goal of this tutorial is to provide a complete, concise analysis of RGB color specification and its relationship to perceptual and physical specifications of color, and to introduce some models for color perception beyond tristimulus theory.

Representing color as three numbers

That color can be represented by three numbers—whether RGB or XYZ—is a direct result of the physiology of human vision. Electromagnetic radiation whose wavelength is in the visible range (370 to 730 nanometers) is converted by photopigments in the retinal cones into three signals, which correspond to the response of the three types of cones. This response is a function of wavelength and is described by the spectral sensitivity curves for the cones, as Figure 1 shows.

Colored light can be represented as a spectral distribution, which plots power as a function of wavelength. (Other fields, such as signal processing, plot spectra as a function of frequency, which is the inverse of wavelength.) The cones convert this to three cone response values (*L, M, S*)—that is, the cone sensitivities in the long, medium, and short wavelength regions—defined by integrating the product of the spectral sensitivity curves and the incoming spectrum. Figure 2 shows this process.

Two important principles follow from this process:

- *Trichromacy*: all spectra can be reduced to precisely three values without loss of information with respect to the visual system.
- *Metamerism*: any spectra that create the same trichromatic response are indistinguishable.

This means that two different spectra will look the same if they stimulate the same cone response. Figure 3 shows two metameric spectra.

It's important at this point to distinguish between the perception of color and the creation of color. In practice, both can be described by three values, but the discus-

1 Spectral sensitivity curves for the short (blue), medium (green), and long (red) cones. The colored band shows approximate wavelength colors. (Reprinted by permission from A K Peters Ltd.)

Published by the IEEE Computer Society

nature Vol 461 | 8 October 2009 | doi:10.1038/nature08401

LETTERS

Gene therapy for red–green colour blindness in adult primates

Katherine Mancuso[1], William W. Hauswirth[2], Qiuhong Li[2], Thomas B. Connor[3], James A. Kuchenbecker[1], Matthew C. Mauck[3], Jay Neitz[1] & Maureen Neitz[1]

Red–green colour blindness, which results from the absence of either the long- (L) or the middle- (M) wavelength-sensitive visual photopigments, is the most common single locus genetic disorder. Here we explore the possibility of curing colour blindness using gene therapy in experiments on adult monkeys that had been colour blind since birth. A third type of cone pigment was added to dichromatic retinas, providing the receptoral basis for trichromatic colour vision. This opened a new avenue to explore the requirements for establishing the neural circuits for a new dimension of colour sensation. Classic visual deprivation experiments[1] have led to the expectation that neural connections established during development would not appropriately process an input that was not present from birth. Therefore, it was believed that the treatment of congenital vision disorders would be ineffective unless administered to the very young. However, here we show that the addition of a third opsin in adult red–green colour-deficient primates was sufficient to produce trichromatic colour vision behaviour. Thus, trichromacy can arise from a single addition of a third cone class and it does not require an early developmental process. This provides a positive outlook for the potential of gene therapy to cure adult vision disorders.

Gene therapy was performed on adult squirrel monkeys (*Saimiri sciureus*) that were missing the L-opsin gene. In this species, some females have trichromatic colour vision whereas males are red–green colour blind[2]. Serotype 2/5 recombinant adeno-associated virus (rAAV) containing a human L-opsin gene under the control of the L/M-opsin enhancer and promoter (Fig. 1a) was delivered to the photoreceptor layer by subretinal injections (see Methods). Transcriptional regulatory elements were chosen to direct expression preferentially in M cones, but not short- (S) wavelength-sensitive cones or rods[3]. To provide the receptoral basis for trichromacy, animals received three 100-μl injections (containing a total of 2.7×10^{13} viral particles) in each eye, which produced a relatively uniform, third submosaic of approximately 15–36% of M cones that coexpressed the transgene (Fig. 1e, f).

Before treatment, monkeys were trained to perform a computer-based colour vision test, the Cambridge Colour Test[4,5], which was modified for use with animals[6] (Fig. 2a). Dichromats who are missing either the L- or the M-photopigment fail to distinguish from grey: colours near the so-called 'spectral neutral point' located in the blue-green region of colour space (near dominant wavelength of 490 nm) and complementary colours near the 'extra-spectral neutral point' in the red-violet region (near dominant wavelength of −499 nm). Whereas trichromats have the four main hue percepts blue, yellow, red and green, dichromats only have two percepts, nominally blue and yellow. Before treatment, two dichromatic monkeys completed

Figure 1 | rAAV2/5 vector produced functional L-opsin in primate retina. **a**, Molecular map. LCR, locus control region; PA_1, polyadenylation signal; PP, proximal promoter; RHLOPS, recombinant human L-opsin cDNA; SD/SA, splice donor/acceptor; TR, terminal repeats. **b**, Red light mf-ERG stimulus. **c**, mf-ERG 40 weeks after two injections (yellow circles) of a mixture of L-opsin- and GFP-coding viruses. Grey lines show borders of highest response. For comparison, the inset shows mf-ERG 16 weeks after injection; there was no reliable signal from L-opsin, unchanged from baseline. High responses in far peripheral retina were measured reliably and may have originated from offshoot of one of the injections. **d**, Fluorescence photographs from a similar retinal area as in **c**; grey lines from **c** were copied in **d**. **e**, Confocal microscopy showed a mosaic pattern of GFP expression in 5–12% of cones. Because GFP-coding virus was diluted to one-third compared to L-opsin virus, an estimated 15–36% of cones in behaviourally tested animals express L-opsin. **f**, Mf-ERG from a behaviourally tested animal 70 weeks after three injections of L-opsin virus.

[1]Department of Ophthalmology, Box 356485, University of Washington, 1959 North East Pacific Street, Seattle, Washington 98195, USA. [2]Department of Ophthalmology and Powell Gene Therapy Center, University of Florida, 1600 South West Archer Road, Gainesville, Florida 32610, USA. [3]Department of Ophthalmology, Medical College of Wisconsin, 925 North 87th Street, Milwaukee, Wisconsin 53226, USA.

Stone, 2005
Representing Colors

Mancuso et al, 2009
Gene Therapy for Colour Blindness

2. Lead a Class Discussion (25%)

Half of class meetings will be student-led discussion

Prepare and engage class in productive discussion:

- present paper ideas to class (10-15 min)
- lead a group discussion (20 min), e.g.
  - design two breakout discussion questions
  - pose a debate of pros + cons
  - brainstorm new ideas and directions

Assigned slot: online schedule

2. Lead a Discussion (25%)

Comments: presenting paper (10-15 min)

- think of this as a conversation with the class
- study paper thoroughly, as well as key citations in areas that are not clear to you (and come talk to me)
- assume everyone has read paper quickly, but forgotten
- in some cases, the previous lecture will have covered much of the material in the paper. If so, it is important for you to find a non-repetitive angle!
- you can show images / key results as helpful
- distill and teach the key concepts
- go for insight and technical depth
- practice your timing and delivery!
- coordinate with partner for that day

Sign up: Online Schedule

3. Final Project (50%)

Projects are in groups of 2-3

Create something new! (experiment, code, mathematical analysis, idea, etc.)

Deadlines for check-ins (draft — check schedule on website):

- 9/22: choose project team
- 9/29: select topic and submit half-page proposal;
- 10/6: in-class pitches
- 11/3: in-class mid-point demos; check-in report

Final Presentations: 12/1

Report + Video: 12/8

Project Intro

Project Ideas and Resources

- Apply to research projects in your own labs -- computer vision, vision science, neuroscience, computer graphics, ...
- Get involved in Oz Vision research project
  - Opportunities on software [and hardware and experiments]
- Computer simulation to model and study aspects of human visual system and neural coding
- Color practice & applications – graphics, HCI, apps
- Reproduce and extend recent studies: ecological optics, color illusions, ...
- Explore color mathematics, e.g. Schrödinger's Optimal Colors
- You have broad license to define and prosecute your own program of study or research into color

Project Examples from 2019

Huereka: A Smart Painting Palette

- Dalton Omens
- Marc WuDunn
- Frank Yang

Hueureka!

Stable Color Perception from Fixational Retinal Drift

- Arjun Sabnis
- Jesse Ku
- Hugh Johnson

Video by Hugh Johnson, Arjun Sabnis and Jesse Ku

Experiencing Color through Binocular Fusion

- Neerja Aggarwal
- Stephanie Claudino Daffara
- James Smith
- J.D. Zamfirescu-Pereira

Reminder: tetrachromacy = 4D color perception

Experiencing Color through Binocular Fusion

Neerja Aggarwal
Stephanie Claudino Daffara
James Smith
J.D. Zamfirescu-Pereira

Questions?

Welcome to CS294-164 Computational Color!

Today's agenda

- Course basics; introductions
- Why study color?
- Instructor background
- Overview of course topics
- Course logistics, deliverables

<< Break - Mingling in Ohyay >>

- Lecture 1: Tristimulus Theory and Colorimetry

Discussion: Learning Goals

What is something you want to learn about color?

What project topics might you be interested in?

<< Break >>

Mingling in Ohyay

Do we want this for class projects?

Break - Mingling in Ohyay

Today we'll try a new virtual workspace tool

- Considering this as a general class tool for socializing, project teaming, collaborating, hanging out
- Today's space is a fast mockup for us to try
- Recommend Chrome/Firefox on a laptop
- Technical problems? Come back here to zoom
- Mingle, introduce yourself, explore, see what you think
- Will ask for your feedback later
- 15-30 min in Ohyay; I will announce when over.
- Have fun!

http://ohyay.co/s/ren