

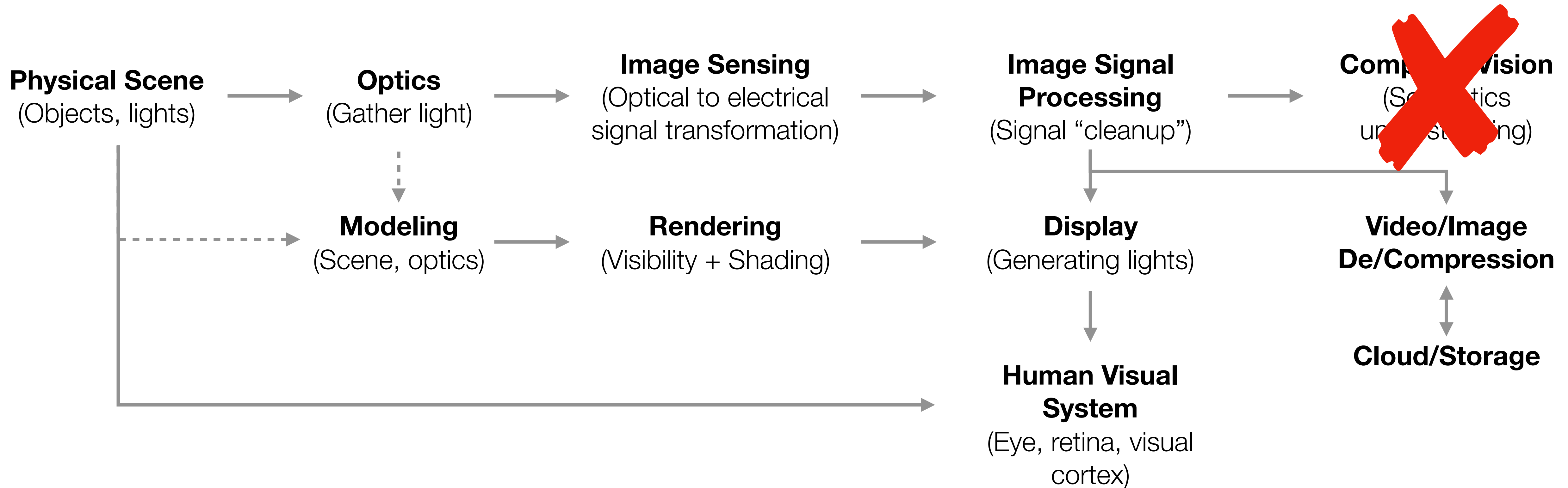
Lecture 1: Introduction and Overview

Yuhao Zhu

<http://yuhaozhu.com>

CSC 259/459, Fall 2026
Computer Imaging & Graphics

Scope of the Course



Conventional Digital Camera



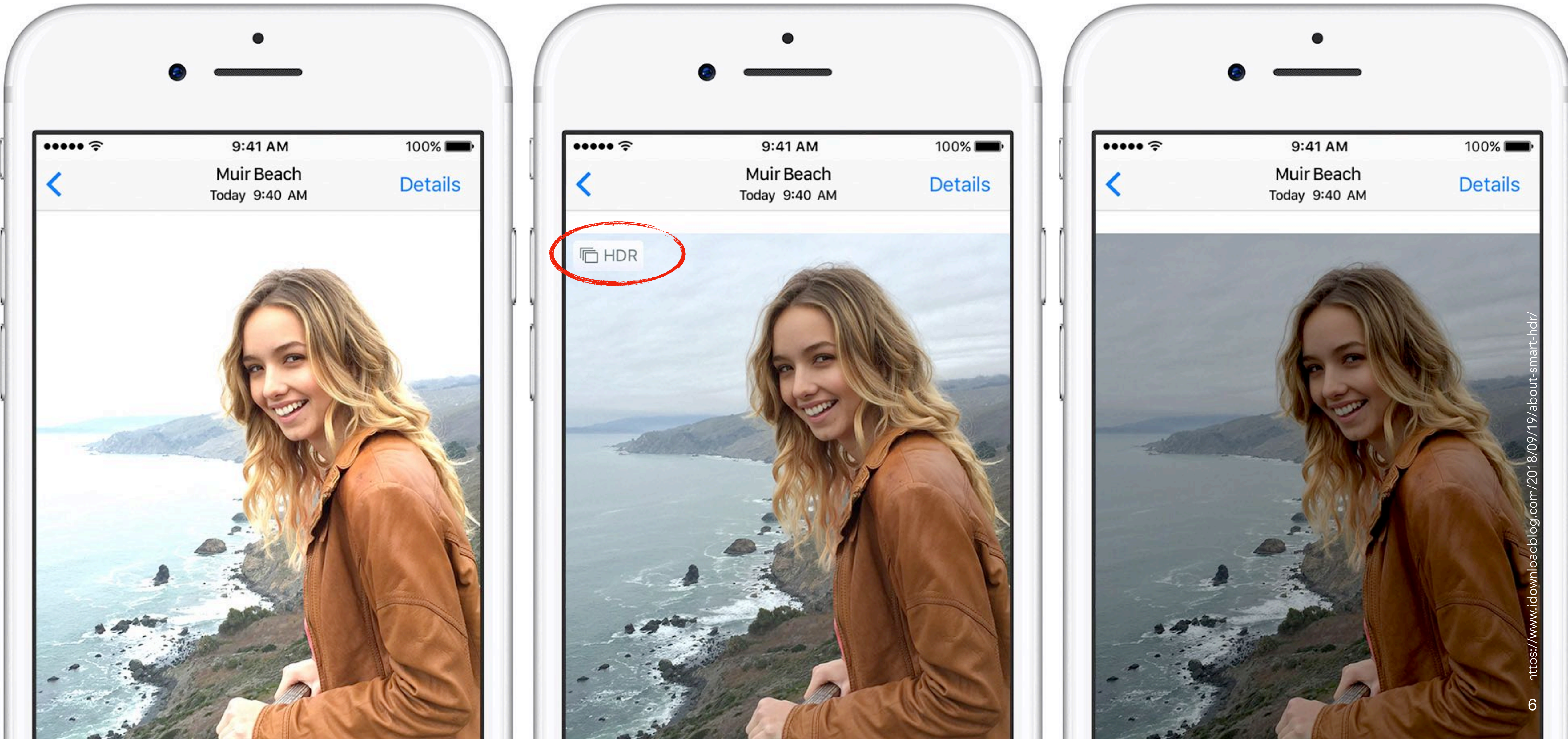
Today's Digital Camera



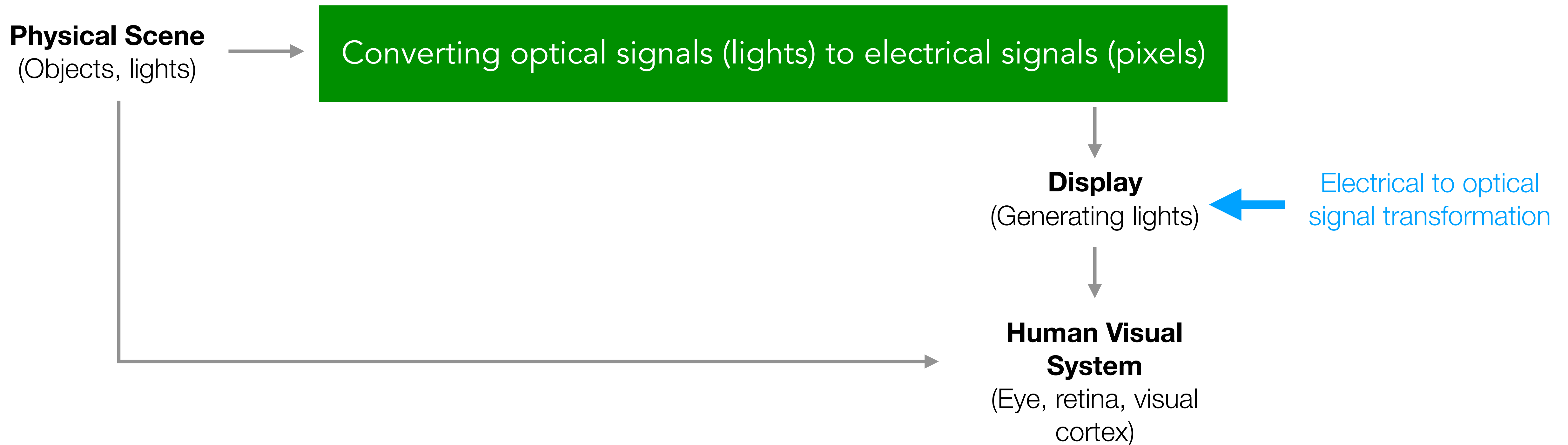
Today's Digital Camera: Portrait Mode



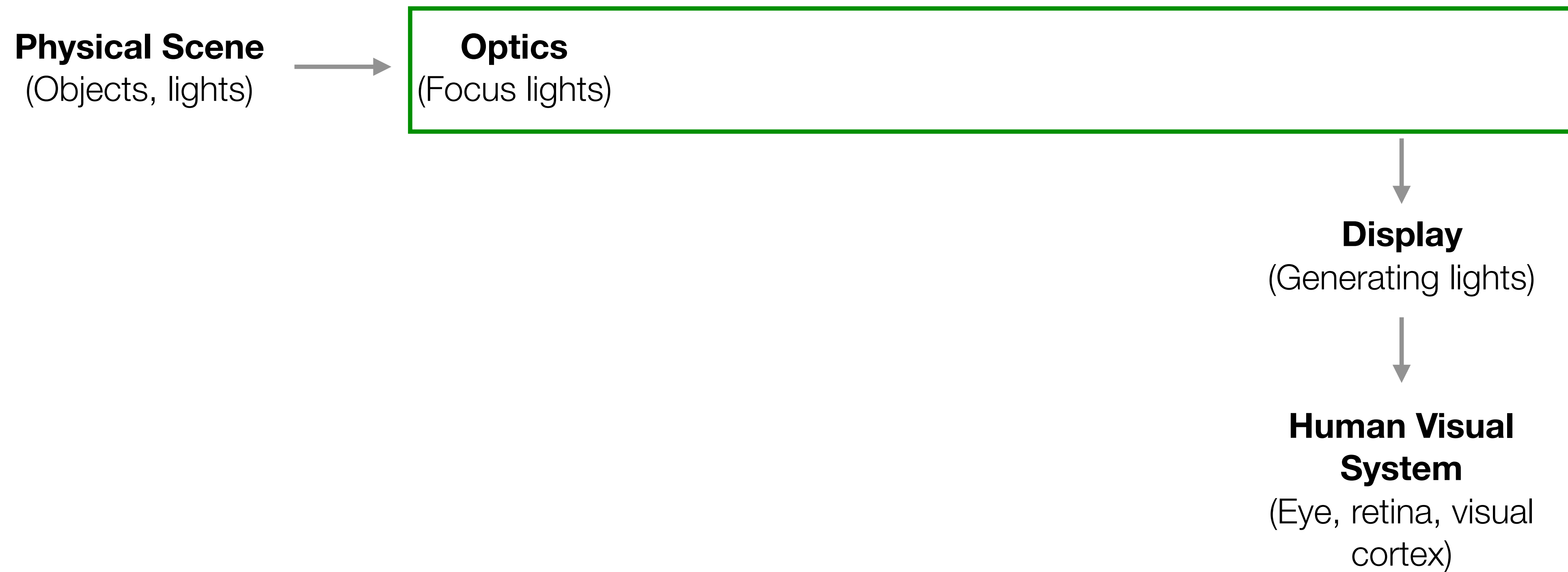
Today's Digital Camera: High Dynamic Range



Digital Camera System



Digital Camera System



Role of Optics in a Camera

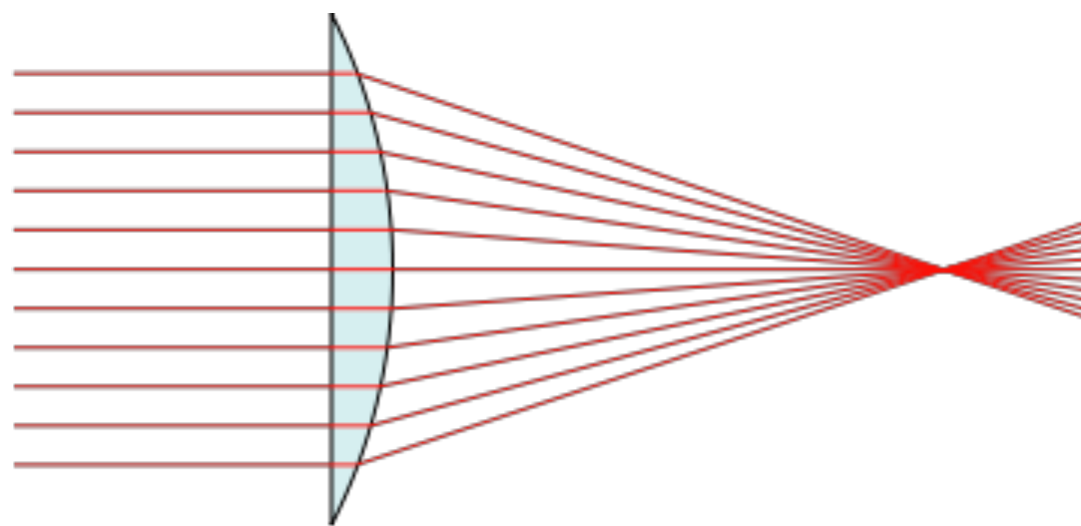
Focus light and capture energy

At a cost of introducing "imperfections" (aberrations)

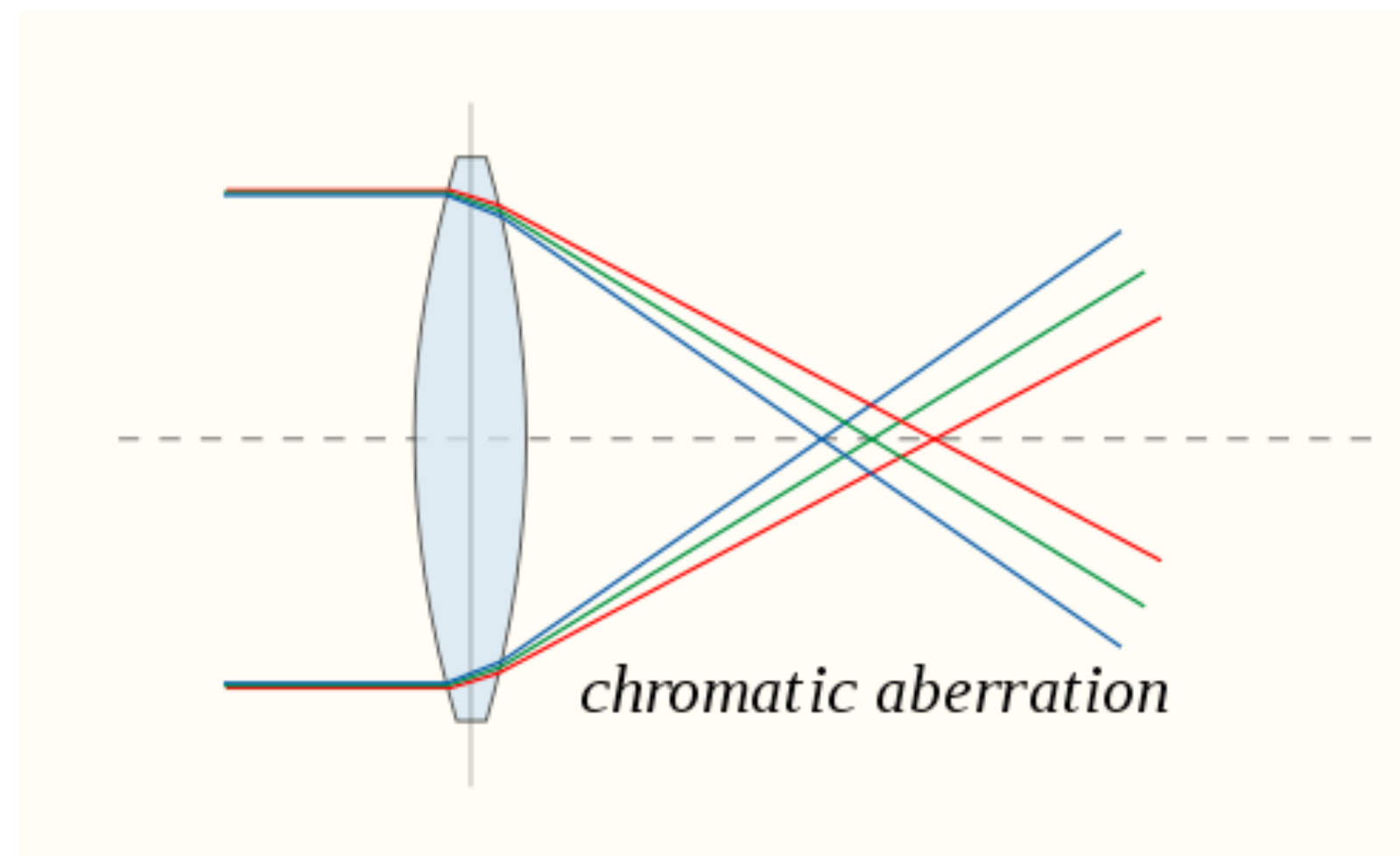
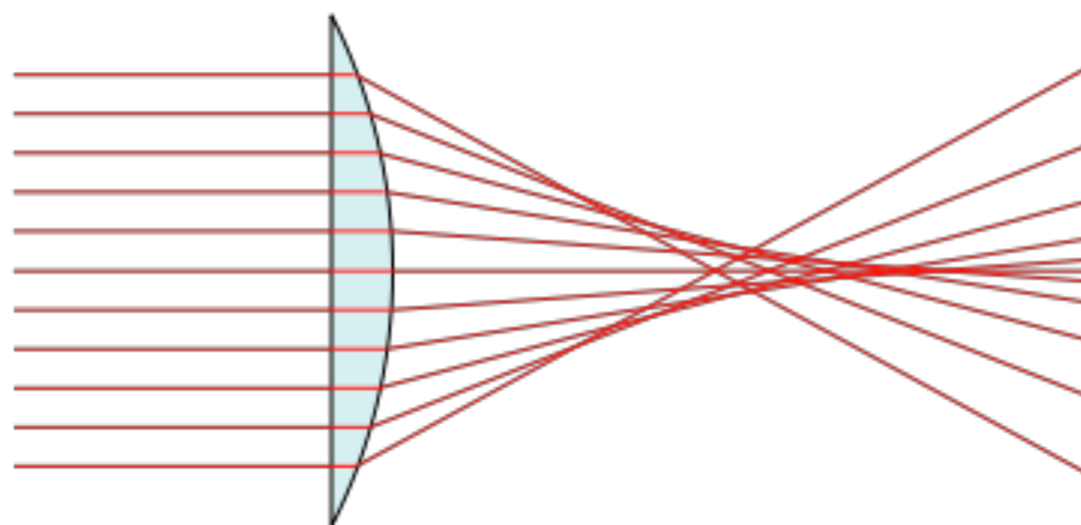
- Distorting incident light signals to another form of light signals



Ideal lens



Spherical aberration



“Desired” Distortion

Shallow depth of field



Vignetting



Motion Blur



“Desired” Distortion

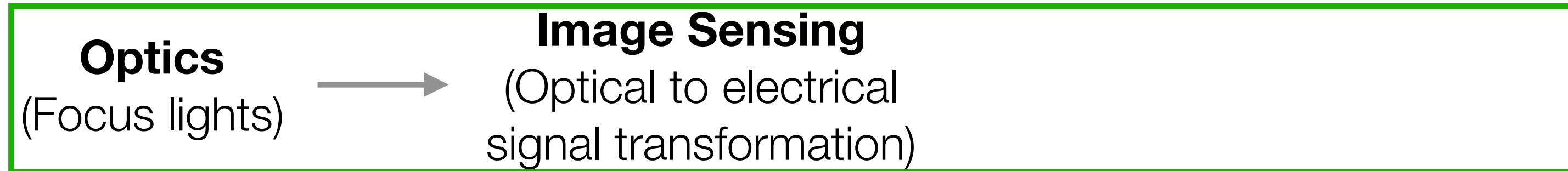
We even intentionally create lenses that do not mimic our eyes.



Digital Camera System

Introduce
"imperfections"

Physical Scene
(Objects, lights)



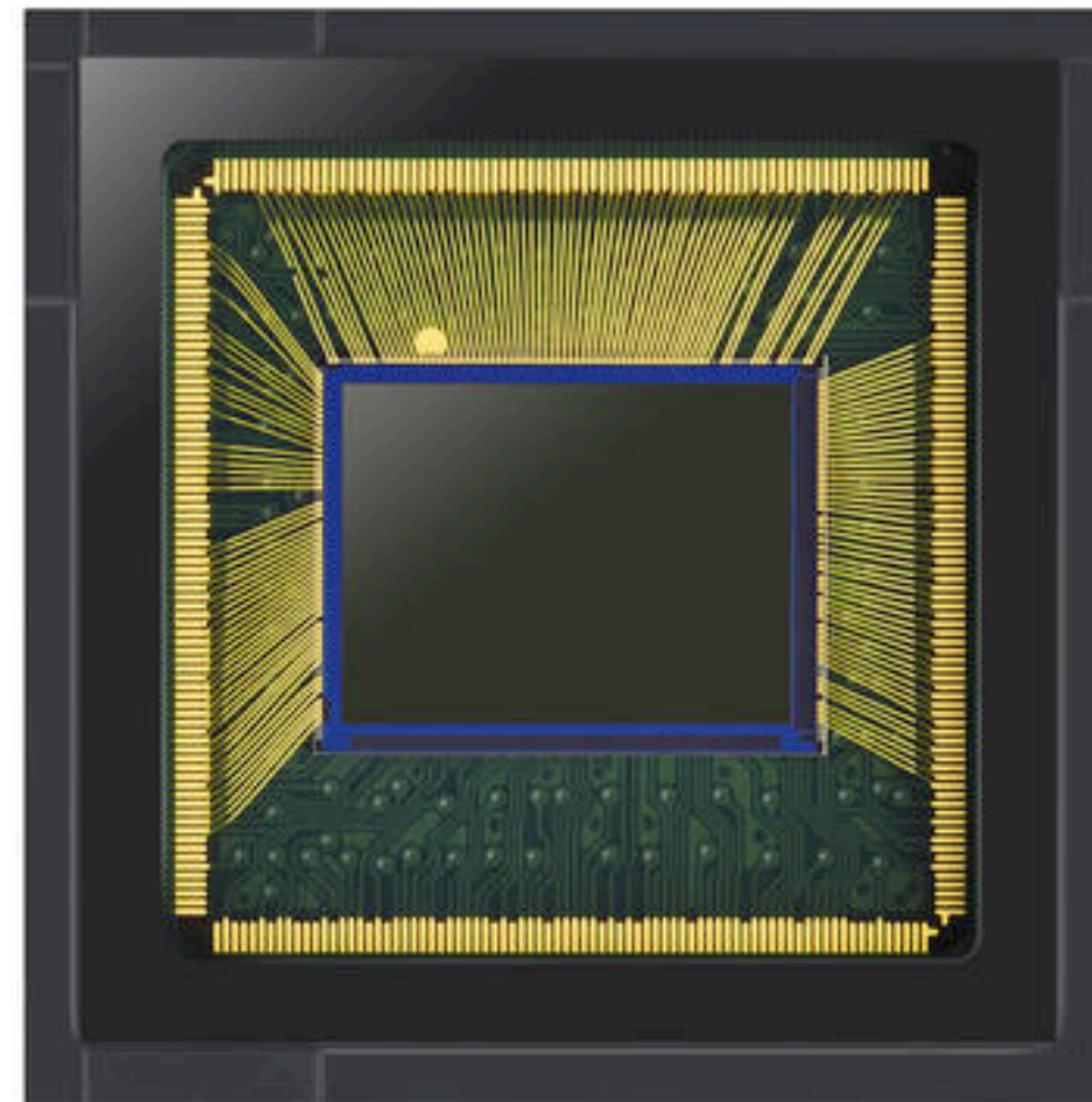
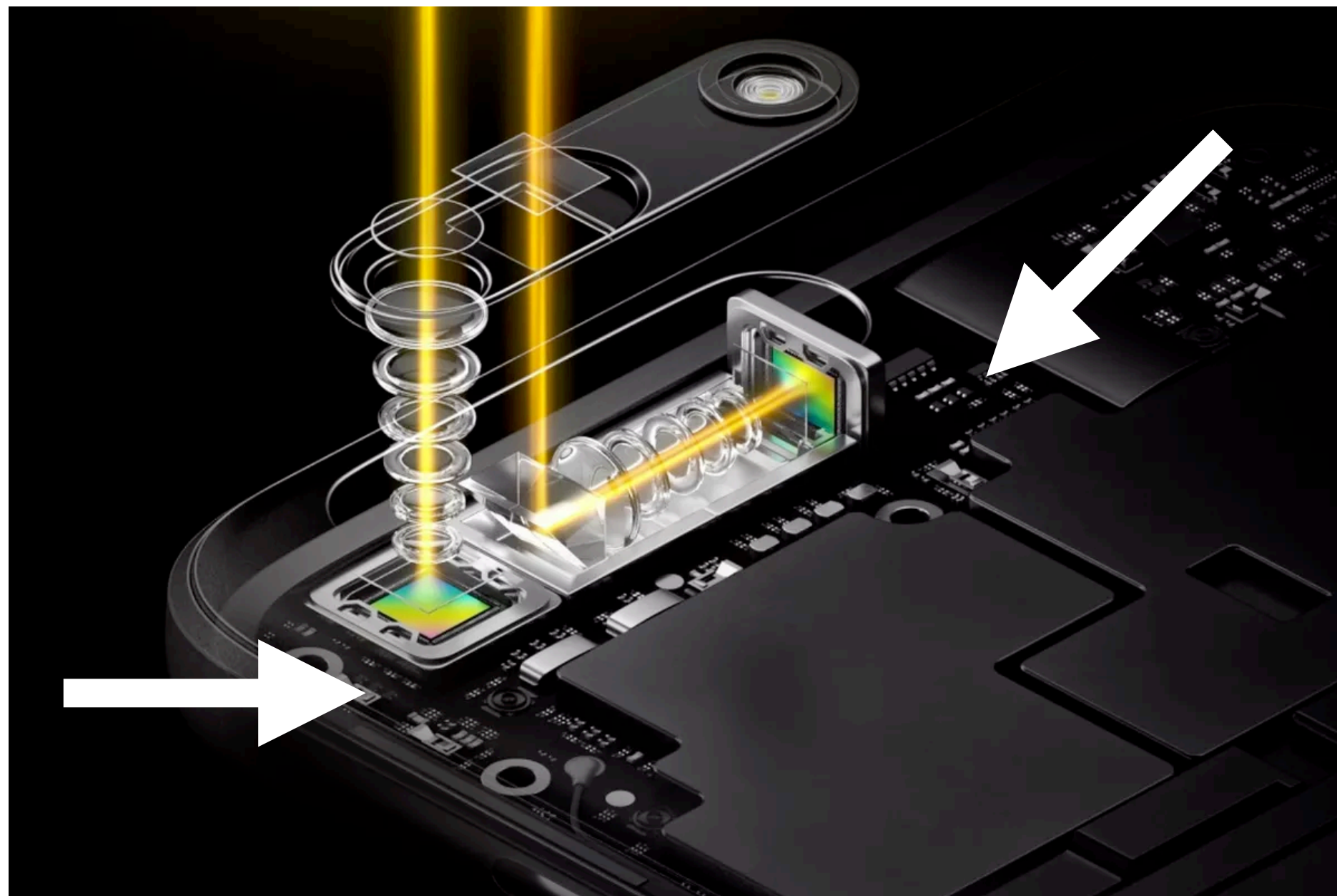
Display
(Generating lights)



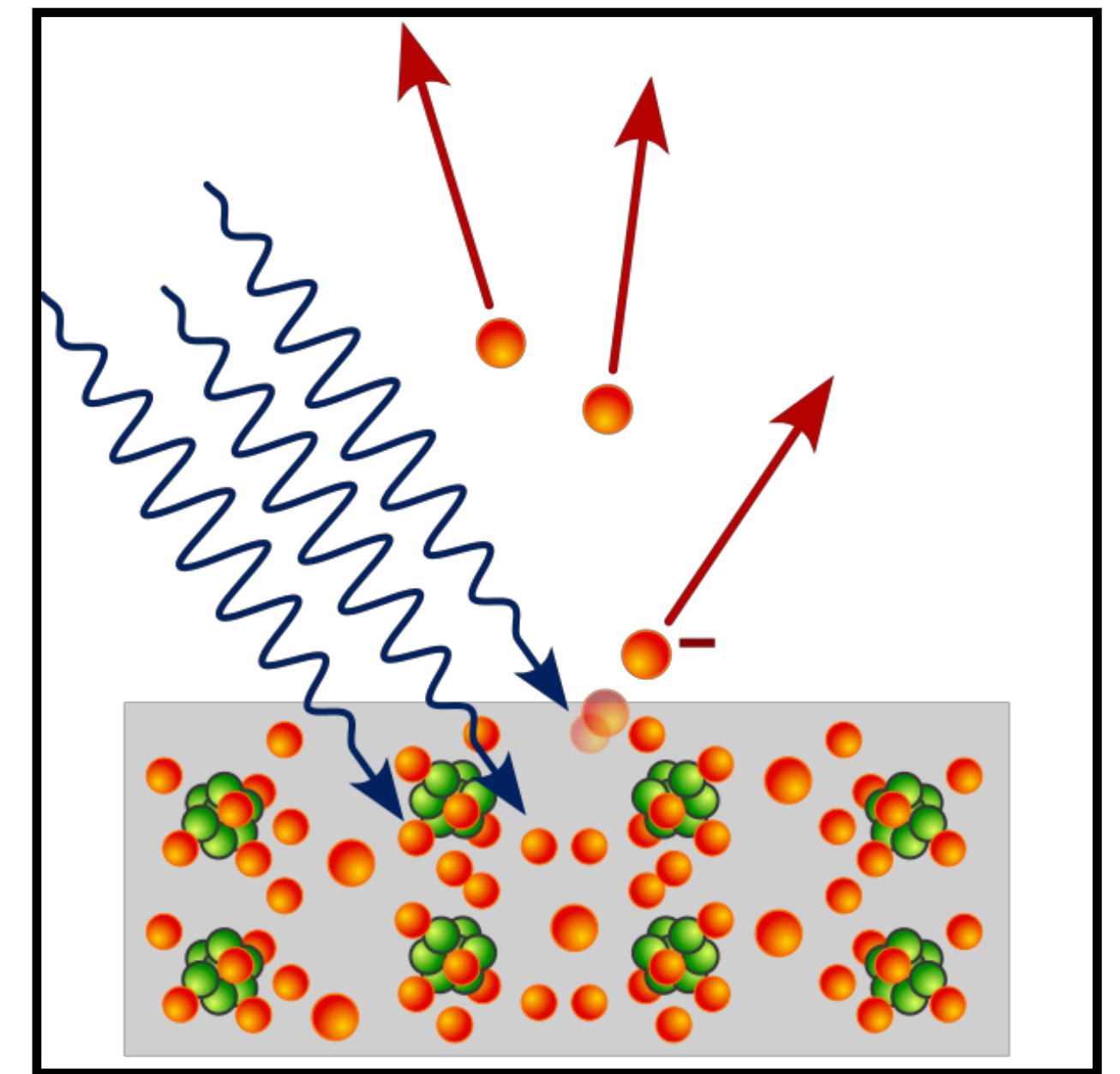
**Human Visual
System**
(Eye, retina, visual
cortex)

Image Sensing

Converts optical signals (lights) to electrical signals (pixels)

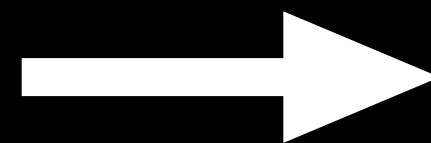


Photoelectric effect



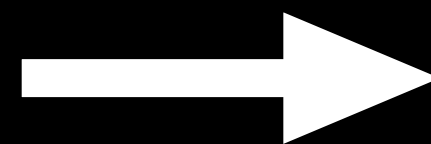
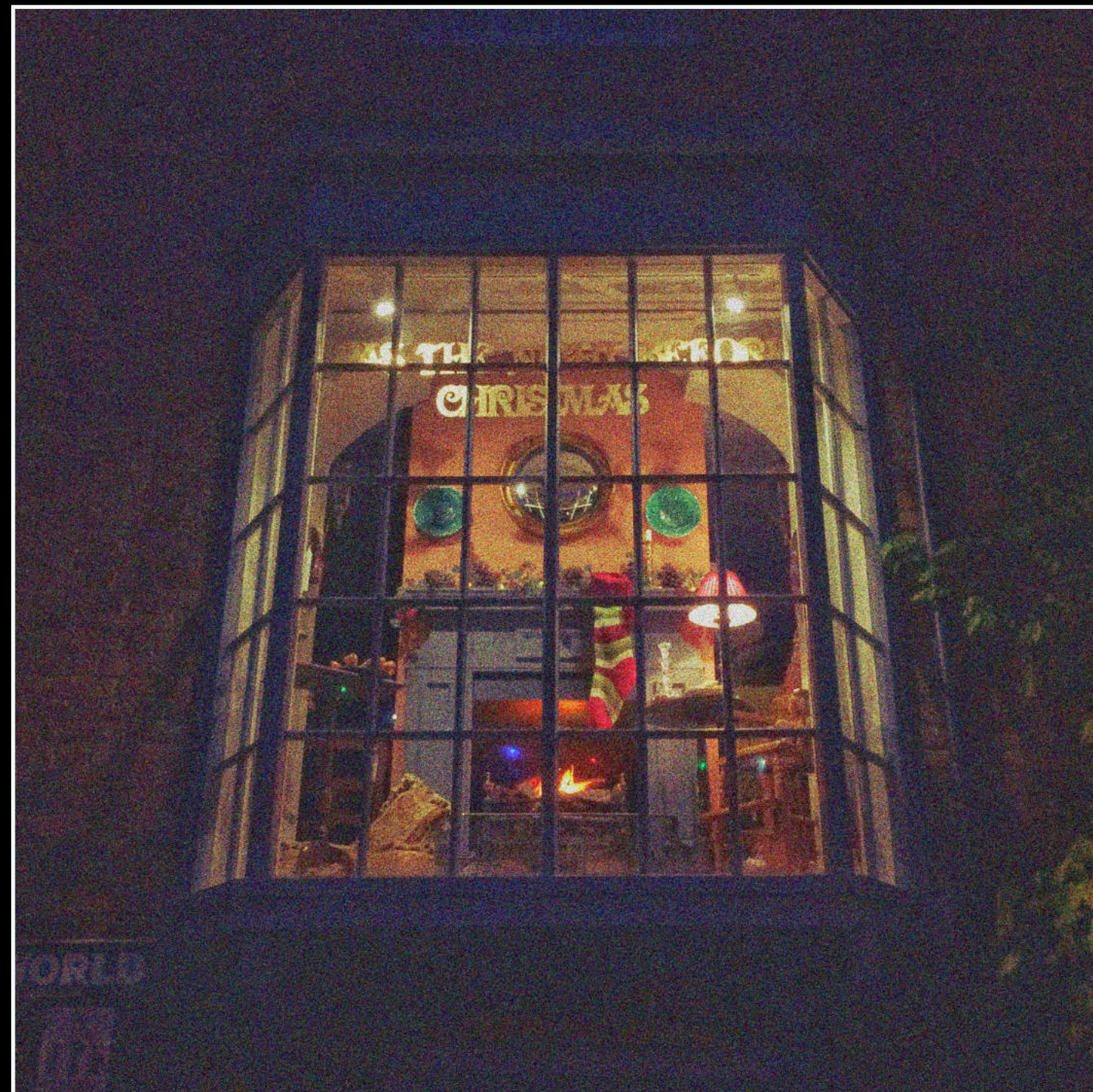
Convert Optical Signals to Electrical Signals

Introduces “imperfections” too, which, unlike optical distortions, are almost always unwanted.

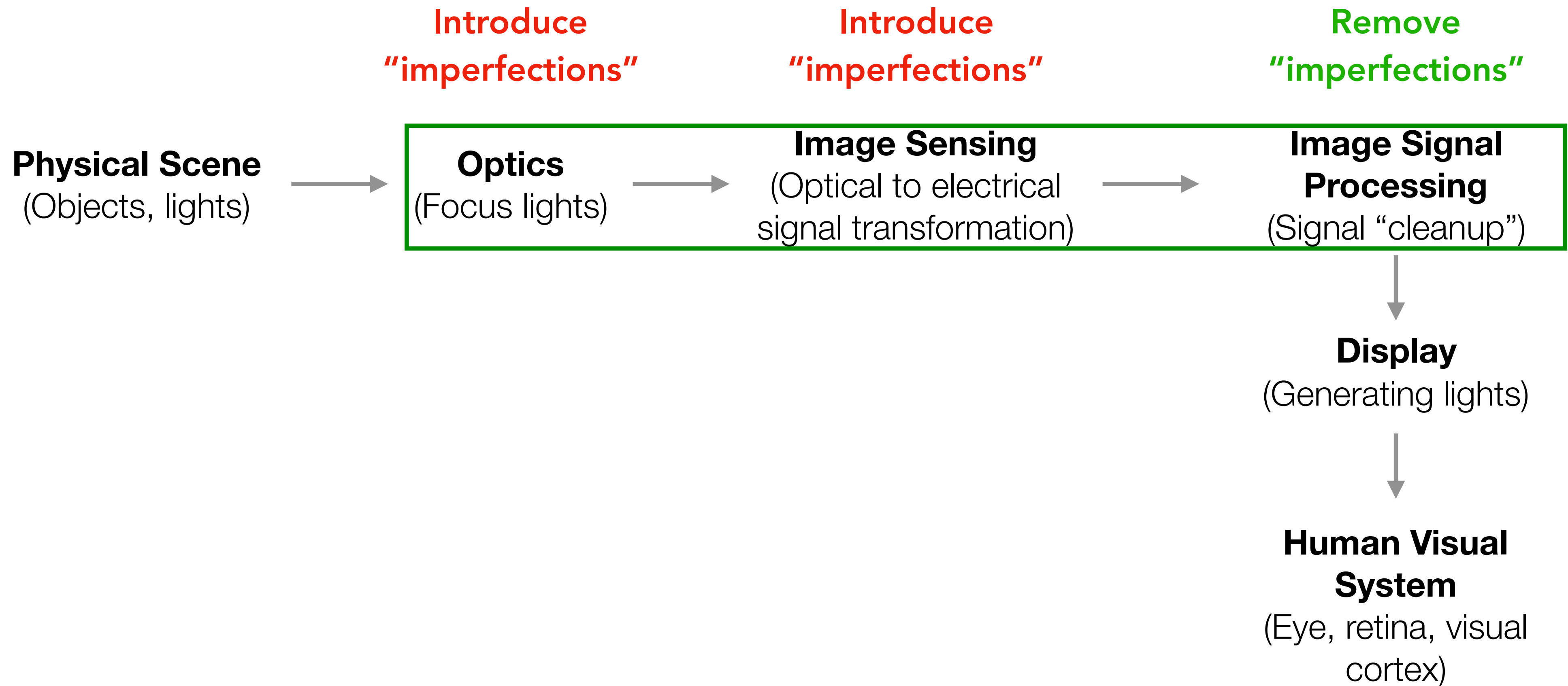


Convert Optical Signals to Electrical Signals

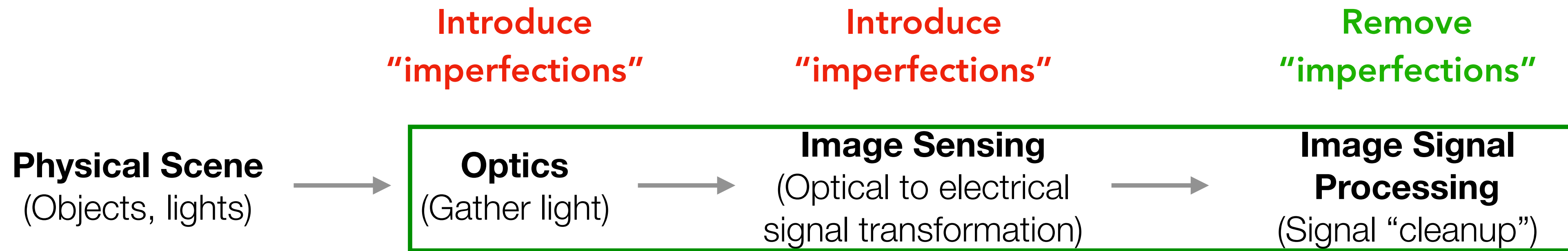
Introduces “imperfections” too, which, unlike optical distortions, are almost always unwanted.



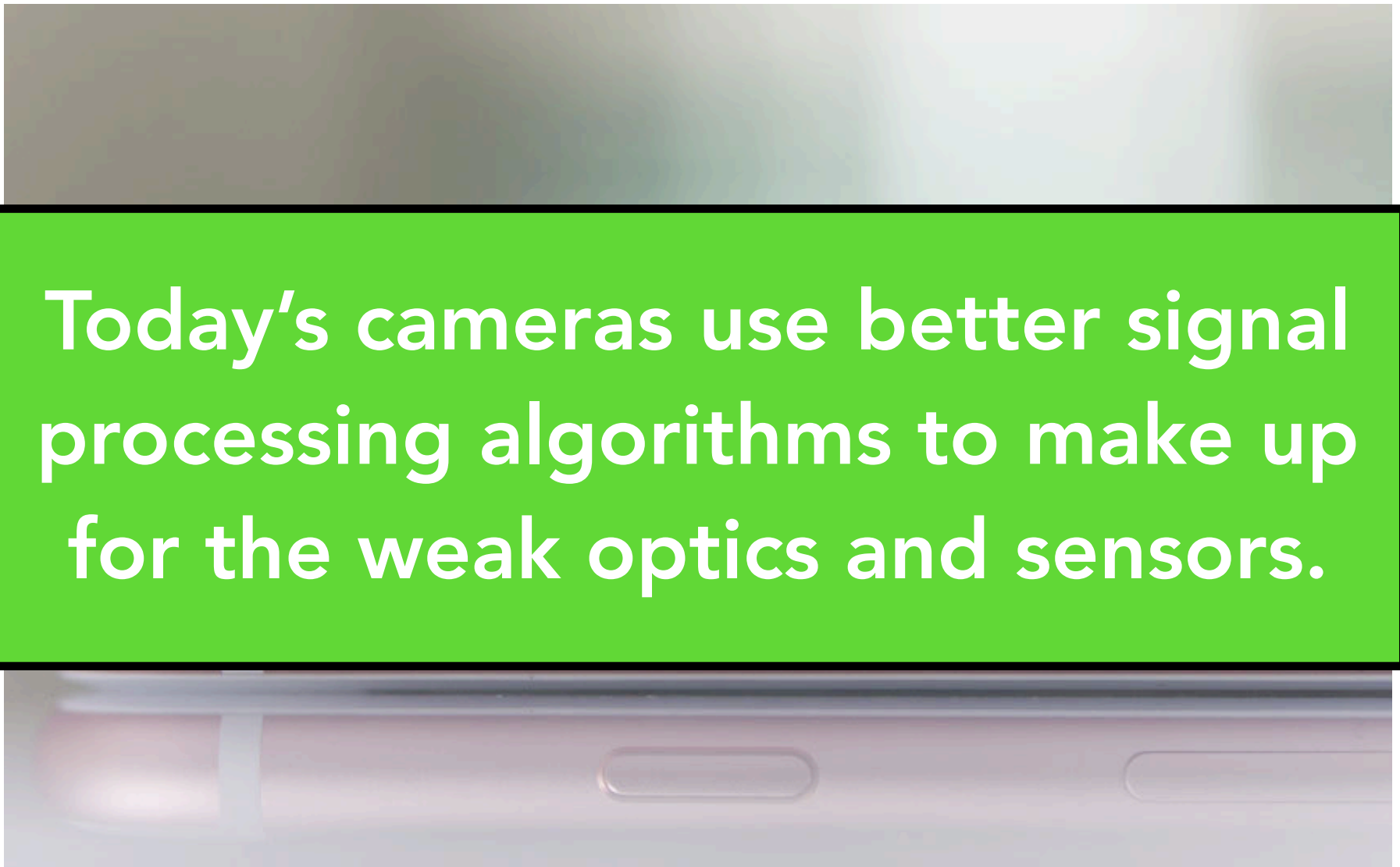
Digital Camera System



Digital Camera System



Conventional cameras use complex and expensive lenses and sensors to minimize imperfections.



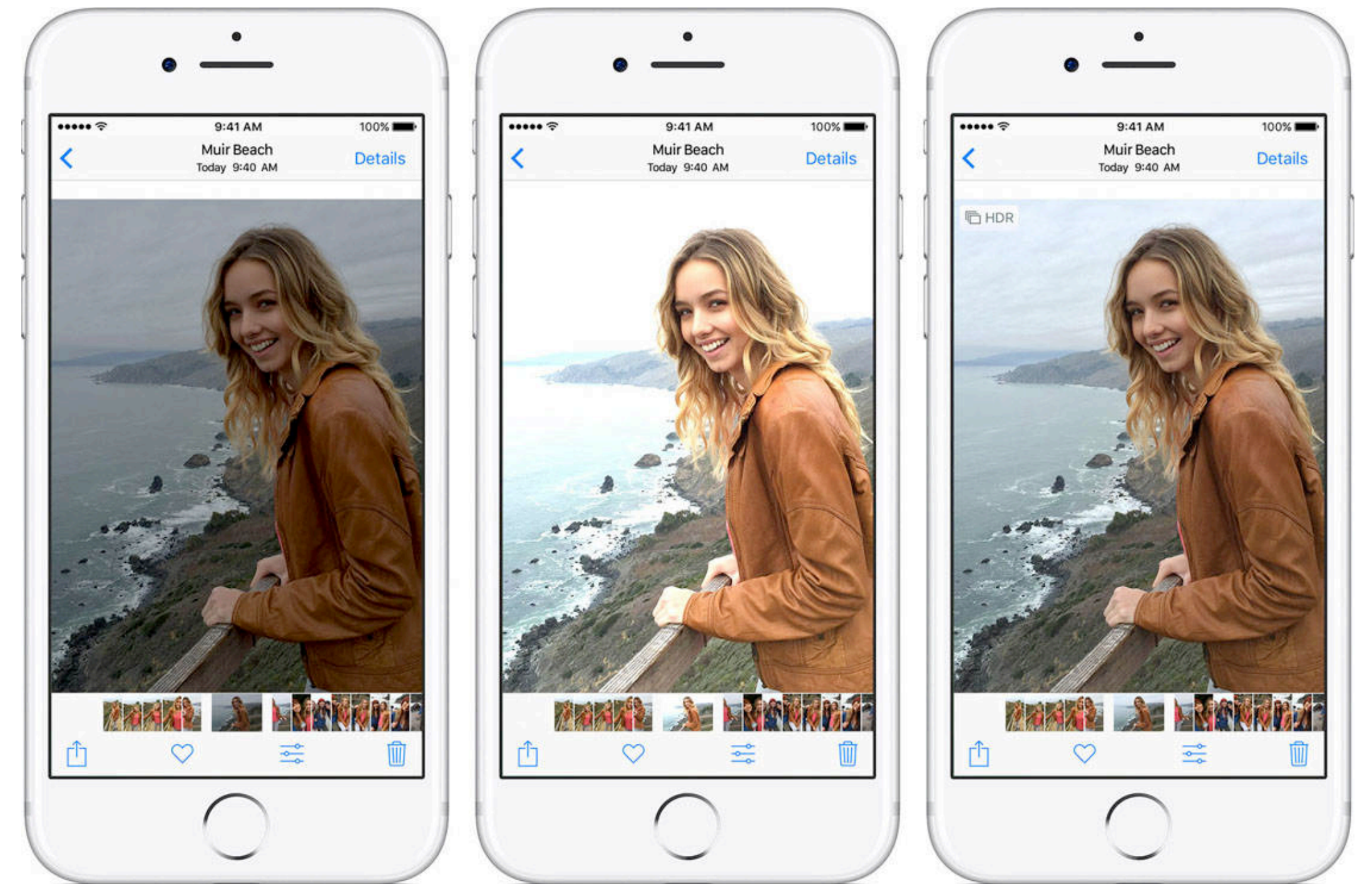
Today's cameras use better signal processing algorithms to make up for the weak optics and sensors.

Computational Photography

Use computational algorithms to simplify optics and sensors



Portrait mode: simulate a large aperture



HDR mode: simulate a high dynamic range sensor

Computational Photography

Jointly design computational algorithms with optics/sensors to overcome limitations that conventional systems face











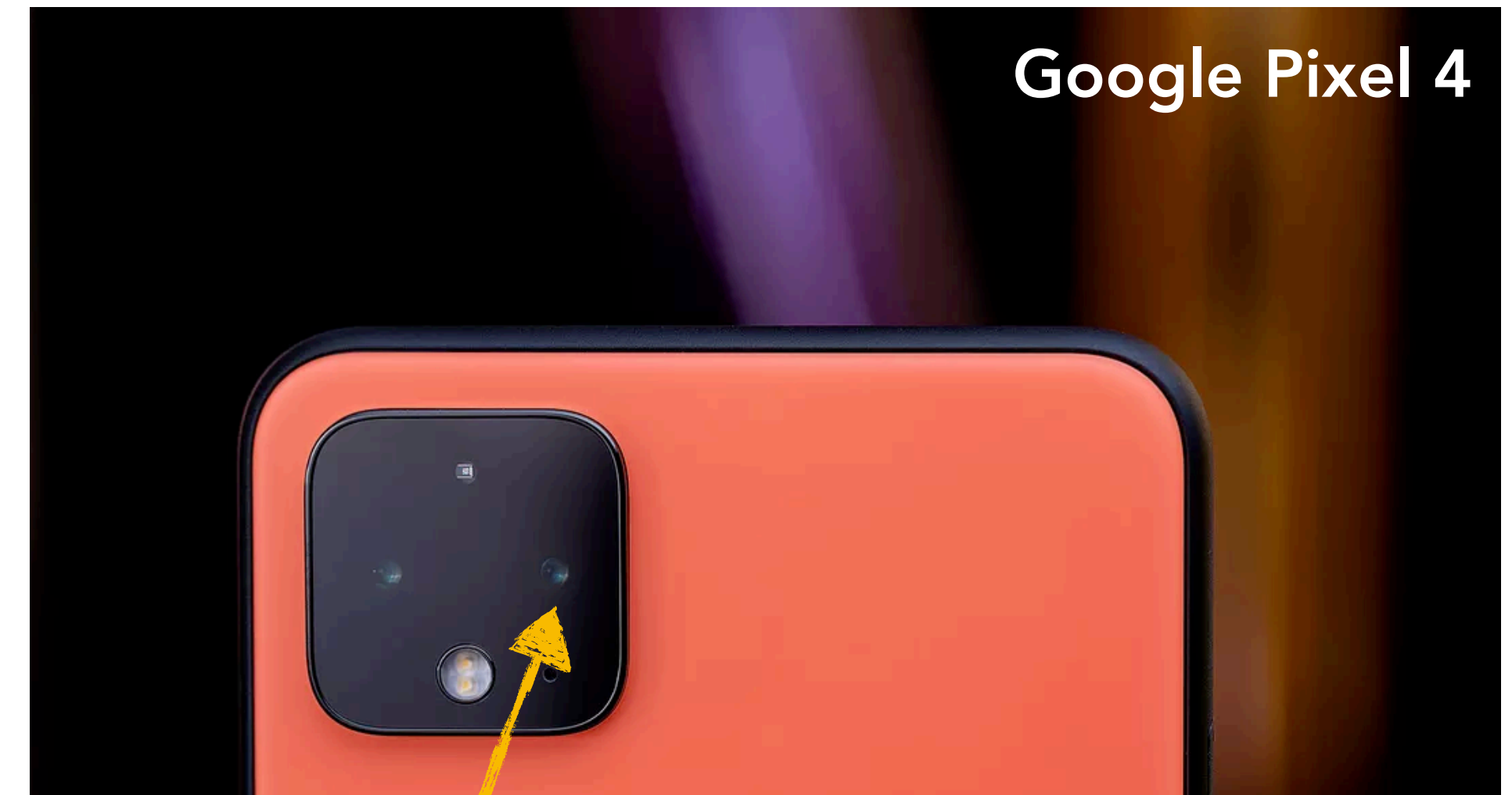




Traditional Telephoto (Long-Focus) Lens



Telephoto (Long-Focus) “Lens” in Smartphones



Telephoto lens ($f = 48\text{ mm}$) + computational photography algorithm for super resolution

Wide Field-of-View

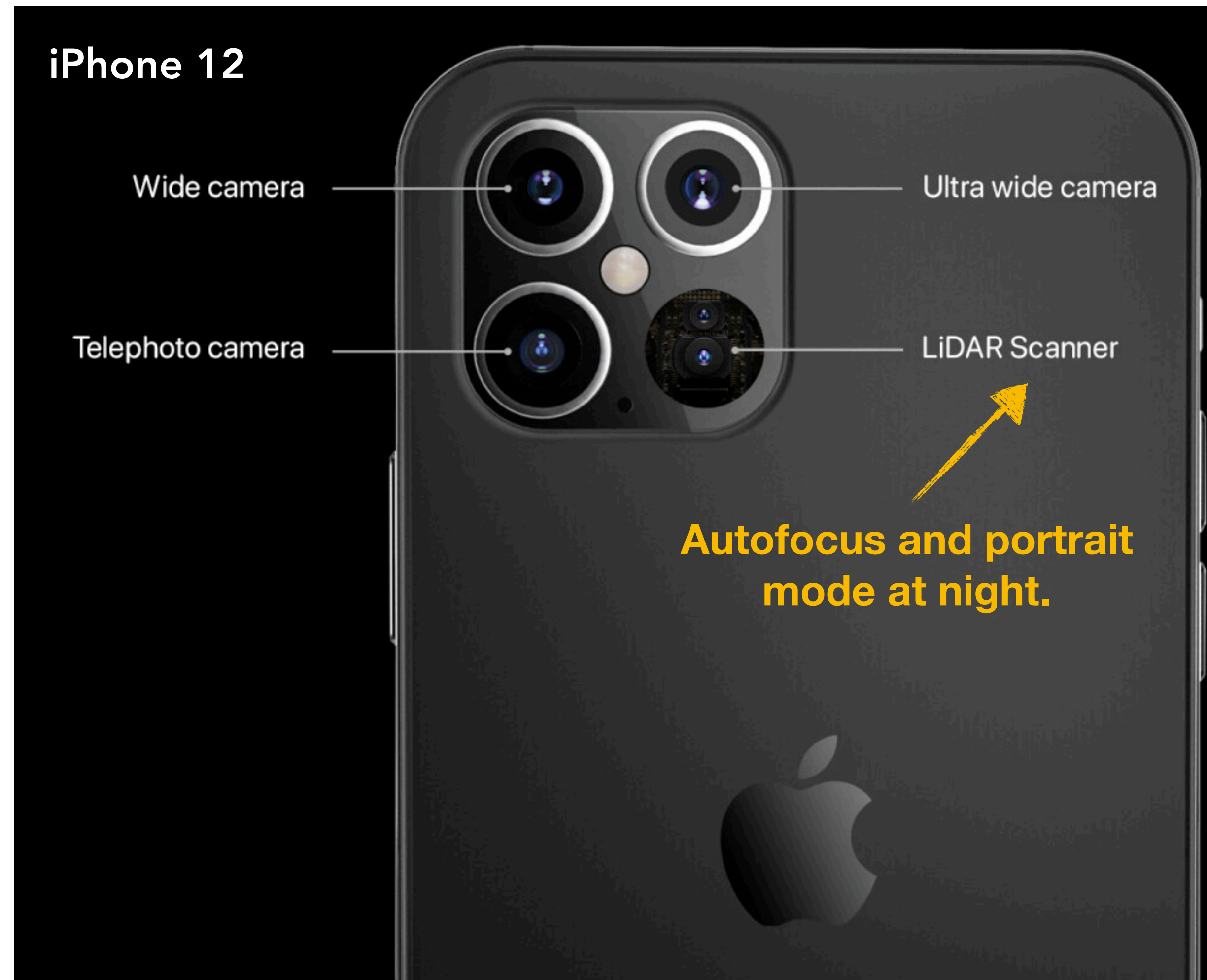




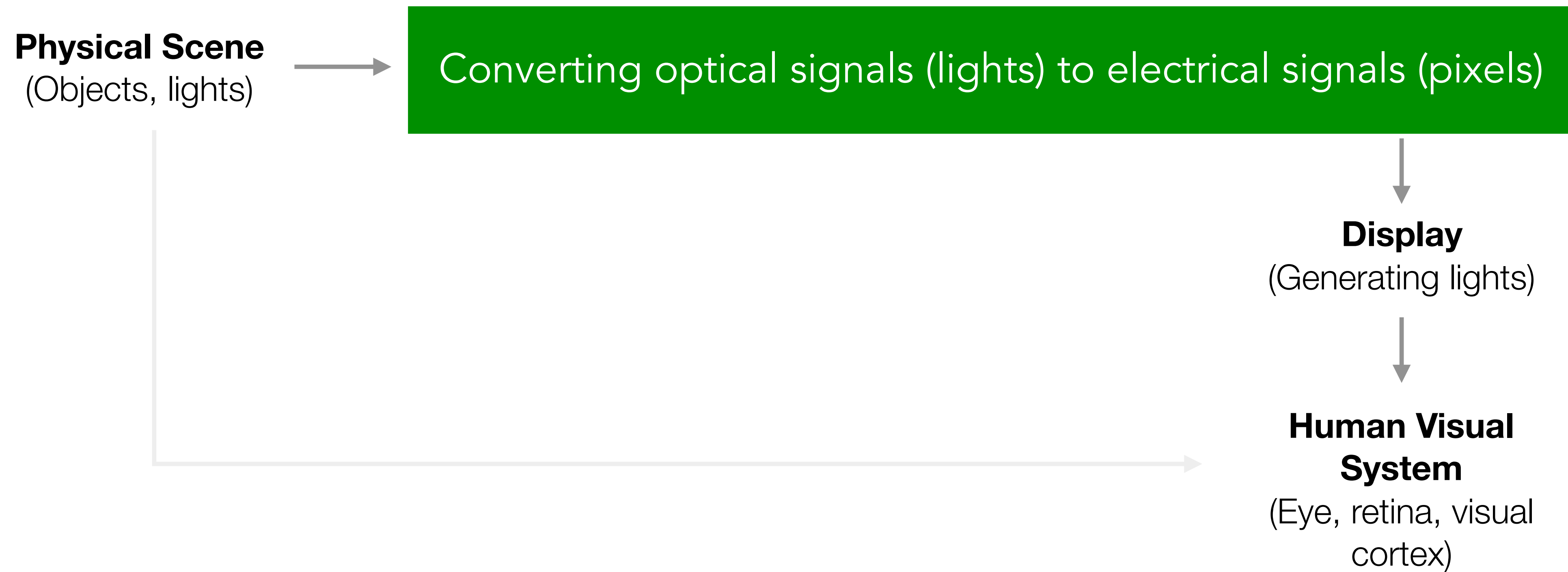
Move iPhone continuously when taking a Panorama.

PHOTO SQUARE **PANO**

Cameras in Modern Smartphones



Digital Camera System



Photorealistic Rendering



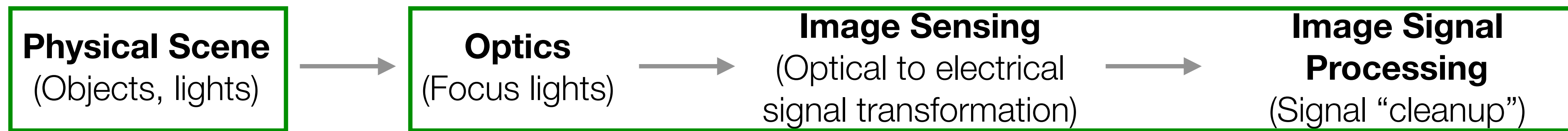
Photorealistic Rendering



Real-Time Photorealistic Rendering (e.g., Gaming)



Graphics



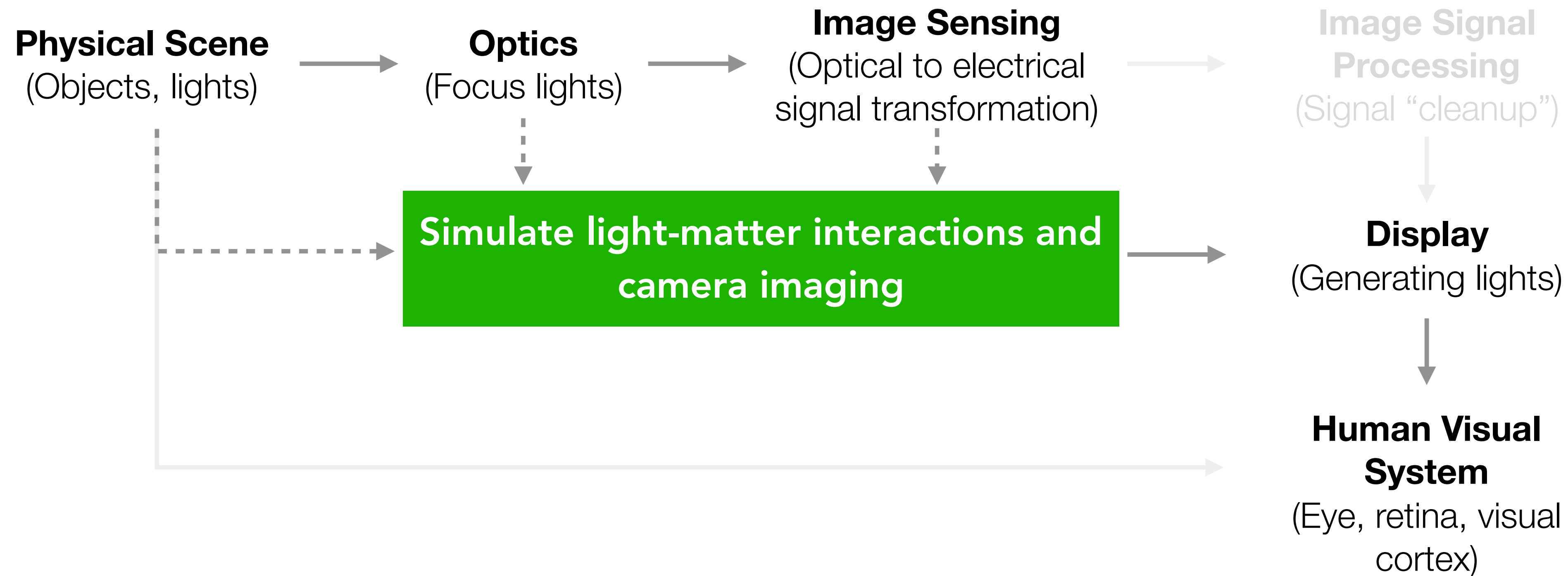
Why do those images look “real” to you?

Photorealism: a rendered image that looks like taken by a camera

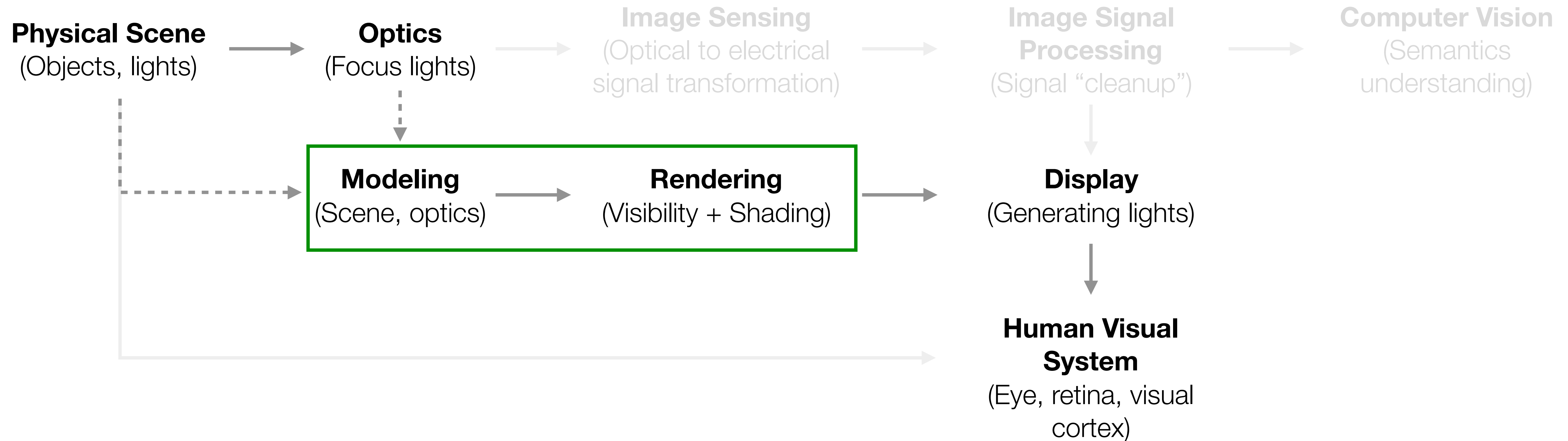
Photorealistic rendering is a simulation of:

- Light-matter interactions in the physical world
- Camera imaging pipeline (can “cheat”)

Graphics



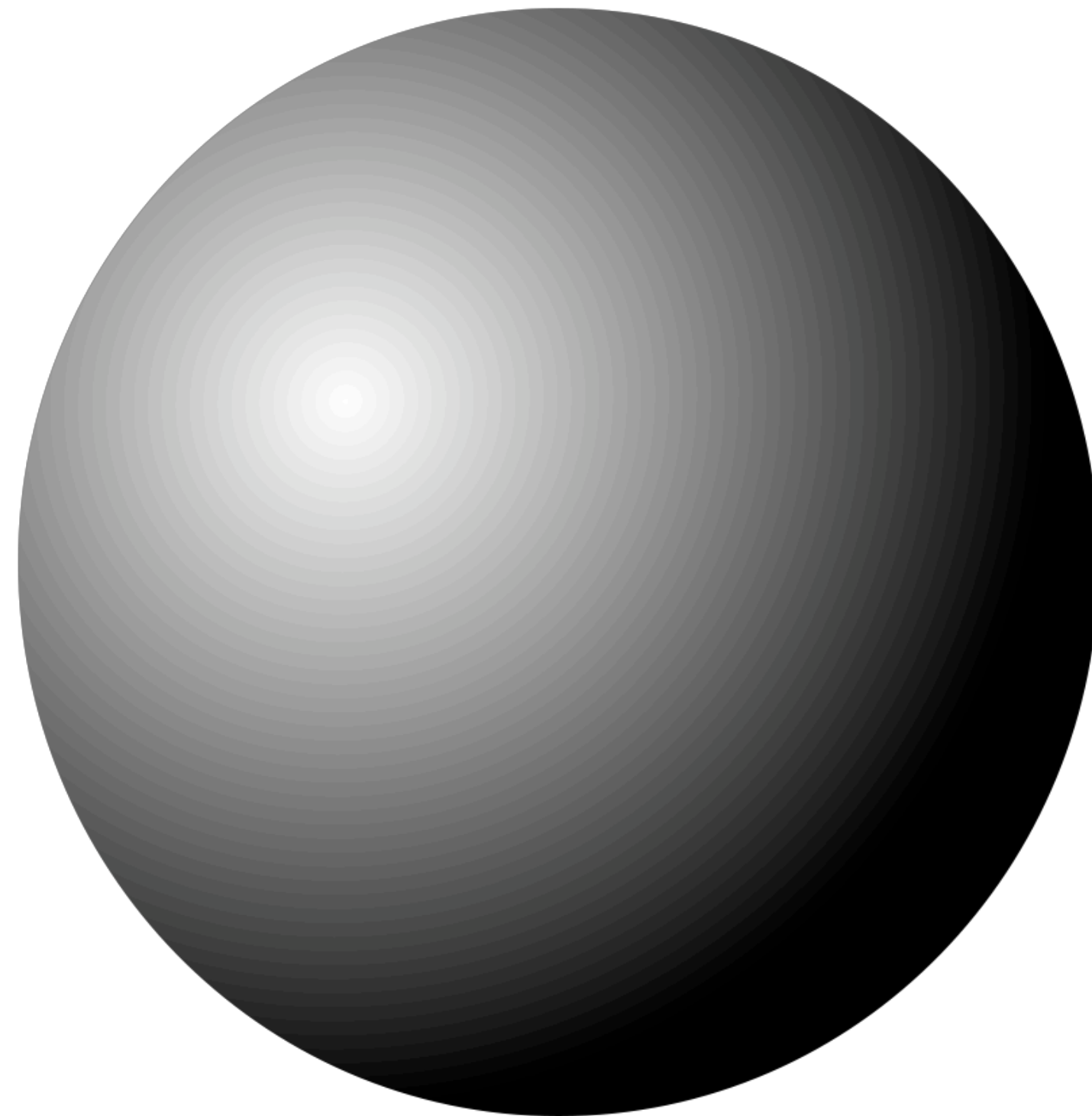
Graphics



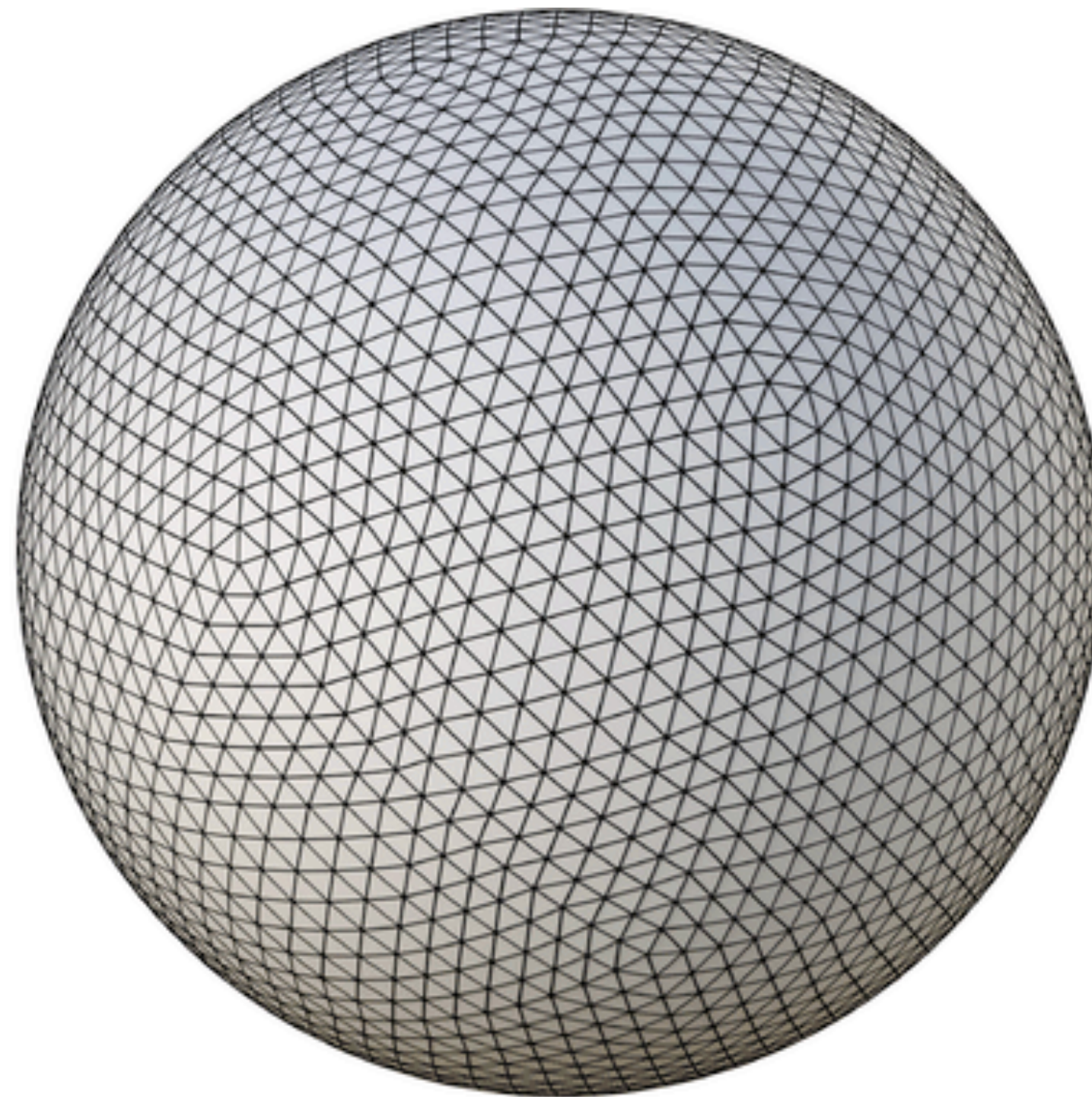
3D Modeling

Parametric surface

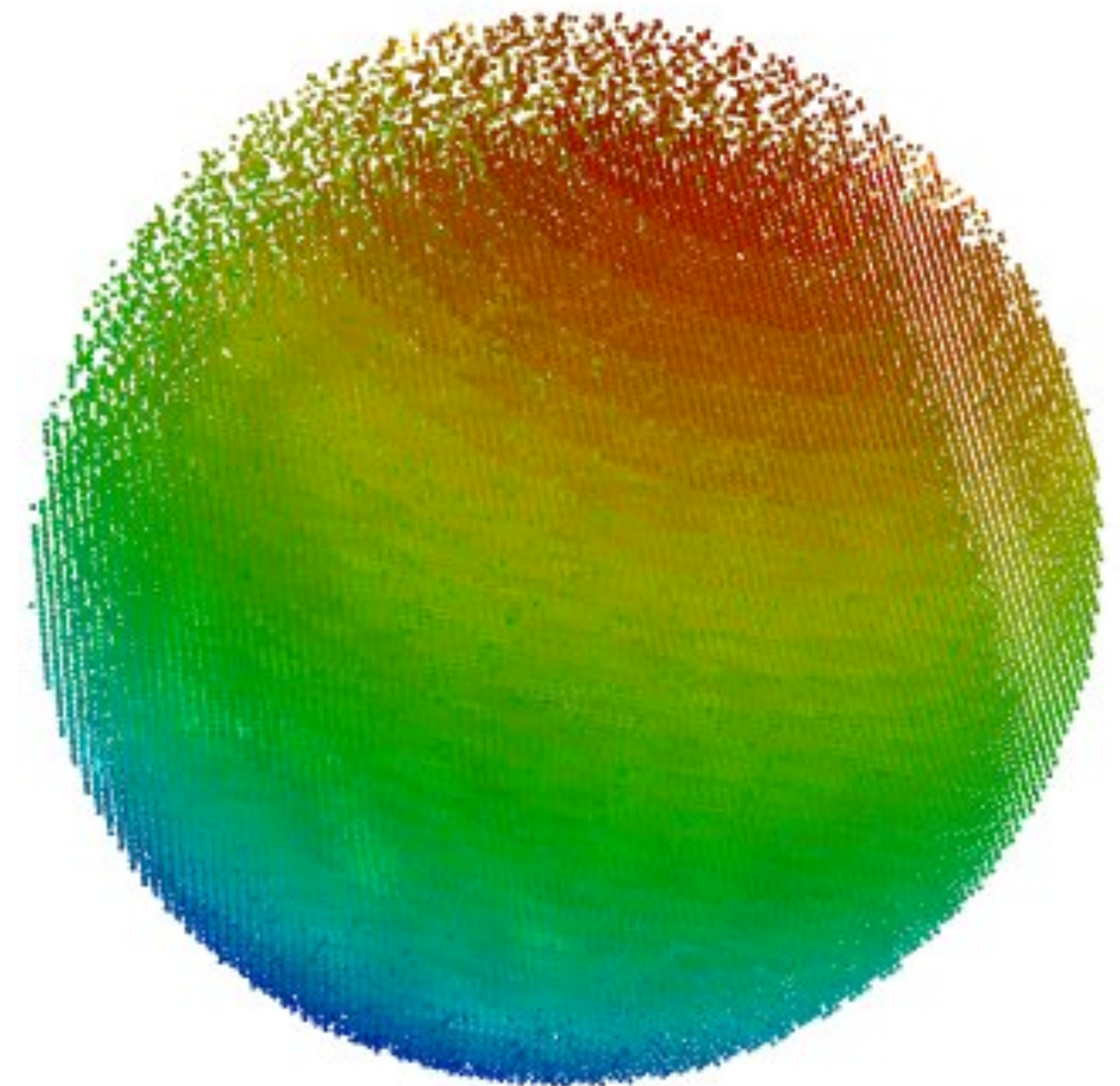
$$x^2 + y^2 + z^2 = R^2$$



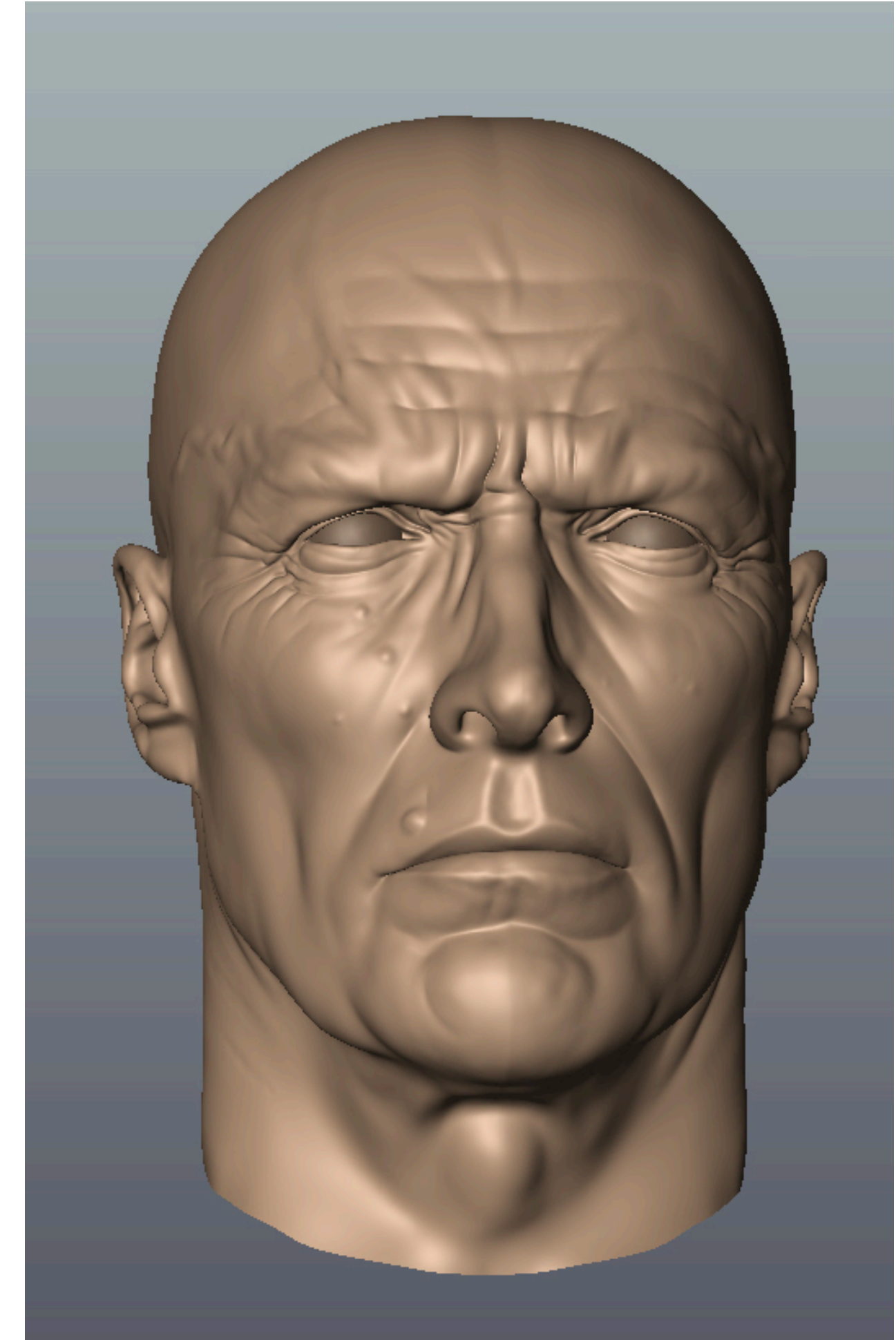
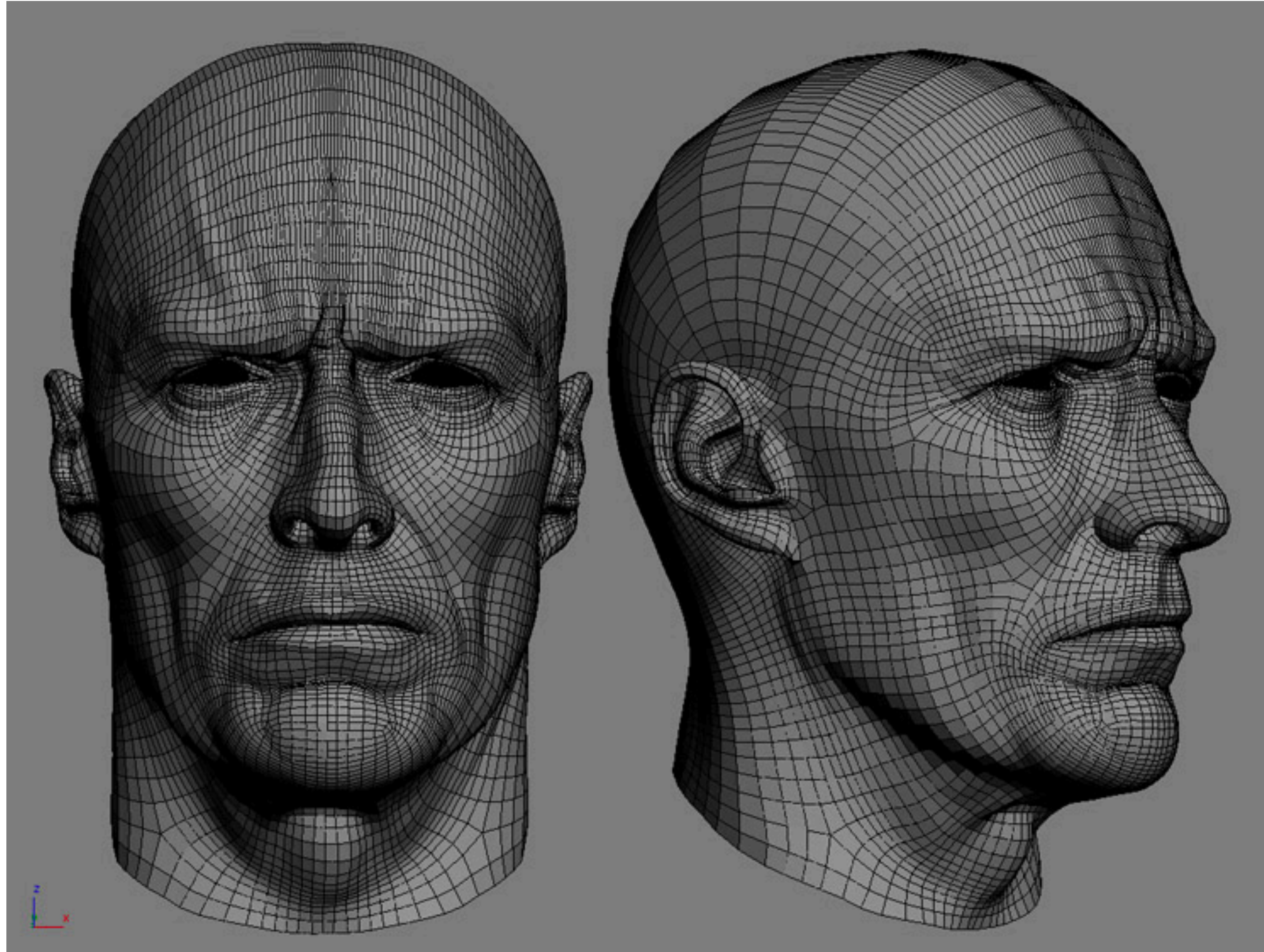
Polygon mesh



Point cloud



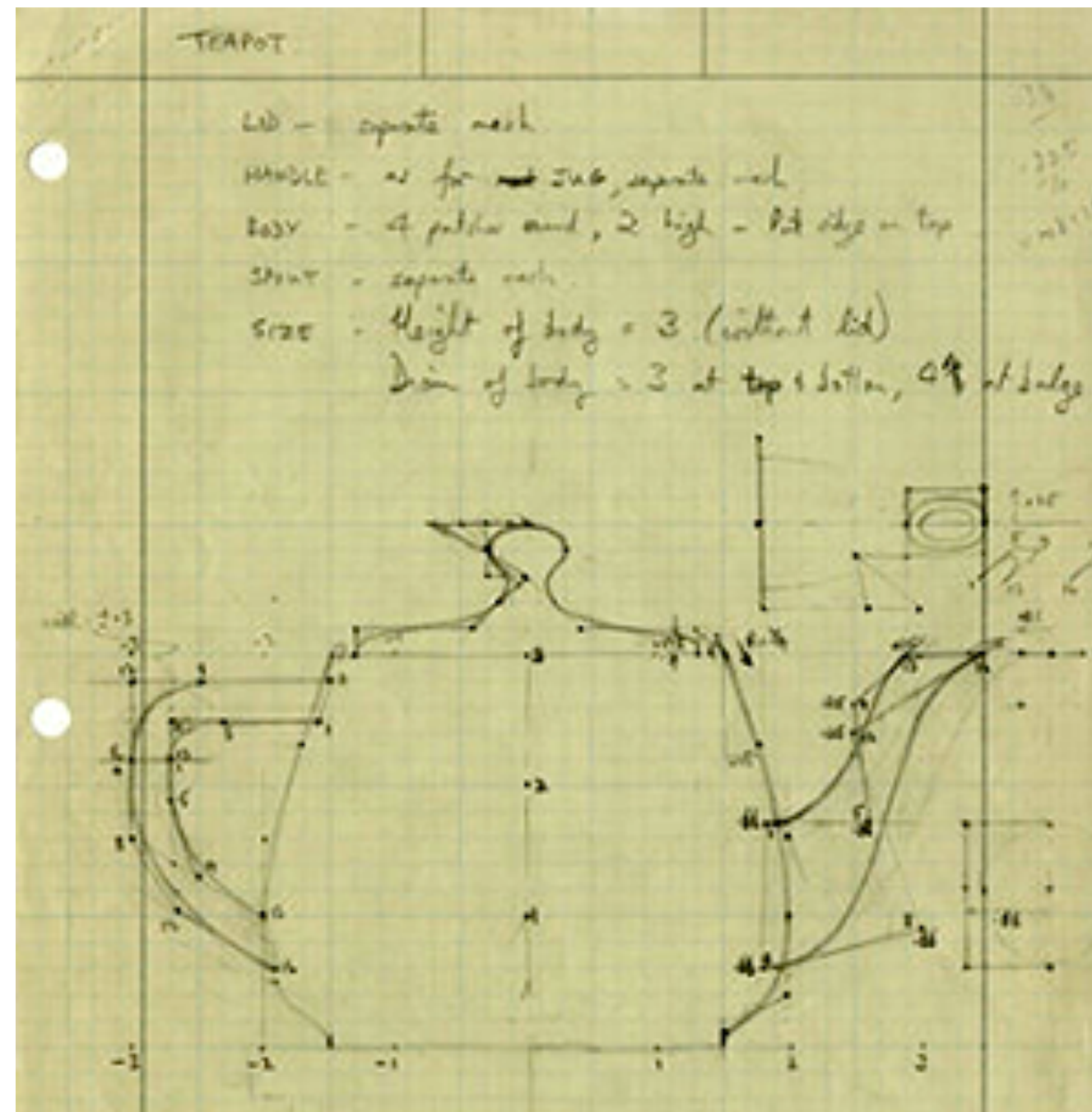
Modeling: Mesh



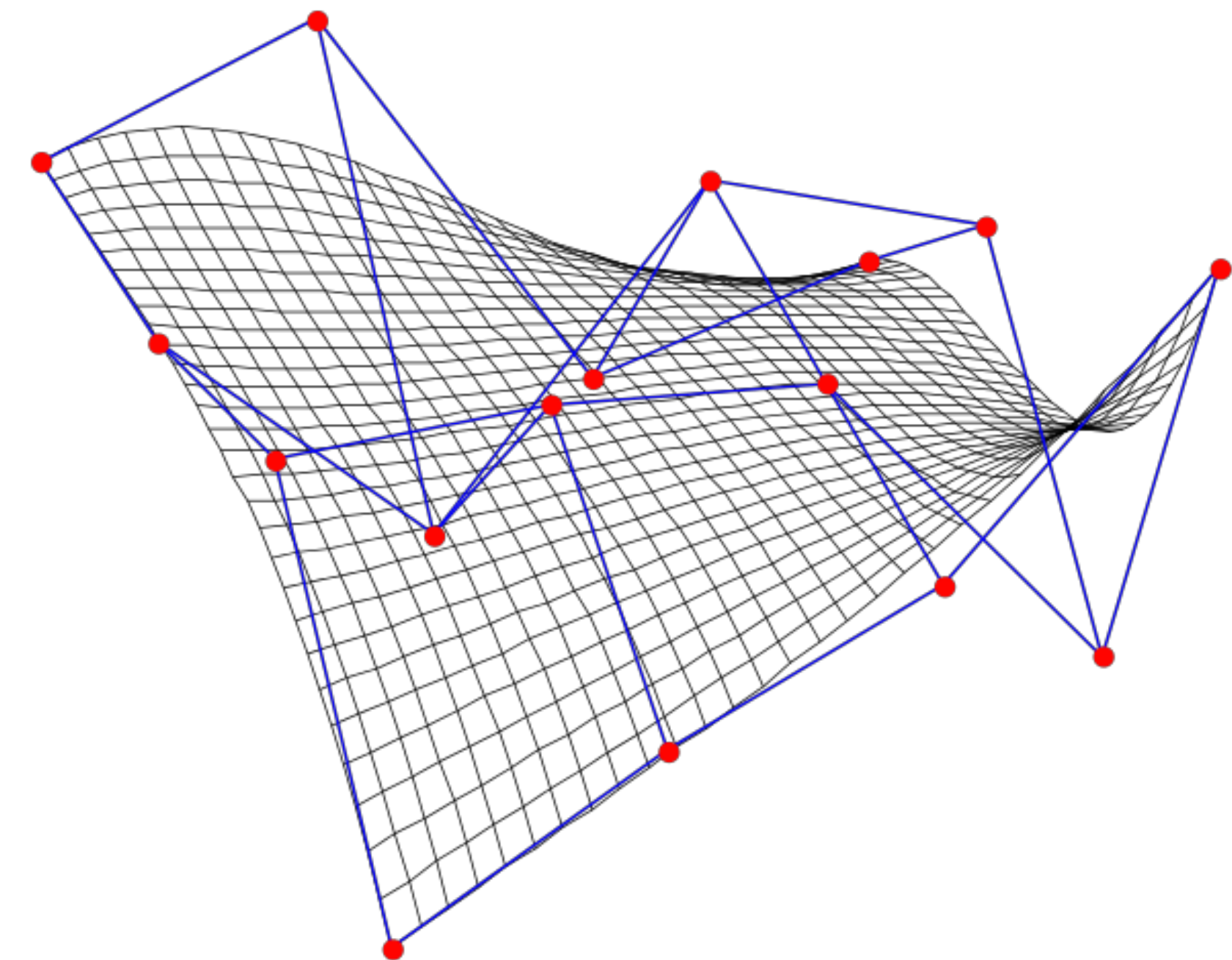
Modeling: Parametric Surface



Utah teapot

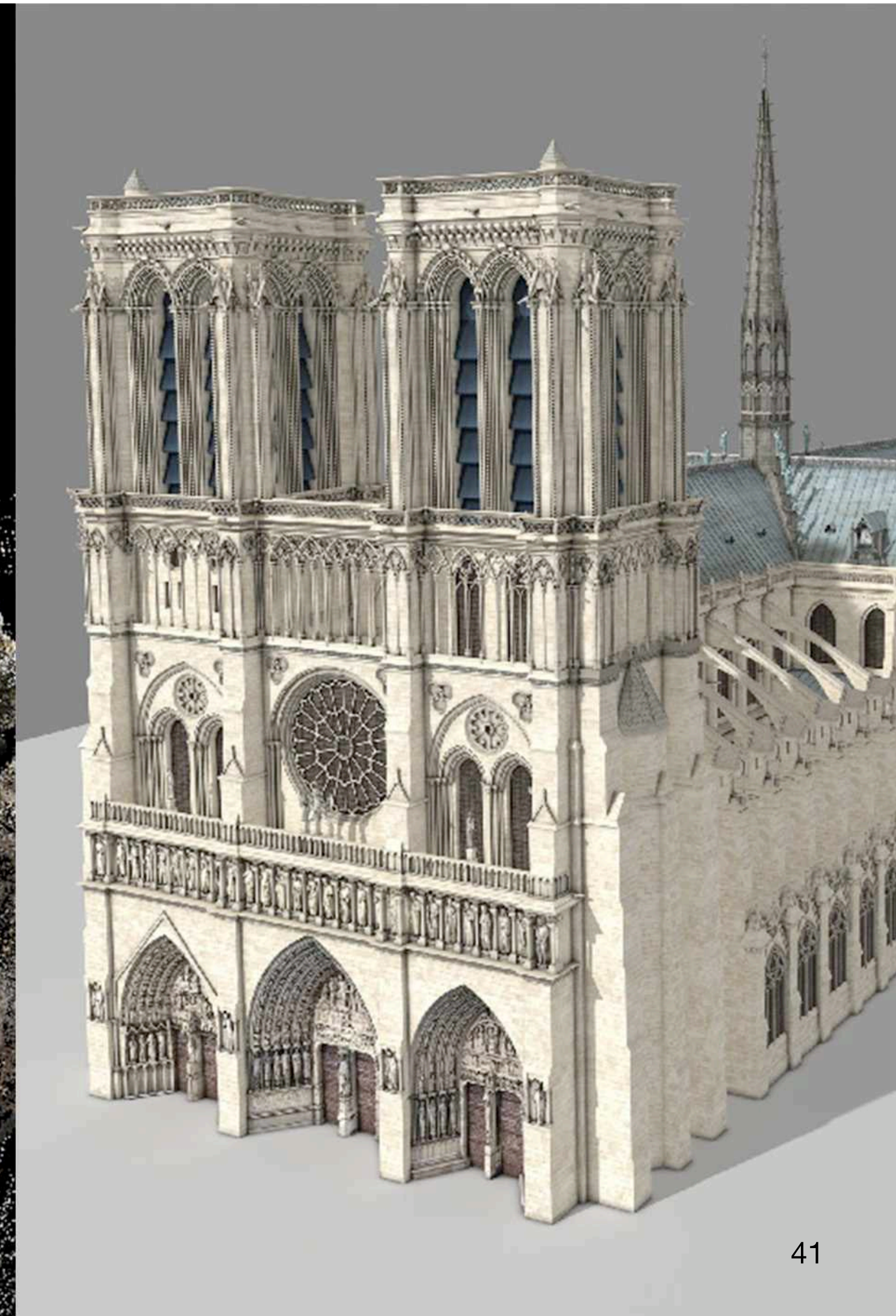
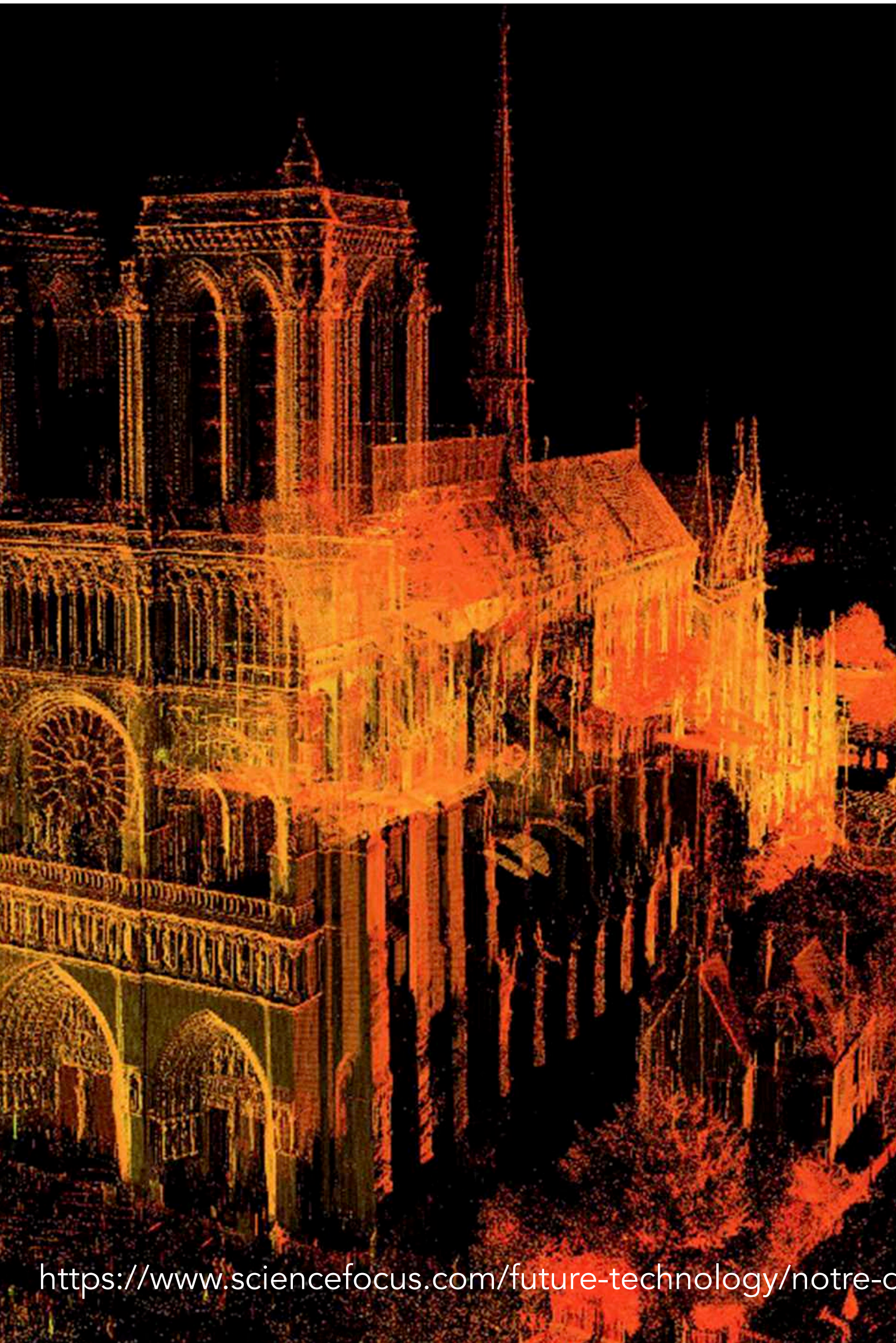


1975 Newell's drawing



Bezier surface

Modeling: Point Cloud



Point Cloud Acquisition



Laser scanner



From Mike Jarvis, Prof. @ History Dept. Scanning Elmina Castle, a UNESCO World Heritage Site at Ghana.

Point Cloud Acquisition

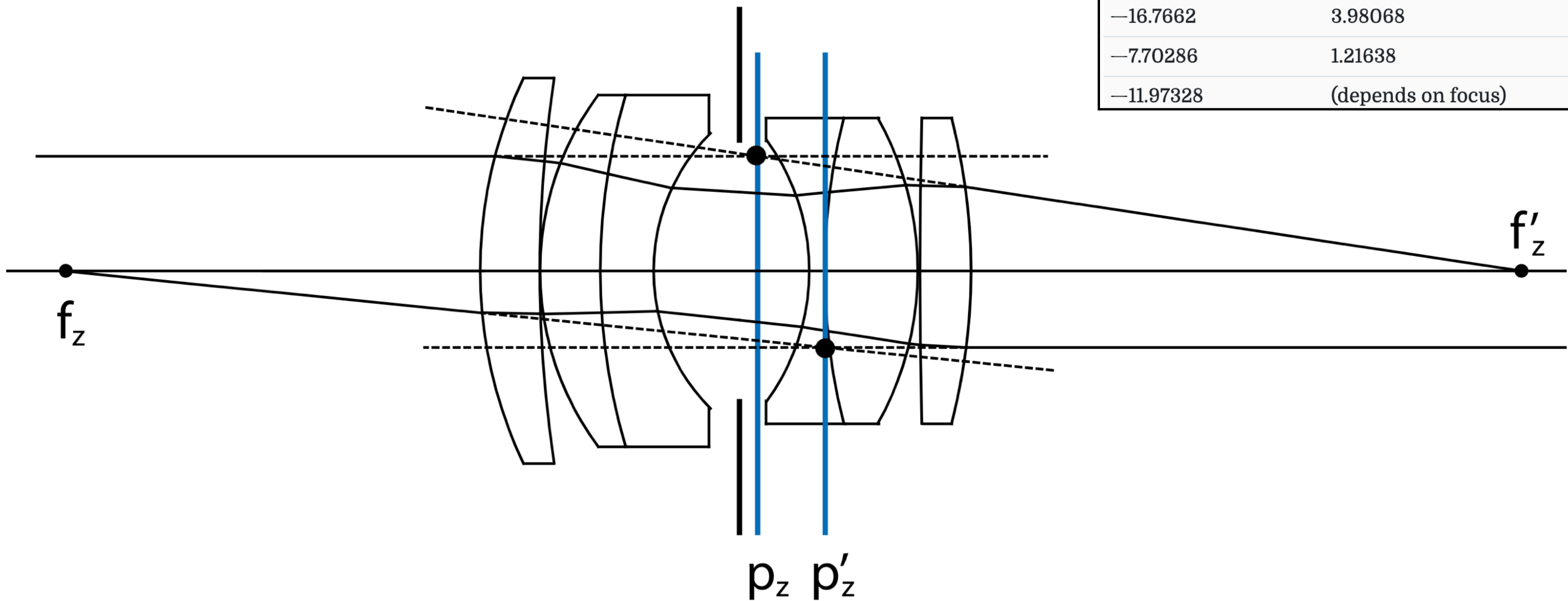
Velodyne LiDAR (Light
Detection and Ranging)

Uber's self-driving car equipped with LiDARs

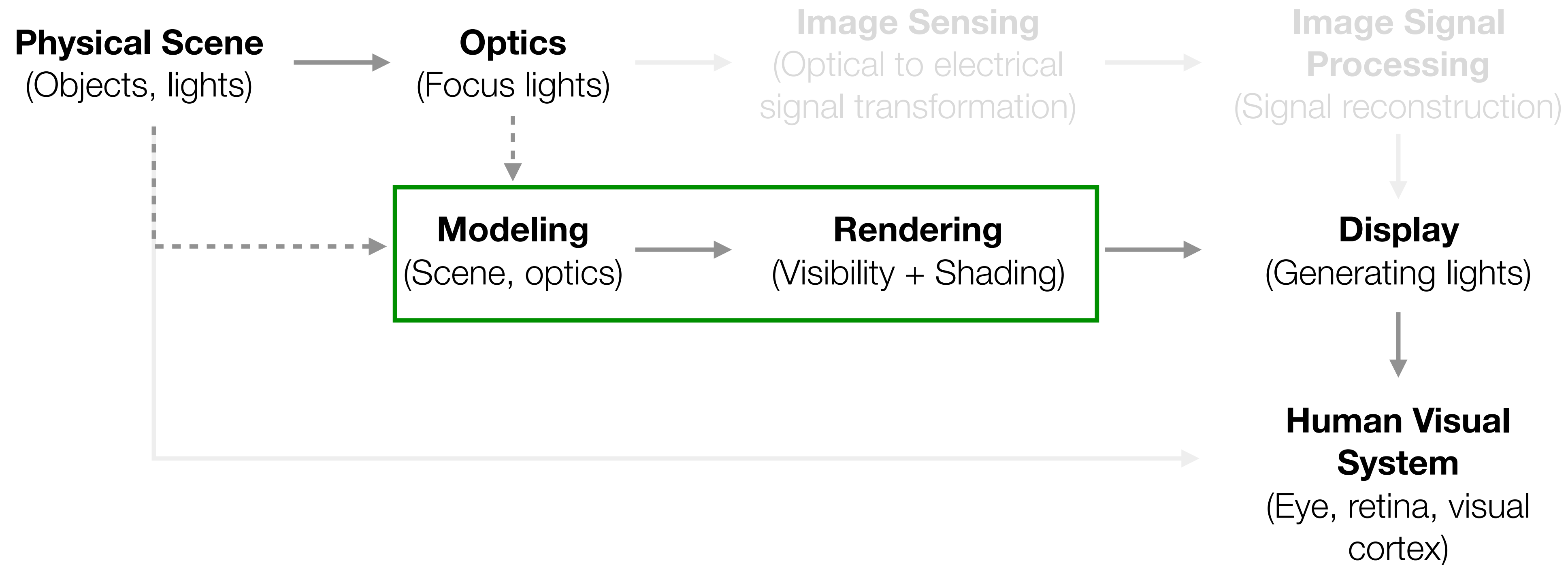


Modeling Optics

Curvature Radius	Thickness	Index of Refraction	Aperture Diameter
35.98738	1.21638	1.54	23.716
11.69718	9.9957	1	17.996
13.08714	5.12622	1.772	12.364
−22.63294	1.76924	1.617	9.812
71.05802	0.8184	1	9.152
0	2.27766	0	8.756
−9.58584	2.43254	1.617	8.184
−11.28864	0.11506	1	9.152
−166.7765	3.09606	1.713	10.648
−7.5911	1.32682	1.805	11.44
−16.7662	3.98068	1	12.276
−7.70286	1.21638	1.617	13.42
−11.97328	(depends on focus)	1	17.996



Graphics

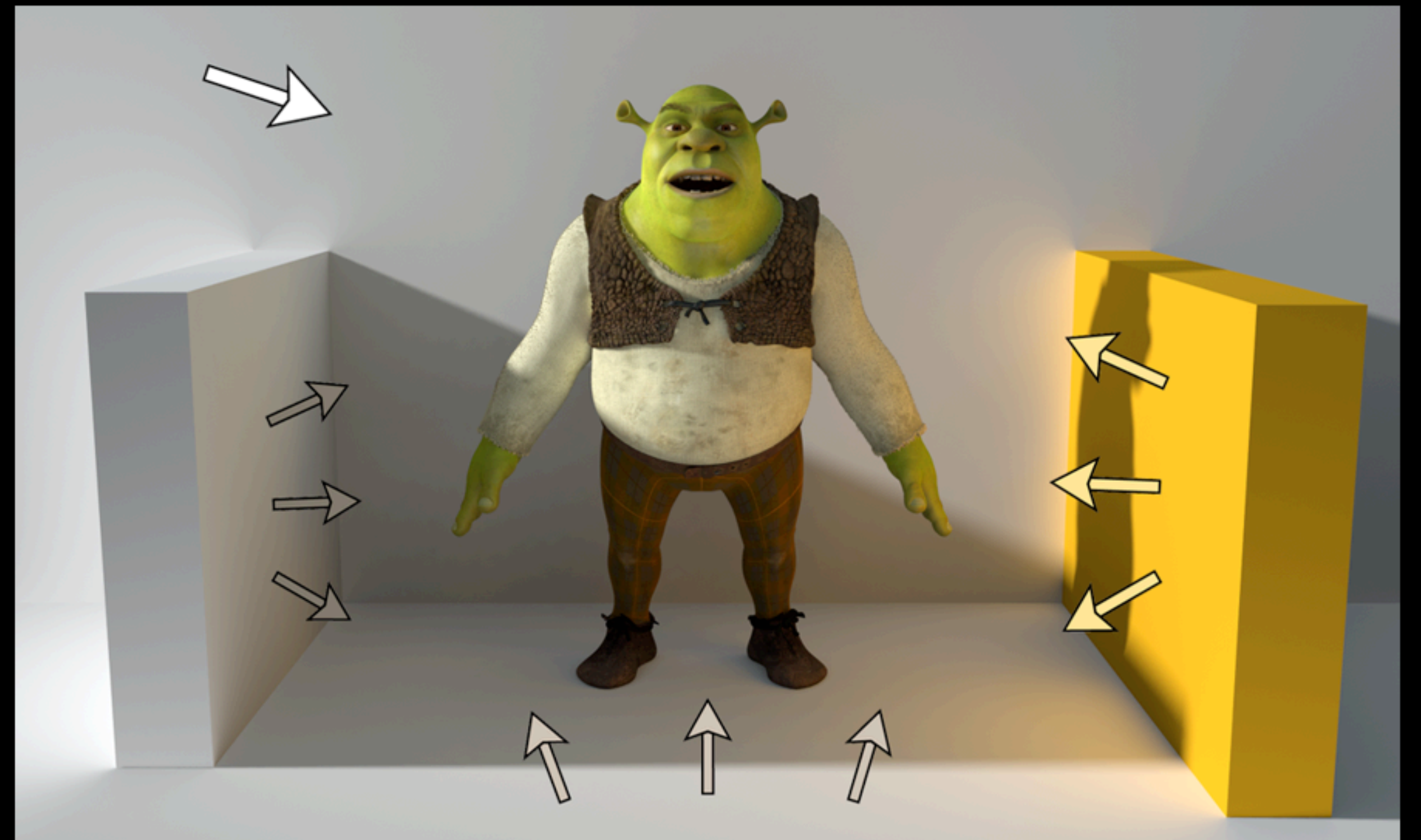


Modeling Light Transport

Direct Lighting Only



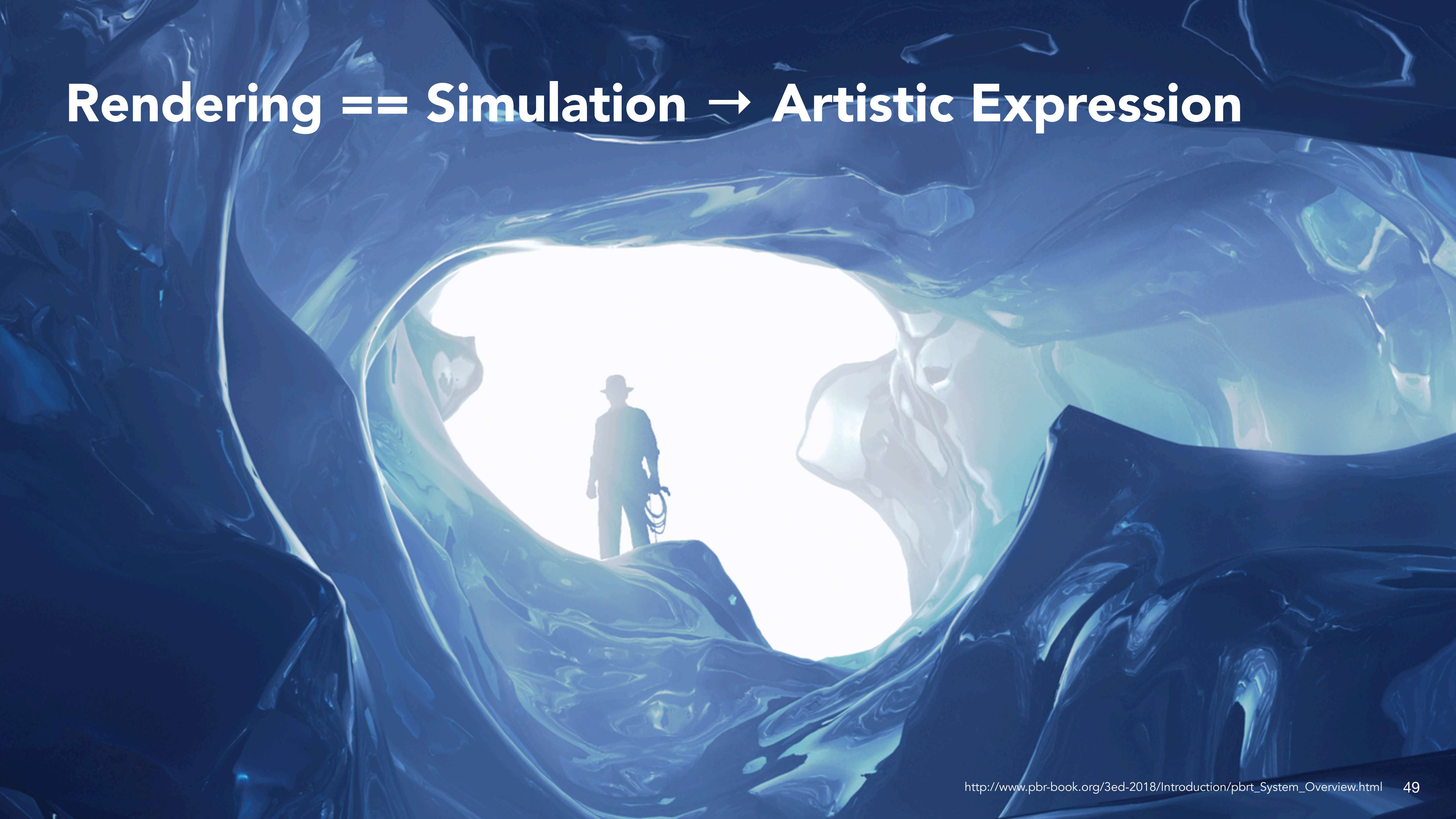
Direct + Indirect Lighting







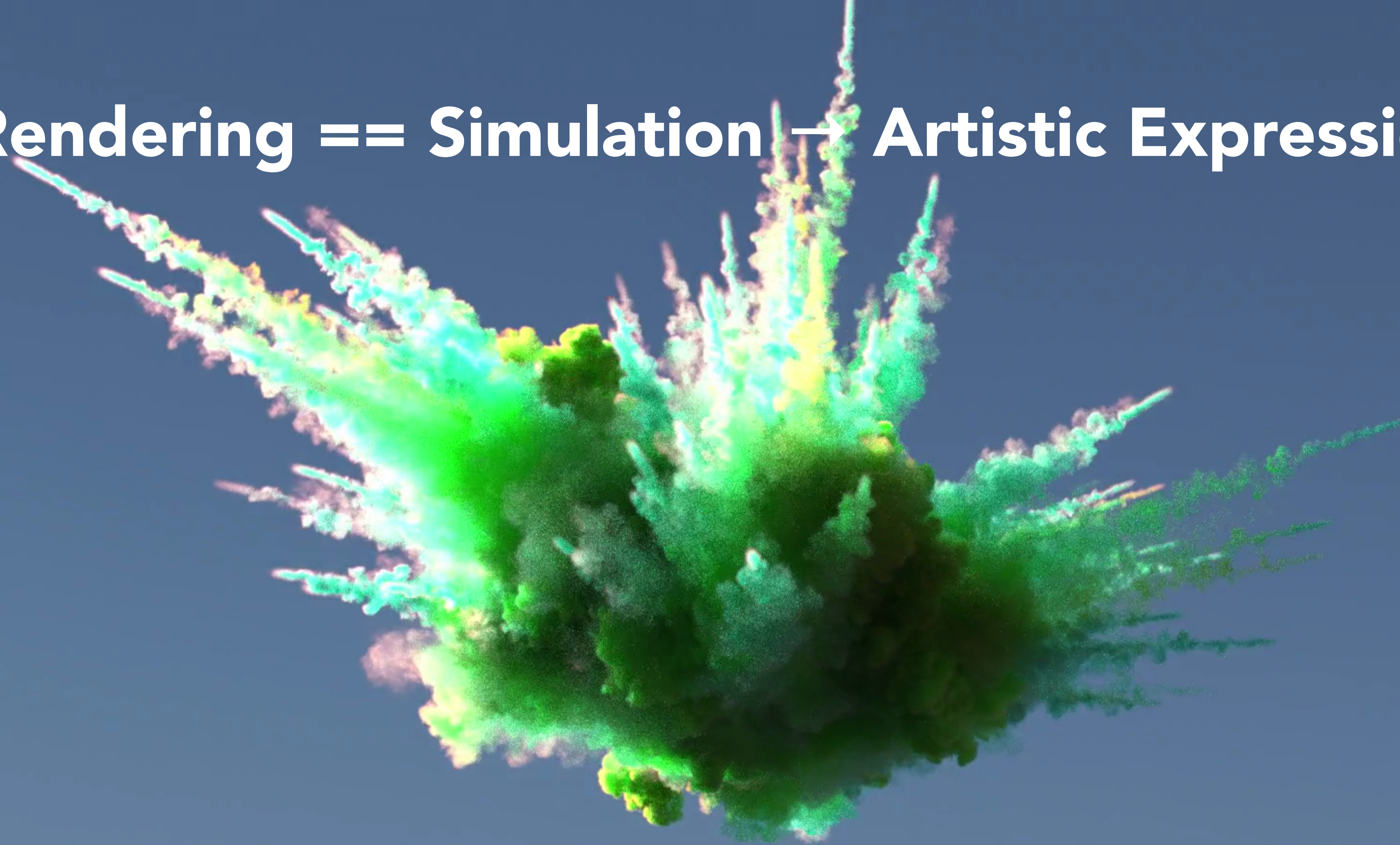
Rendering == Simulation → Artistic Expression



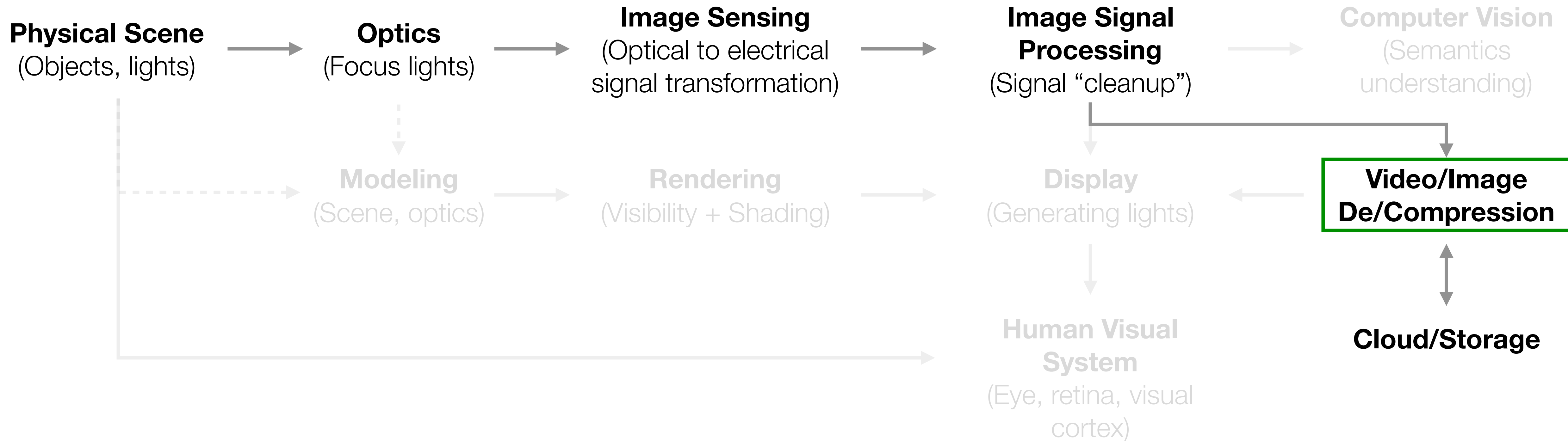
Rendering == Simulation → Artistic Expression



Rendering == Simulation → Artistic Expression



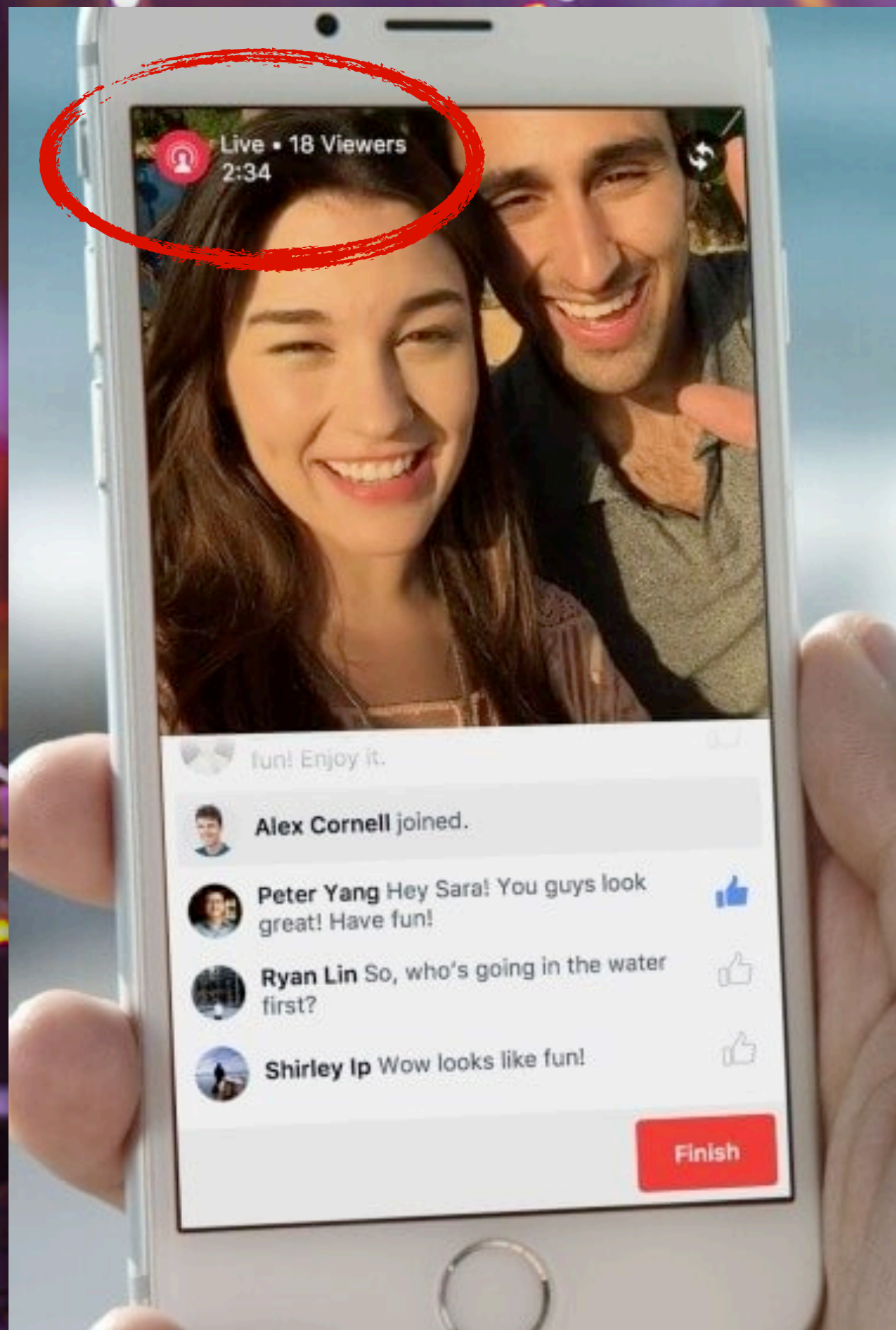
Video/Image Compression



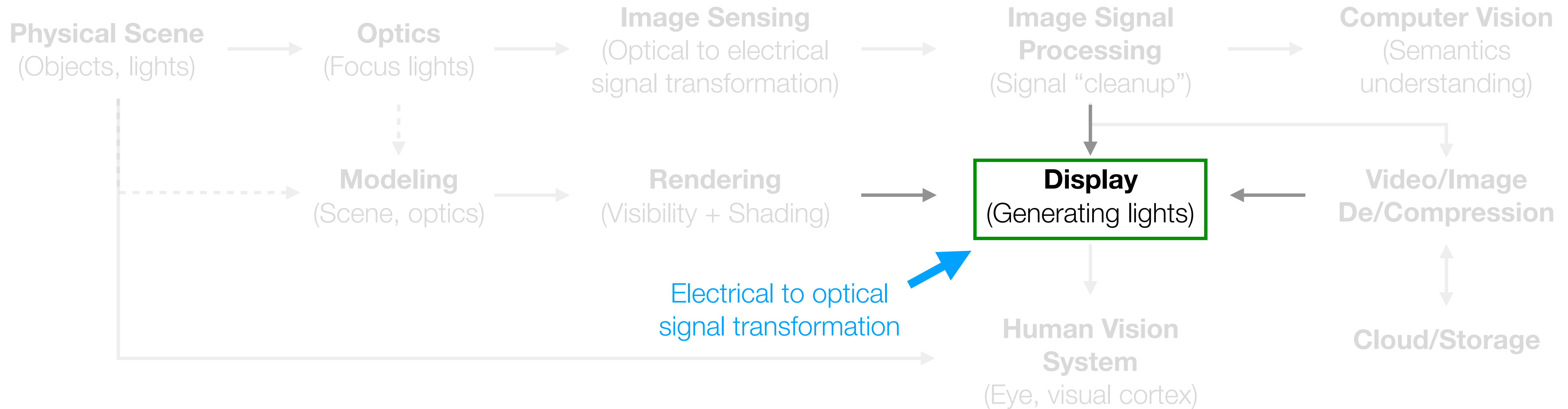


30-second video @ 1080p resolution (1920 x 1080 pixels per frame) @ 30 frames per second (FPS)
3 colors per pixel + 1 byte per color → 6.2 MB/frame → 6.2 MB x 30 s x 30 FPS = 5.2 GB total size
Actual H.264 video file size: 65.4 MB (80-to-1 compression ratio).
Compression/encoding done in real-time without you even realizing it!

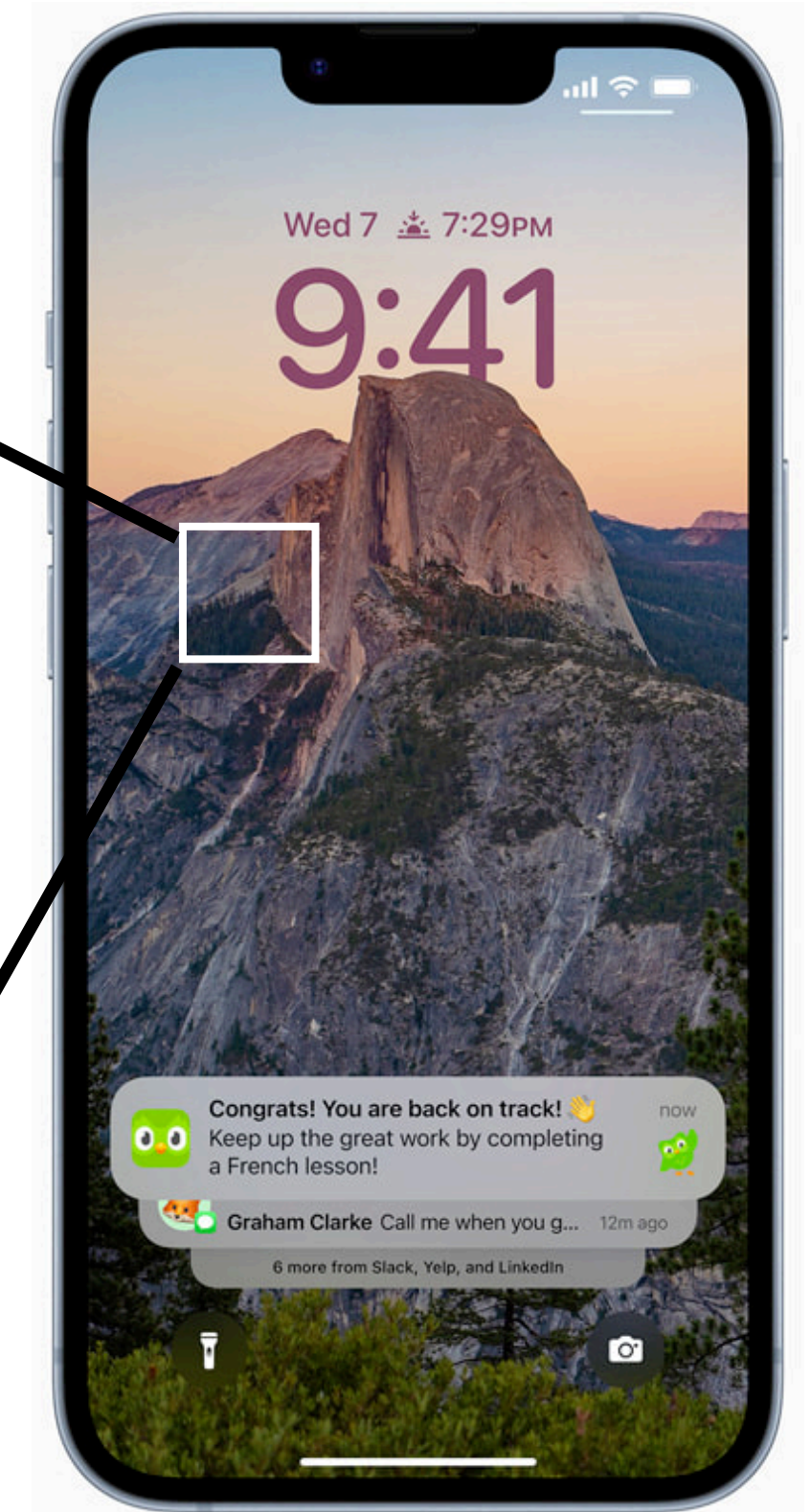
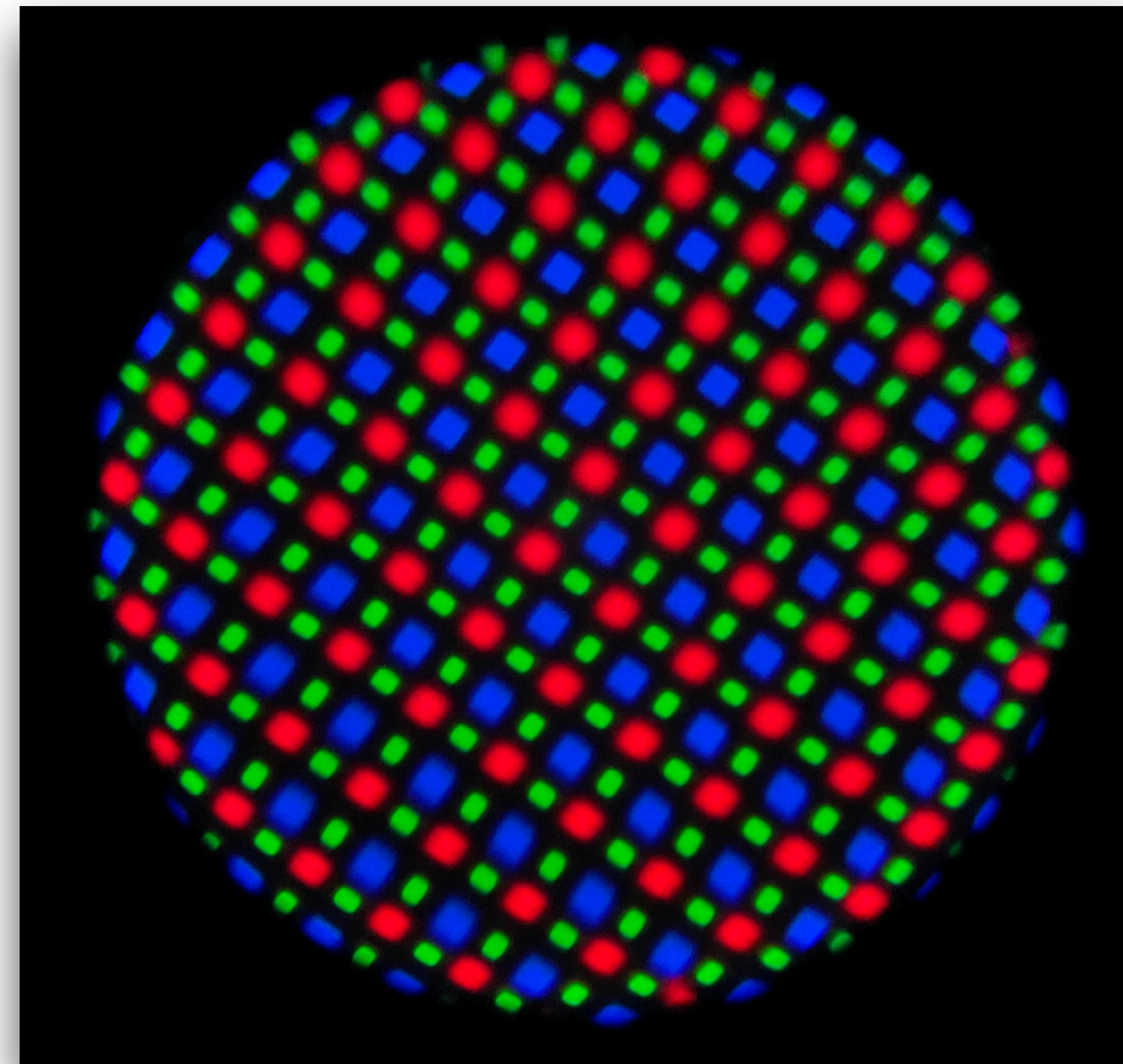
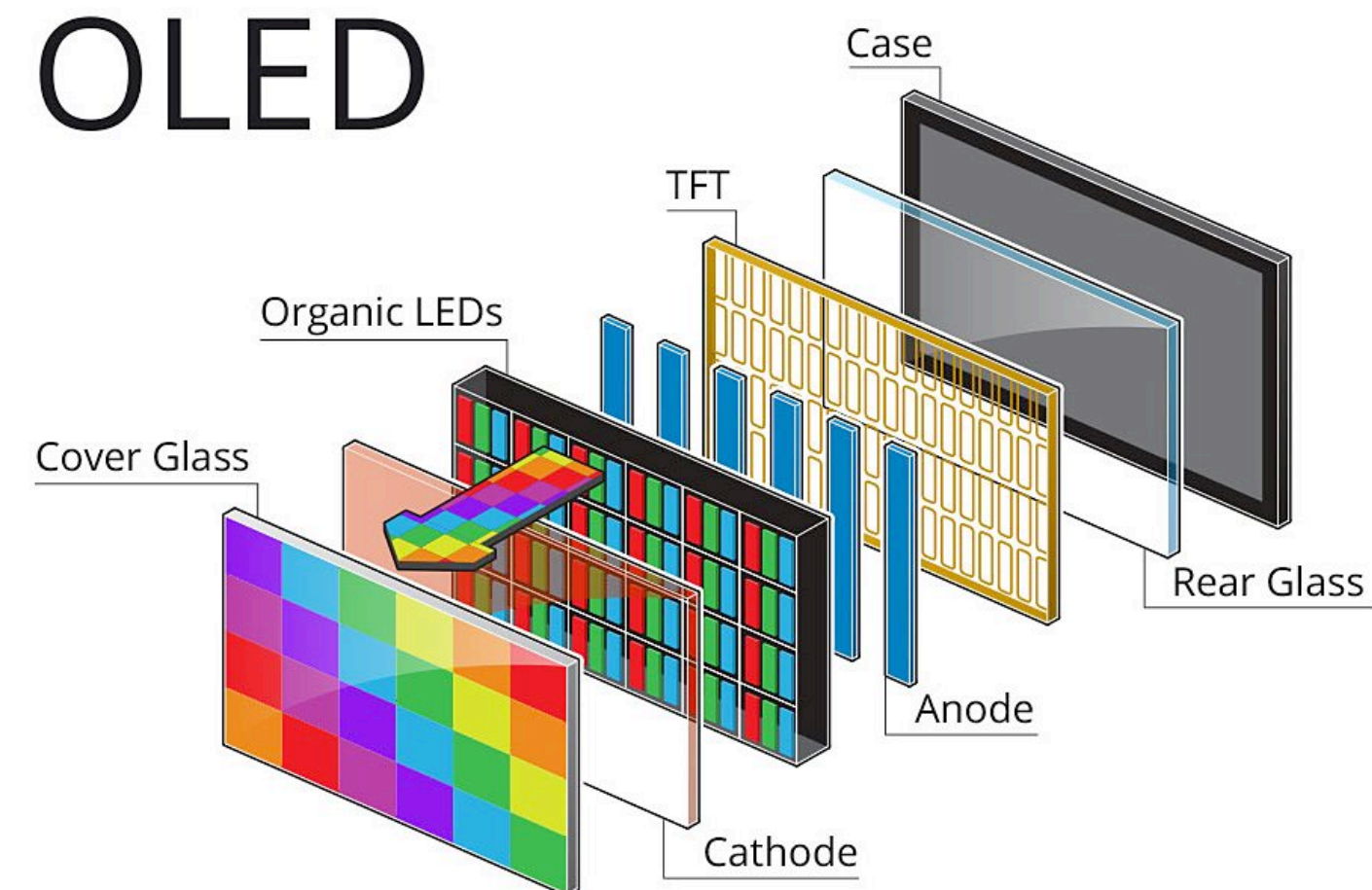
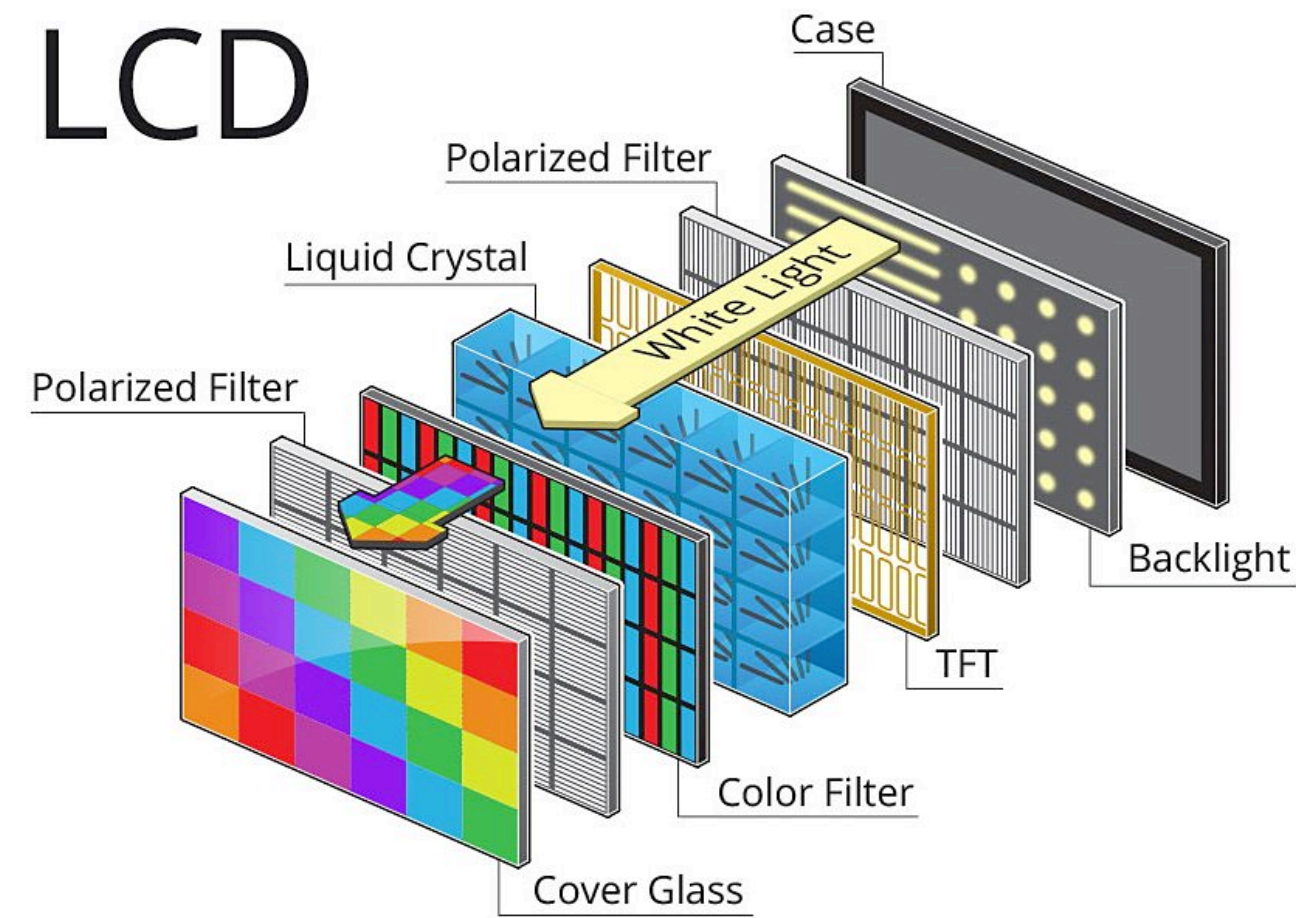




Scope of the Course



Display: Transform Electrical Signals to Optical Signals



iPhone 11

3D Display

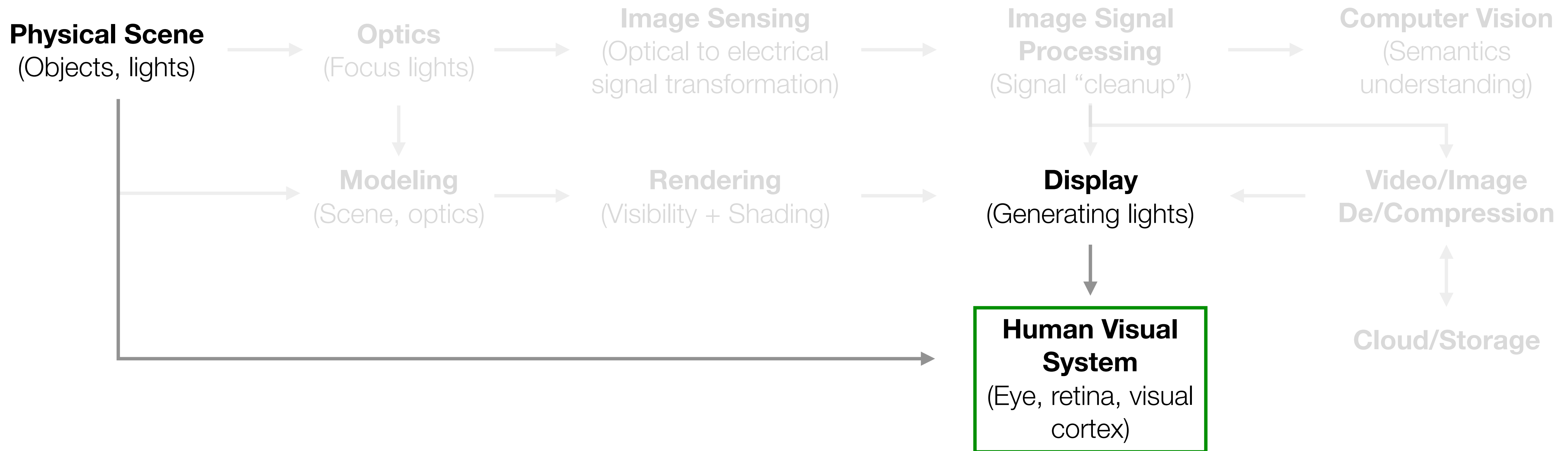


Sequence filmed with 4DViews' volumetric capture technology

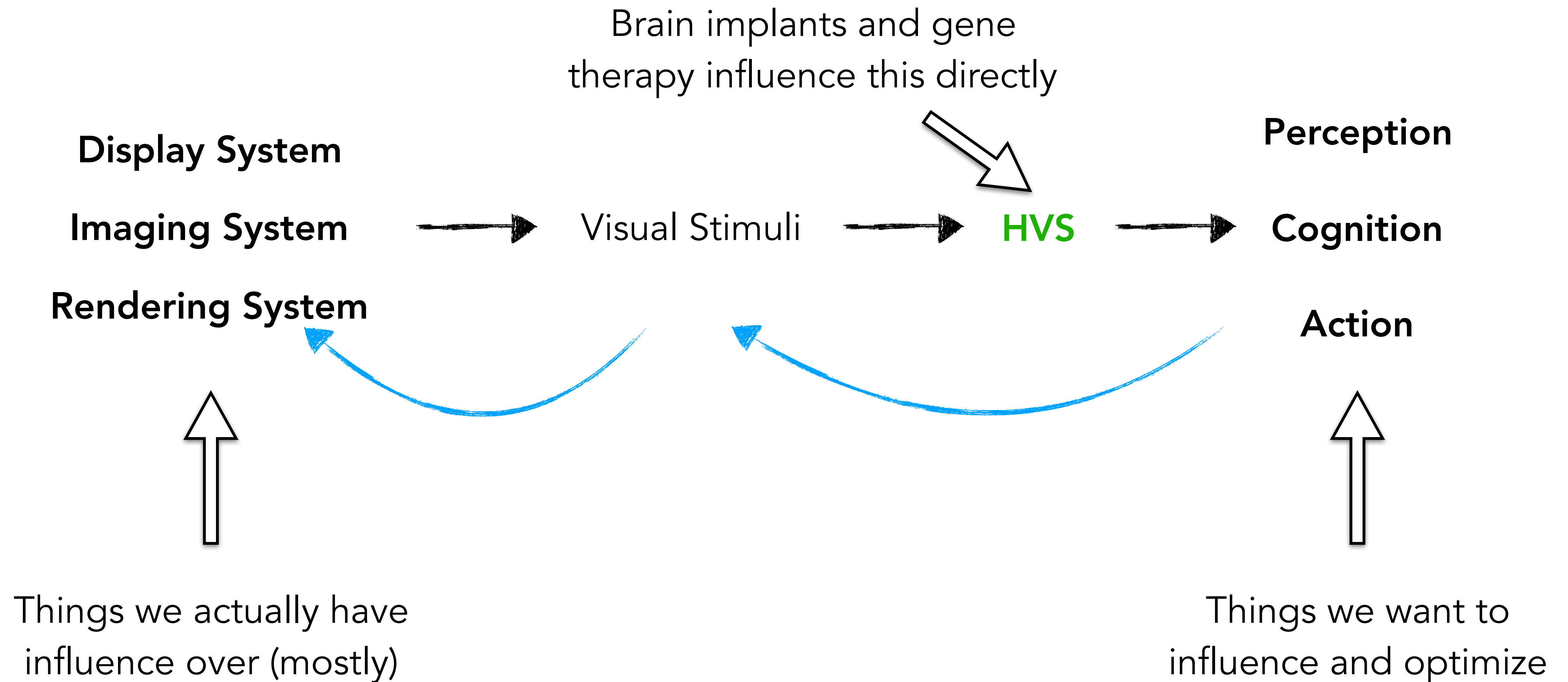
3D Display



Human Visual System



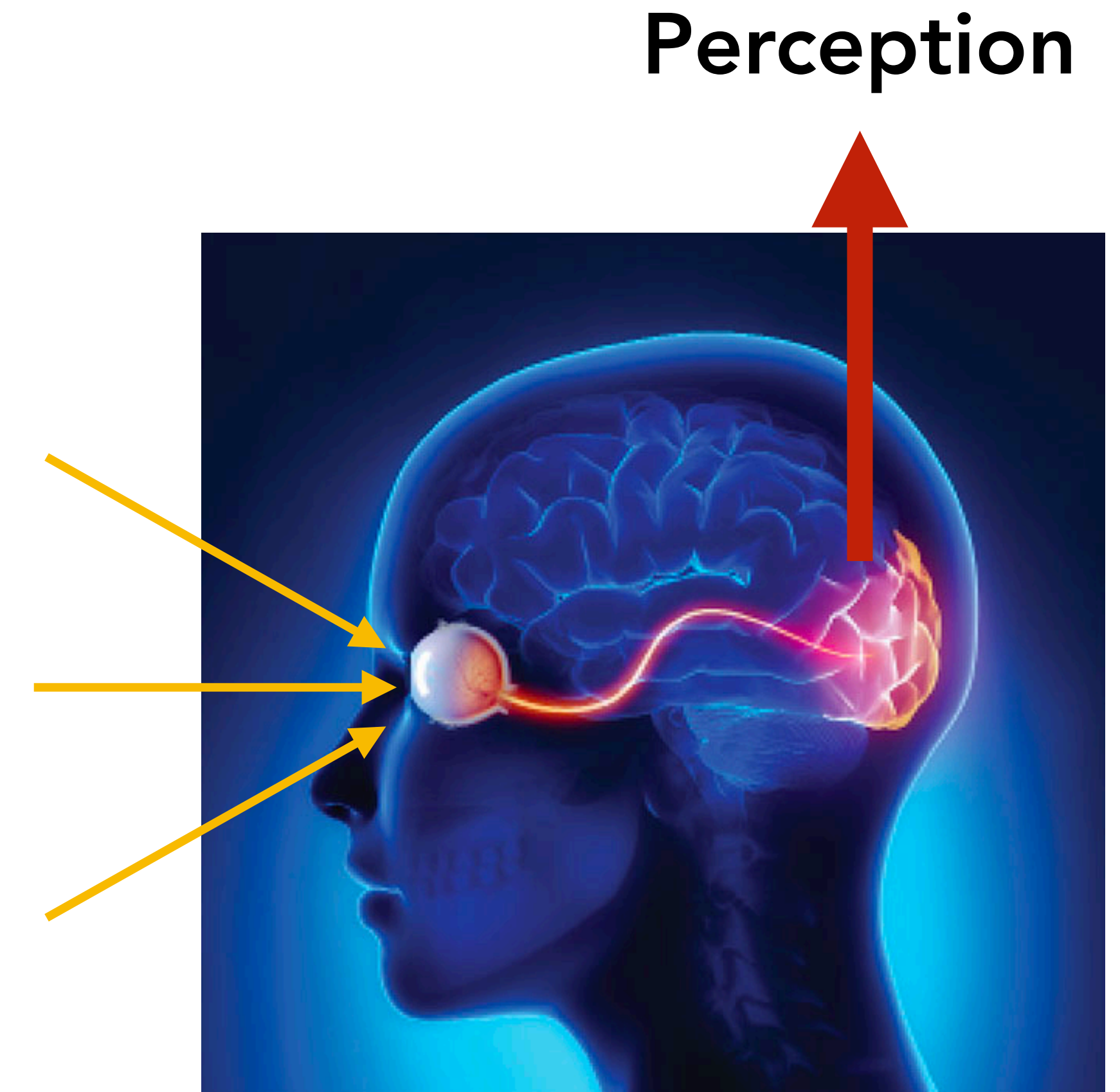
Why Study Human Vision (Other Than For Science Itself)?



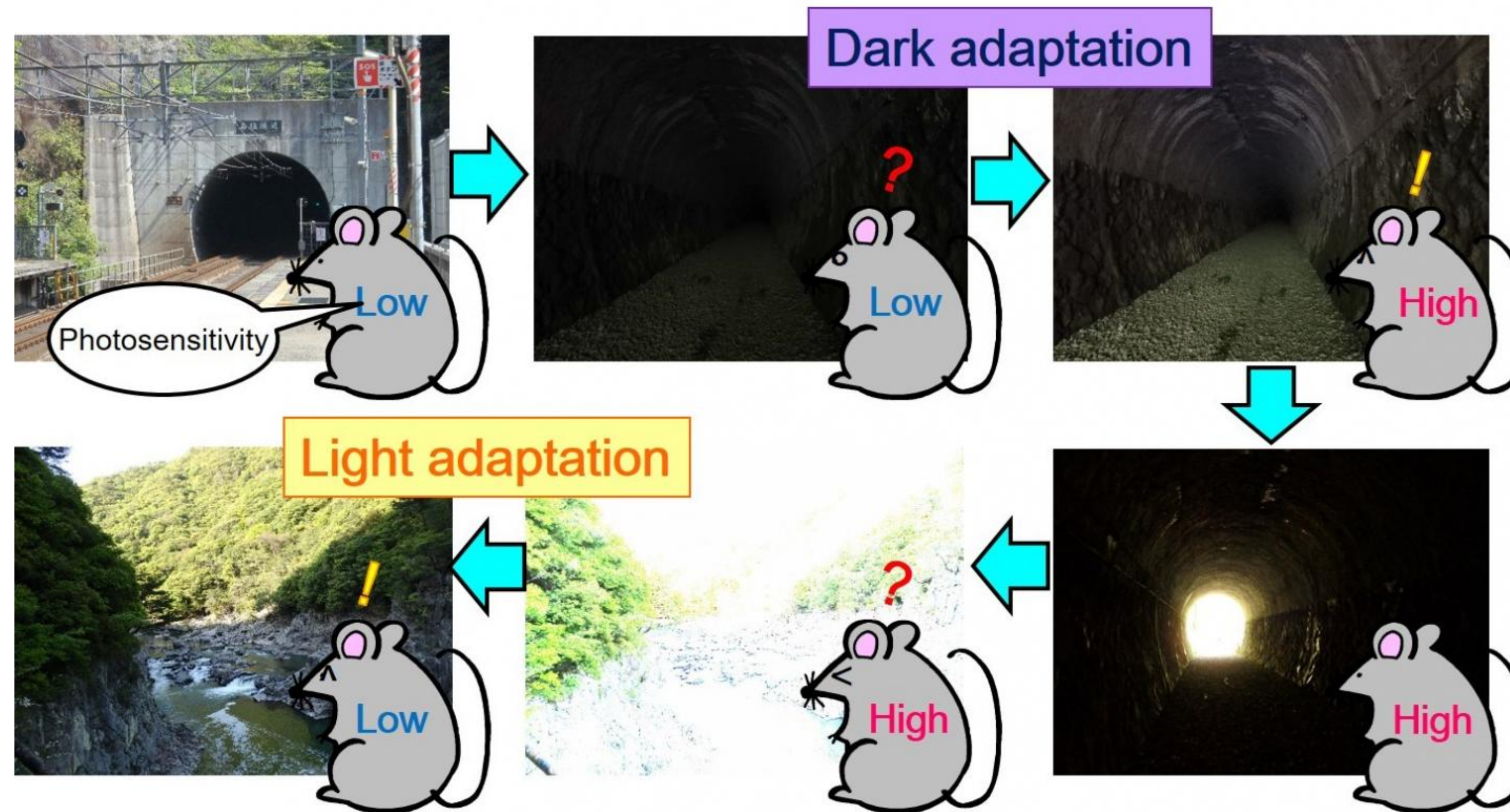
Human Visual System

Another sequence of signal transformations

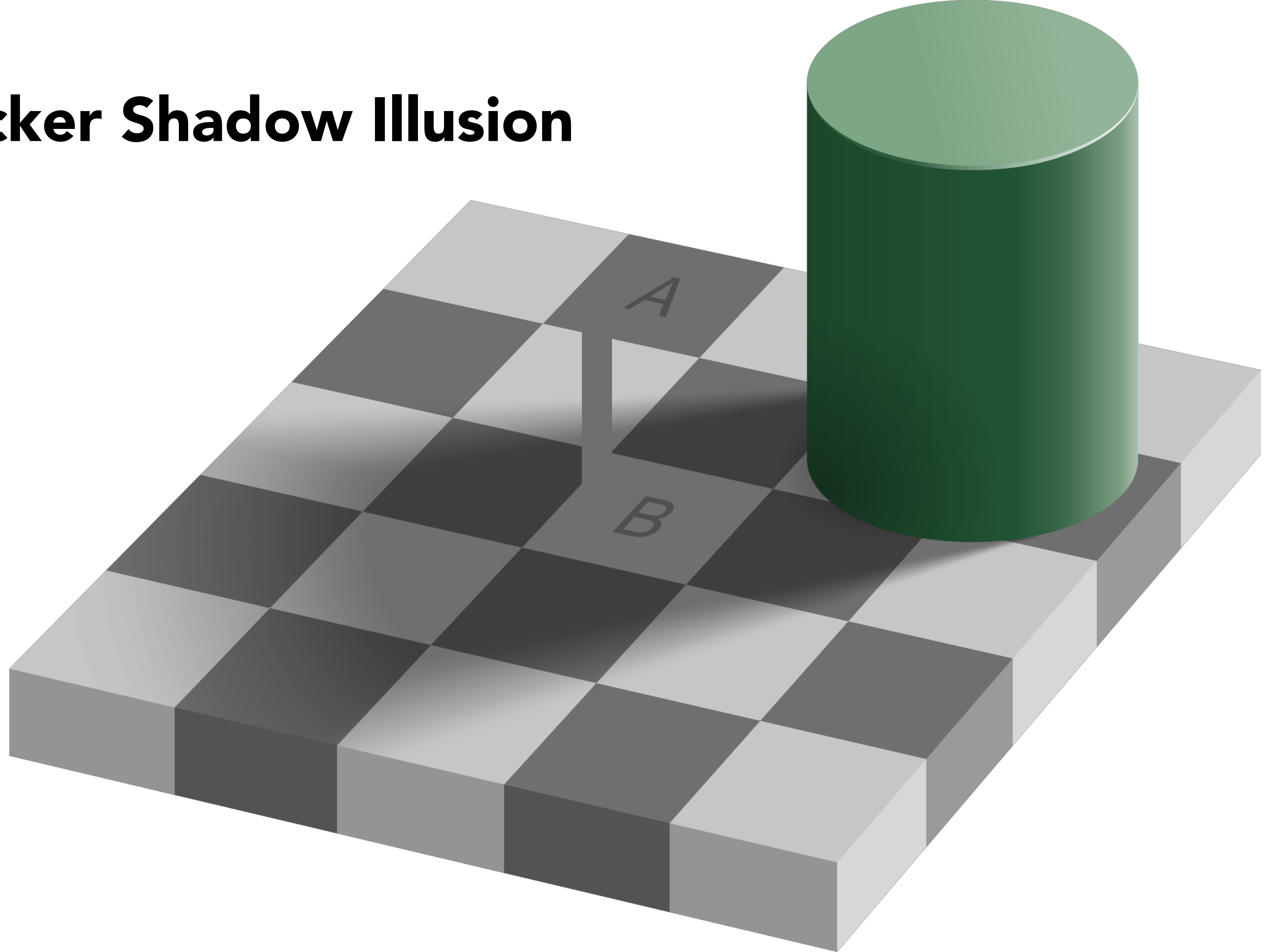
- Eye optics focus lights
- Photoreceptors turn photons to electrical responses (photocurrents across cell membrane)
- The rest of the HVS (neurons on retina, LGN, visual cortex) further processes the electrical signals and gives rise to semantic meanings



Light and Dark Adaptation



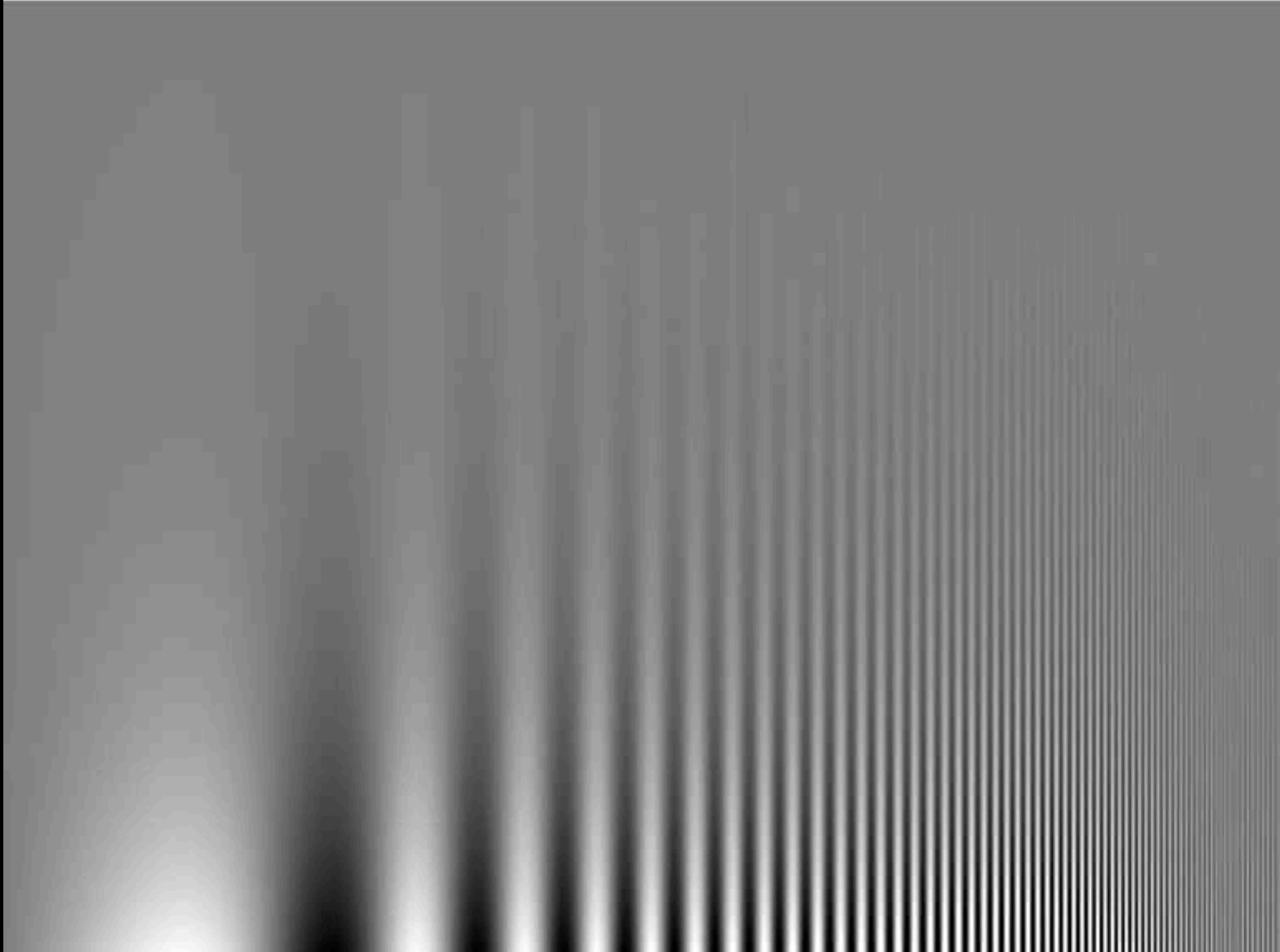
Checker Shadow Illusion



Red Without Any Red Pixel



Limits of Human Vision



Color Vision Deficiency

With two, we
are dichromatic:

Protanopia (missing red sensor)



Tritanopia (missing blue sensor)



Deuteranopia (missing green sensor)



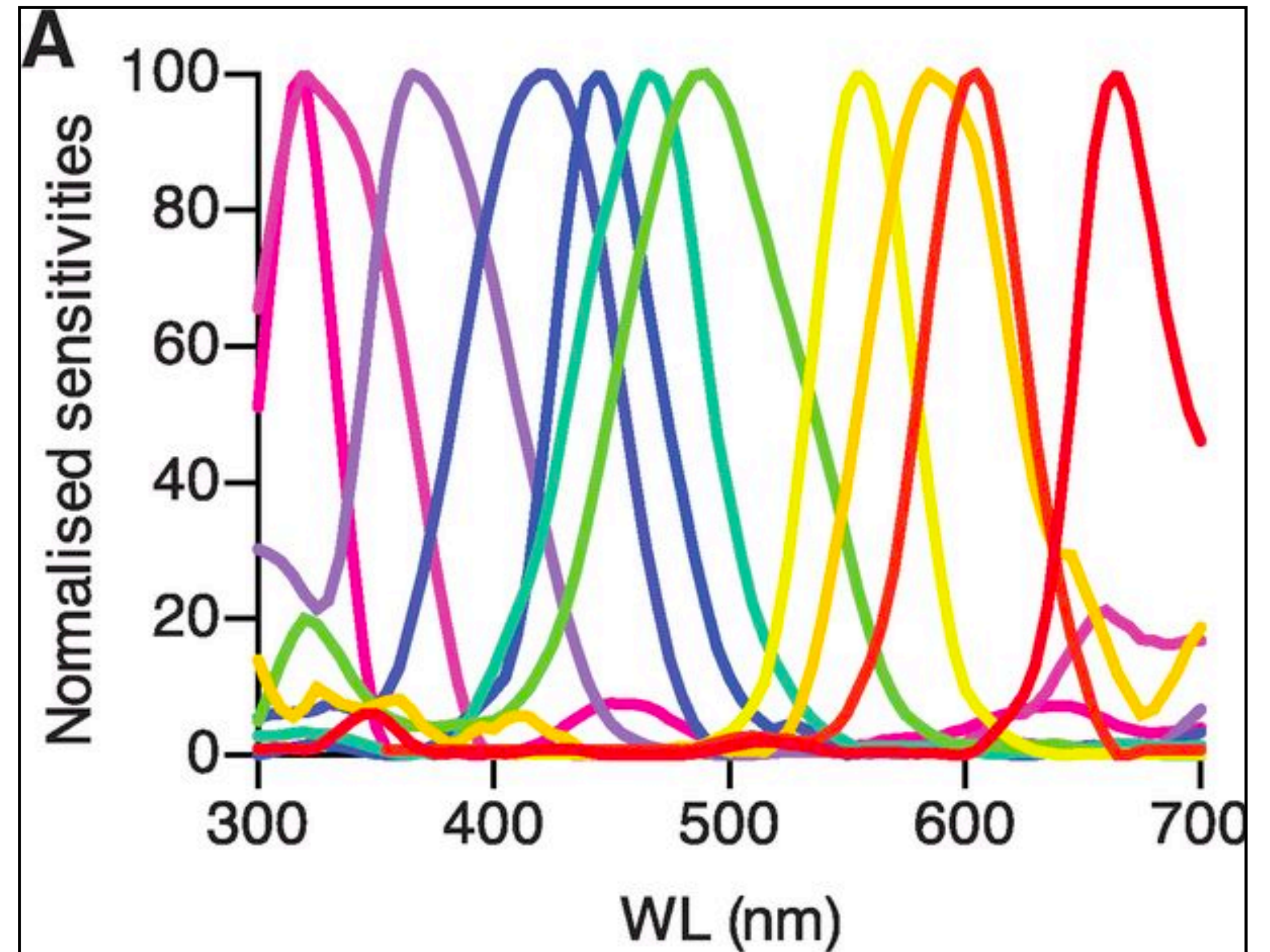
Super-human Color Vision?

Tetrachromacy: Do you have superhuman vision?

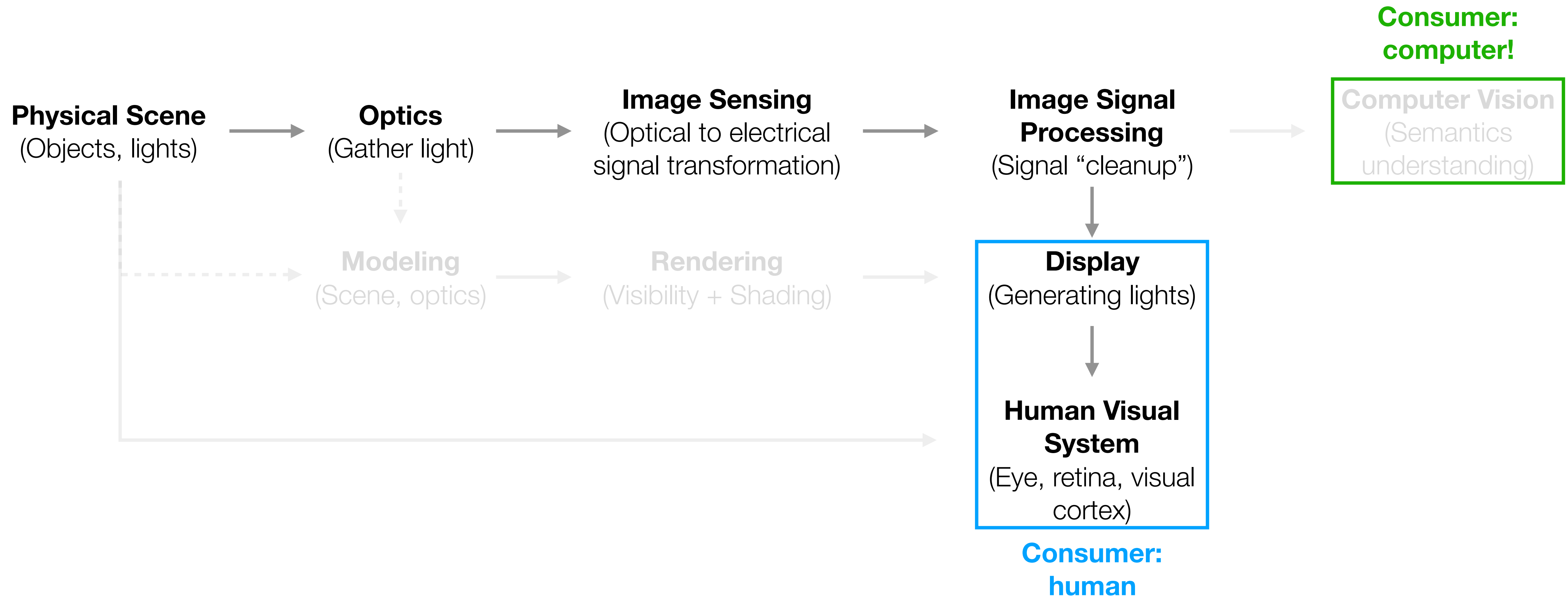
19 JANUARY 2021
AUTHOR: KATE GREEN



Mantis Shrimp



Computer Vision: Semantic Understanding



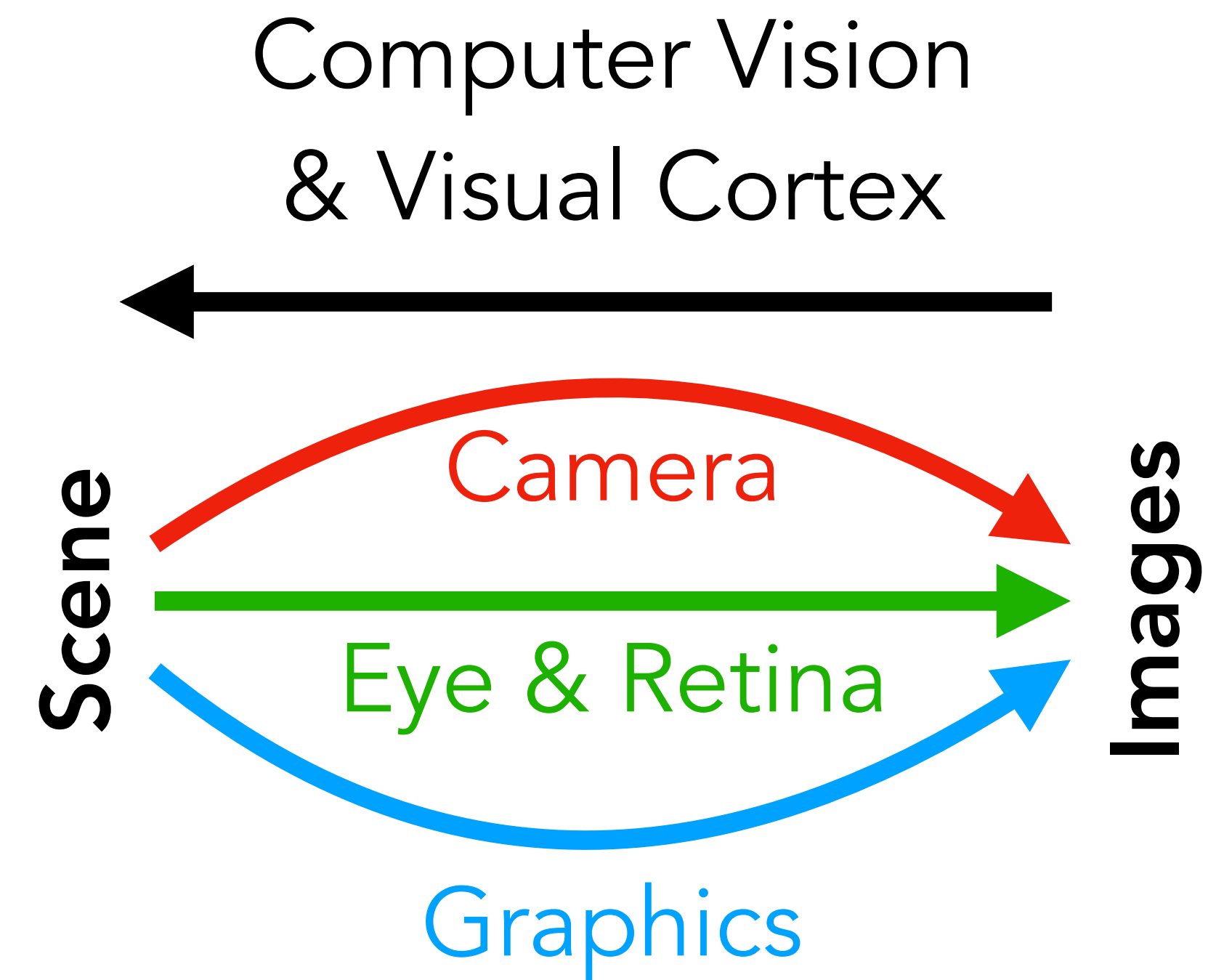
Not a Computer Vision Course

Computer vision is concerned with understanding scene from images.

What this course focuses on is how images are formed from scenes.

- Both in biological systems and in engineered systems (cameras, rendering, etc.)

We will touch upon many computer vision topics whose solutions rely on the fundamental image formation process.



Visual Computing Systems

The most exciting applications on the horizon are visual computing applications, and they challenge the way we build computers.



Computer vision: recognize table and estimate its orientation

Computer graphics: draw the virtual content to overlay

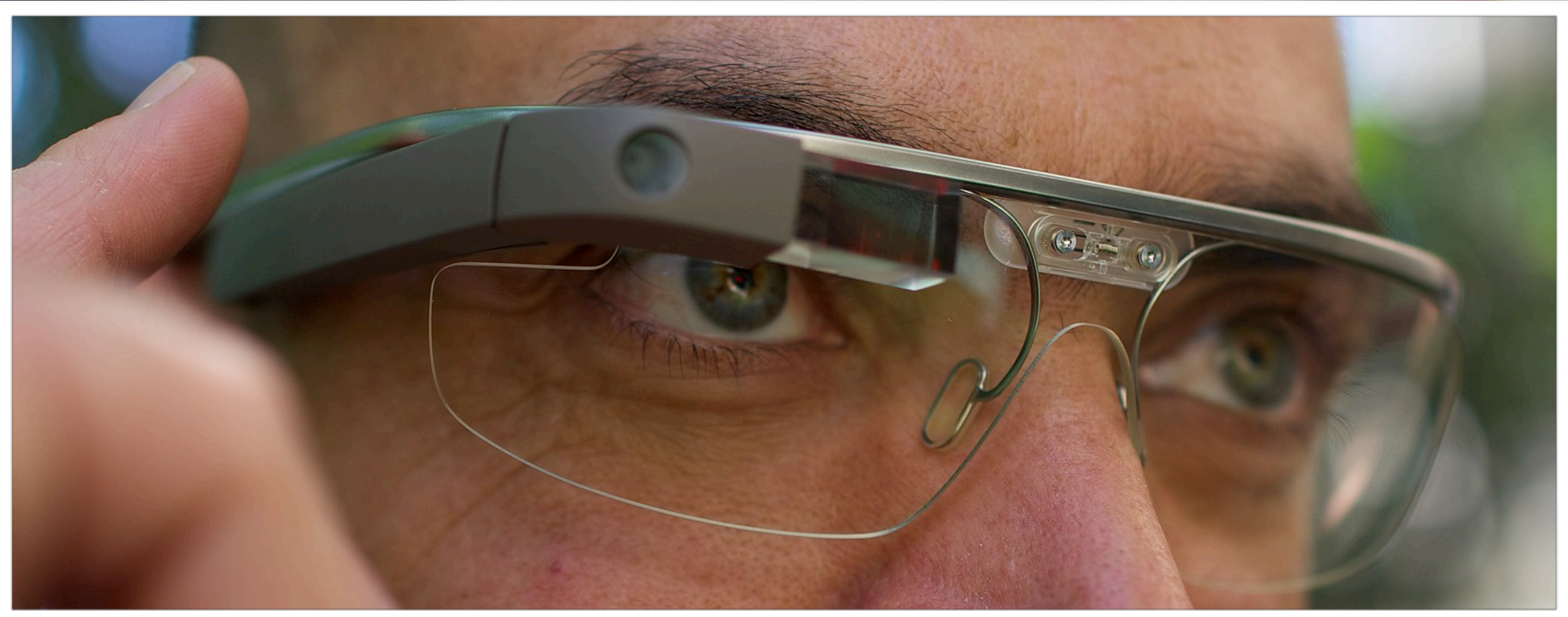


Image Sensing: sense the environment

Display: lenses, mirrors, waveguides

Virtual Reality



How Do I Teach (and How You Should Learn)?

- The First-Principles approach.
- Nothing is magic.
- Things don't have to be that way.

Logistics

Course website: <https://cs.rochester.edu/courses/259/fall2026>

We meet on Wednesdays and Fridays (9 - 10:15).

All announcements will be made through blackboard.

Feel free to send me emails.

Office hours by appointment.

TA: Can Yagmur (iyagmur [at] ur [dot] rochester [dot] edu)

"Pre-requisites"

Basic geometry (similar triangles, etc.)

High-school physics (power, energy, etc.)

Basic calculus (integration, derivatives, etc.)

Good to know:

- basic linear algebra (e.g., matrix multiplication, solving systems of linear equations)
- basic probability (e.g., random variables)
- basic computer systems (CSC 252 equivalent) could be helpful depending on what you want to get out of this course.

Reference Materials

Main book: <https://learnvisualcomputing.github.io/>.

There will be readings assigned (some are required and others are recommended).