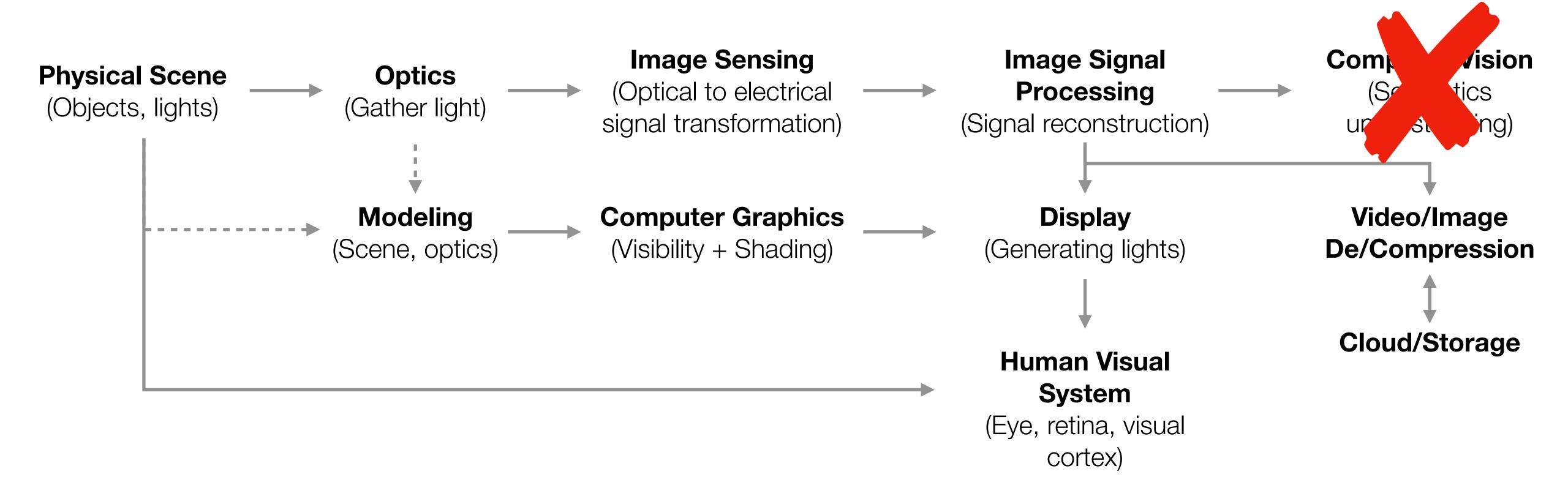
Lecture 1: Introduction and Overview



CSC 259/459, Fall 2024 Computer Imaging & Graphics

Scope of the Course



Conventional Digital Camera

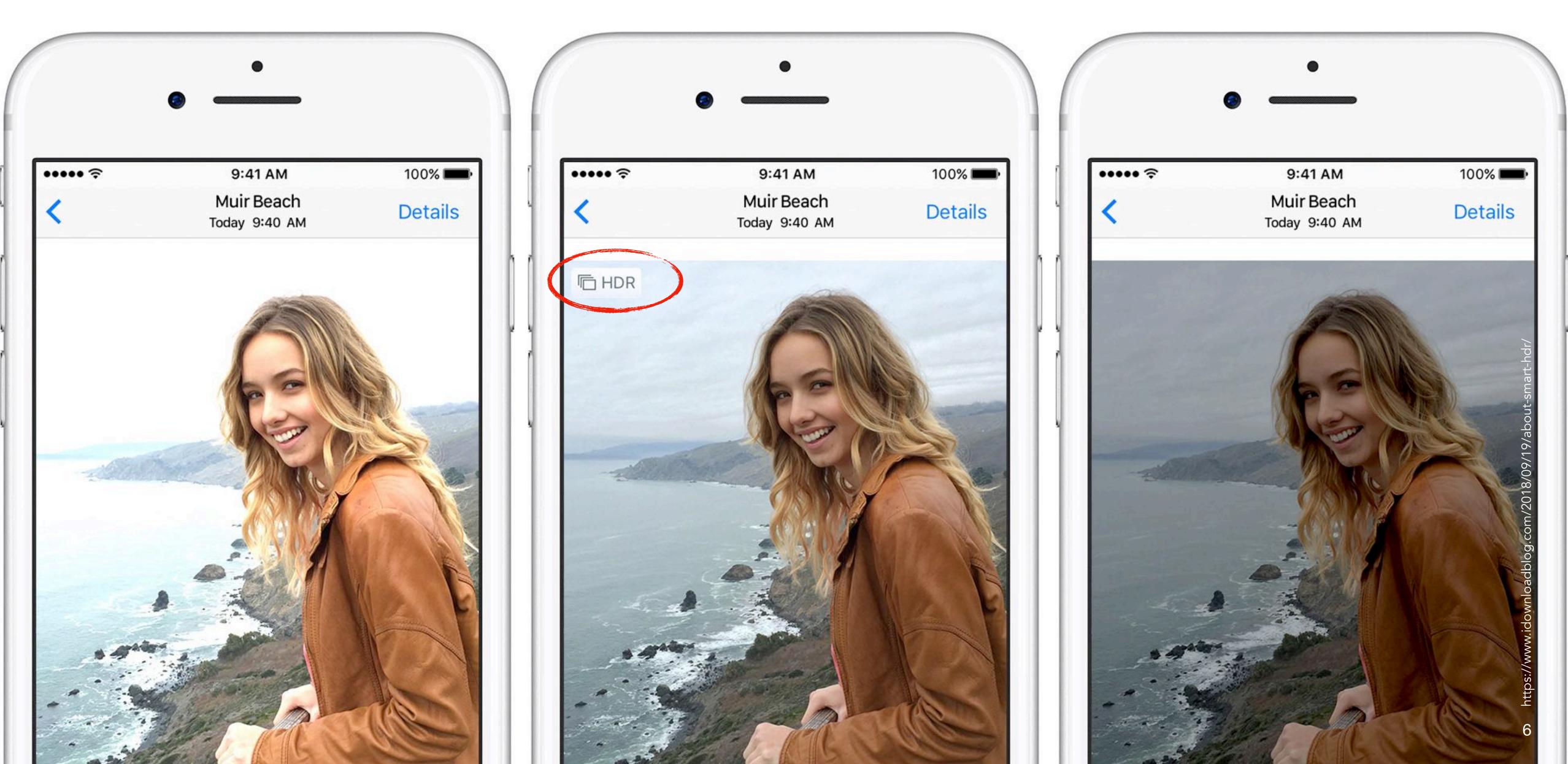


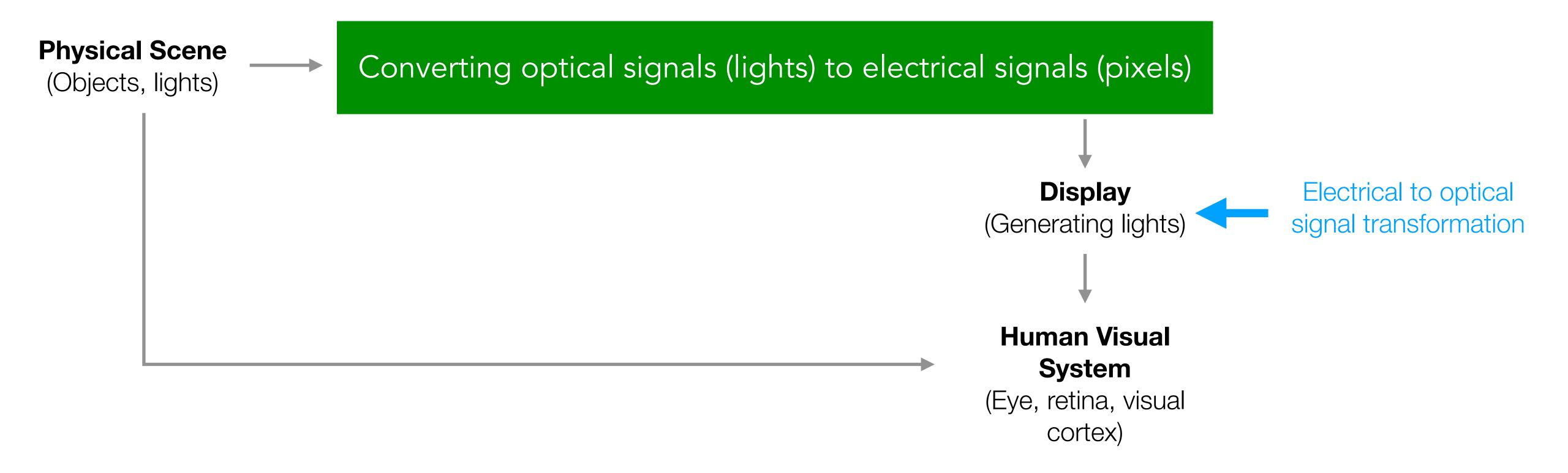
Today's Digital Camera

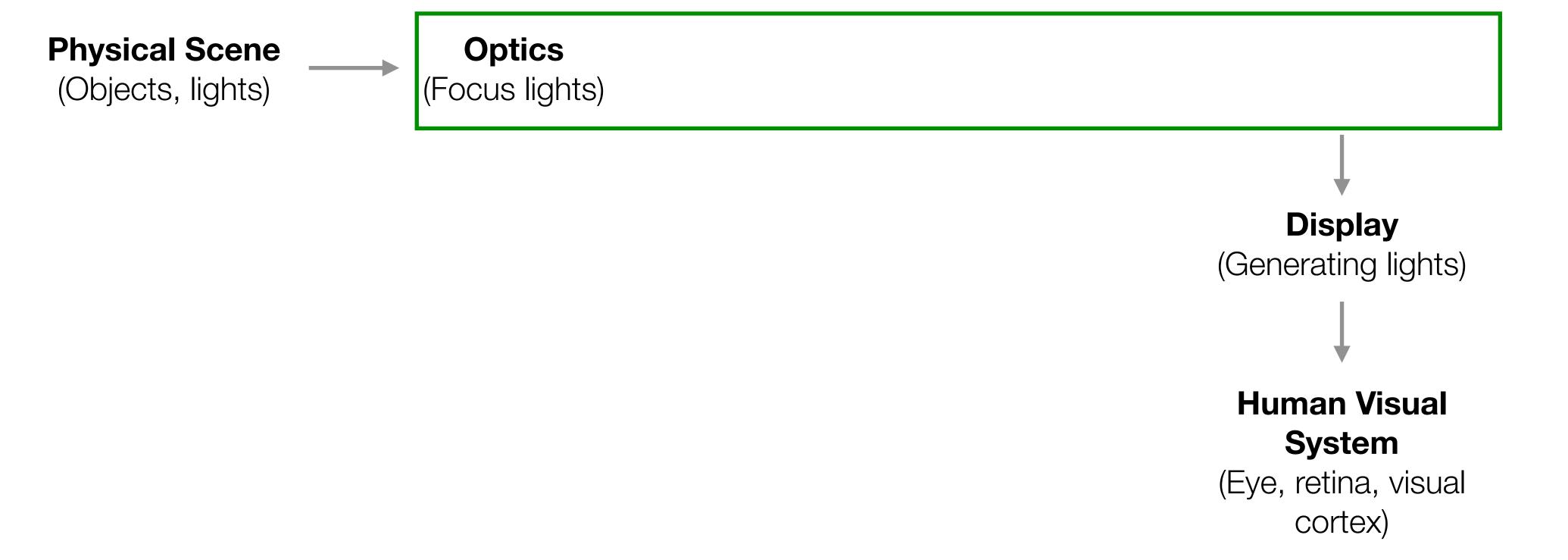




Today's Digital Camera: High Dynamic Range







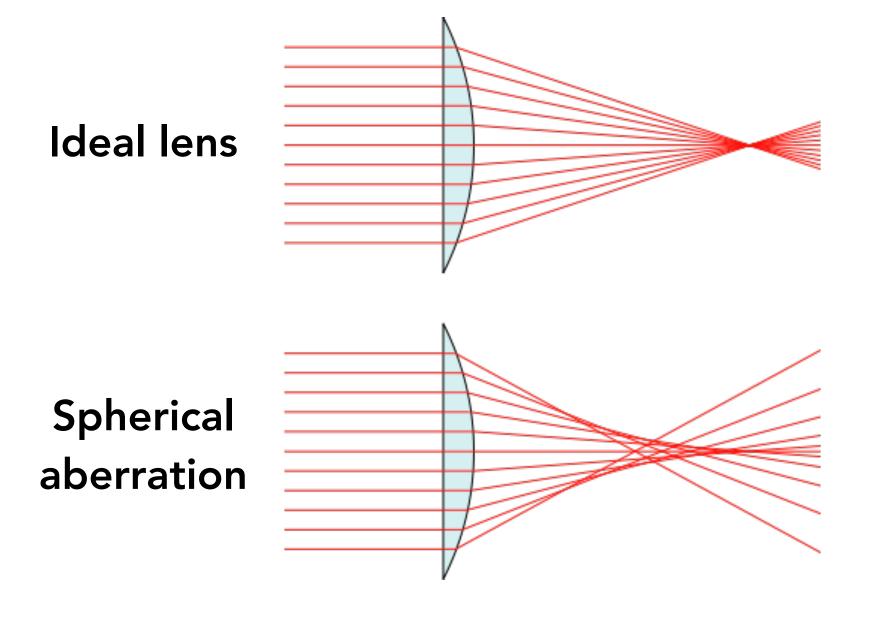
Role of Optics in a Camera

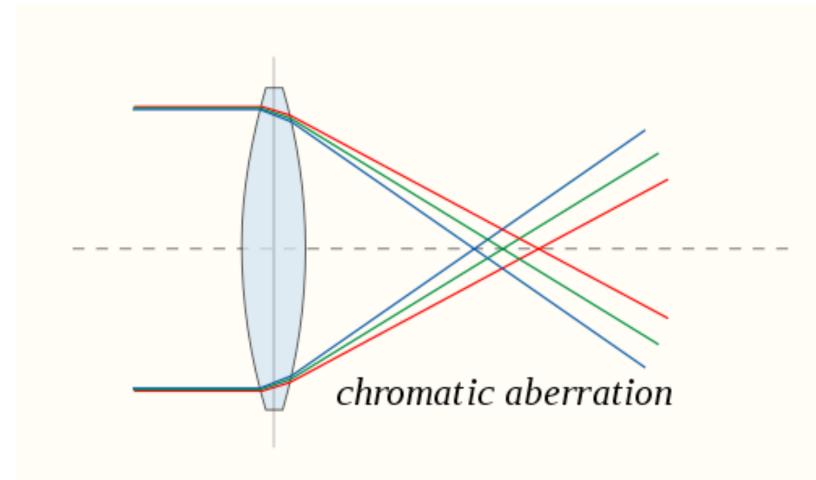
Focus light and capture energy

At a cost of introducing "imperfections" (aberrations)

• Distorting incident light signals to another form of light signals









"Desired" Distortion

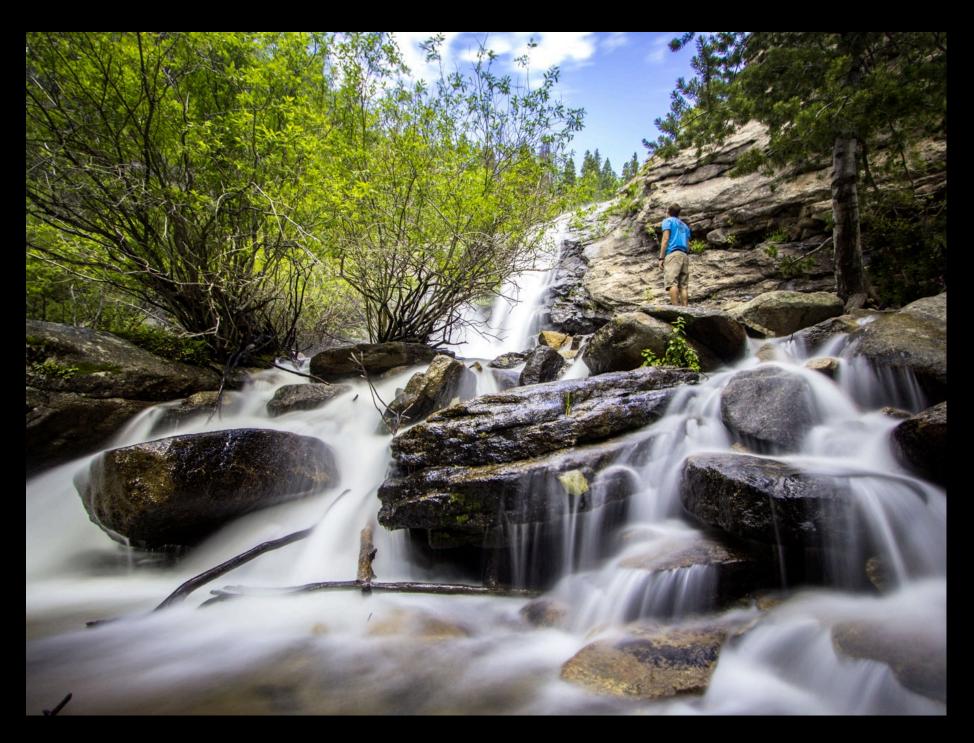
Shallow depth of field



Vignetting



Motion Blur



"Desired" Distortion

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

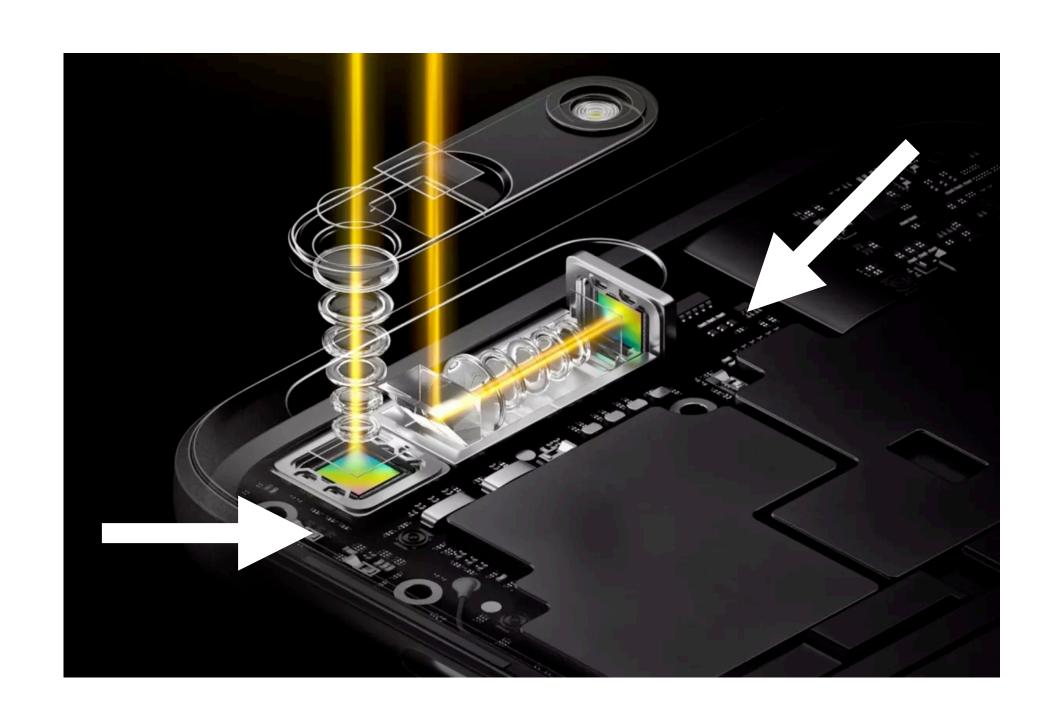


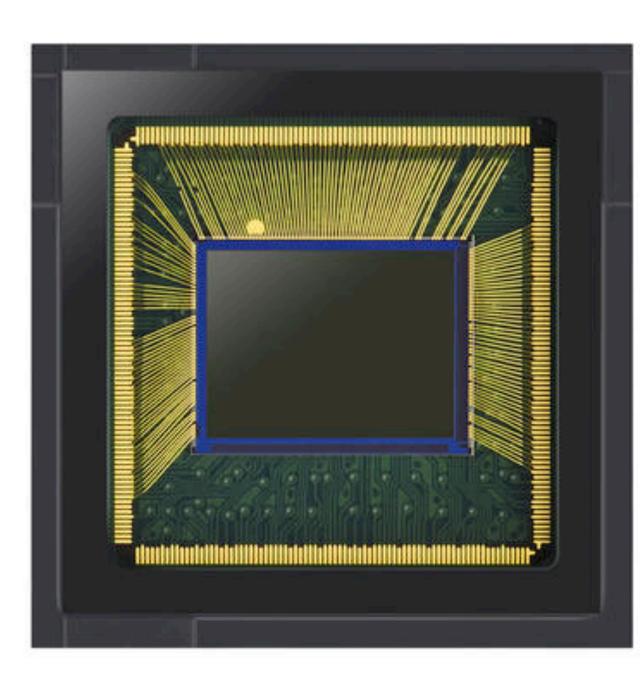


Introduce "imperfections" **Image Sensing Physical Scene Optics** (Optical to electrical (Focus lights) (Objects, lights) signal transformation) **Display** (Generating lights) **Human Visual System** (Eye, retina, visual cortex)

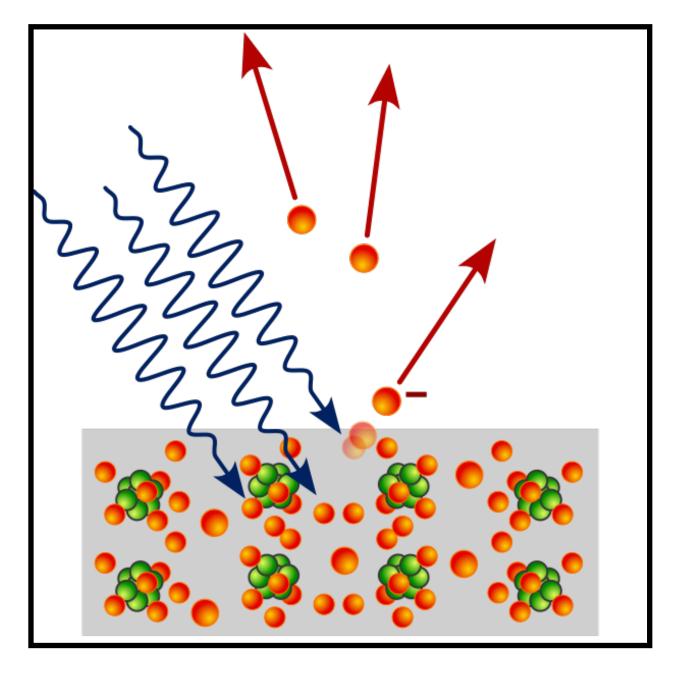
Image Sensing

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





Photoelectric effect



Convert Optical Signals to Electrical Signals

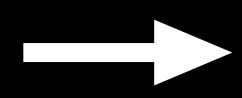
Introduces "imperfections" too, which, unlike optical distortions, are almost always unwanted.



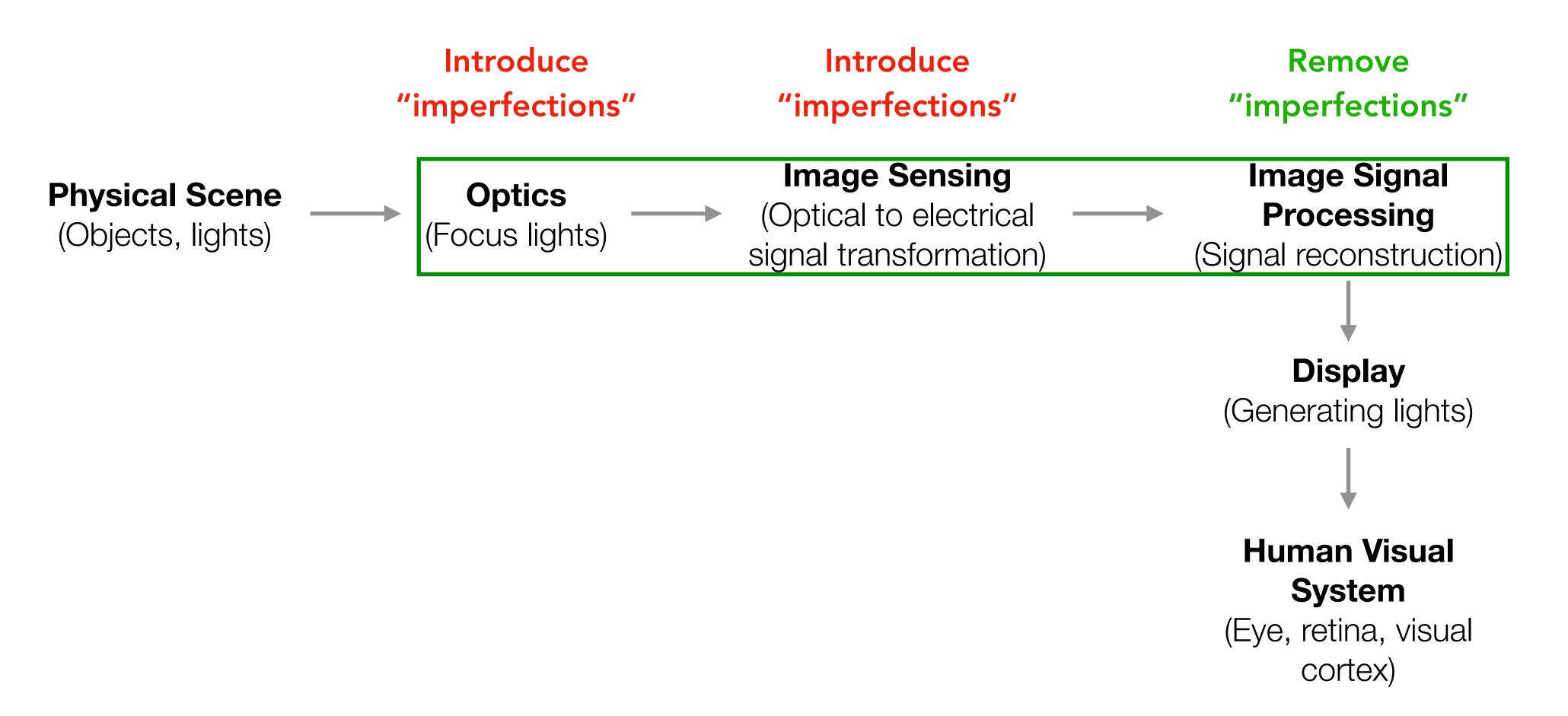
Convert Optical Signals to Electrical Signals

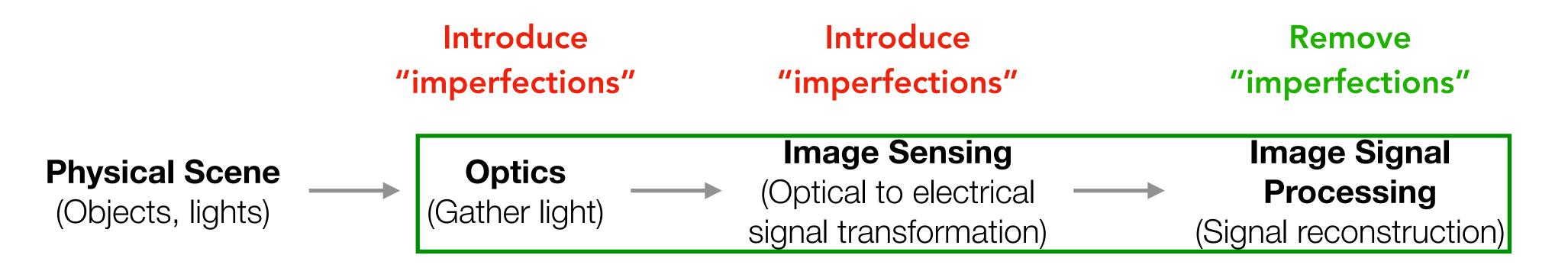
Introduces "imperfections" too, which, unlike optical distortions, are almost always unwanted.



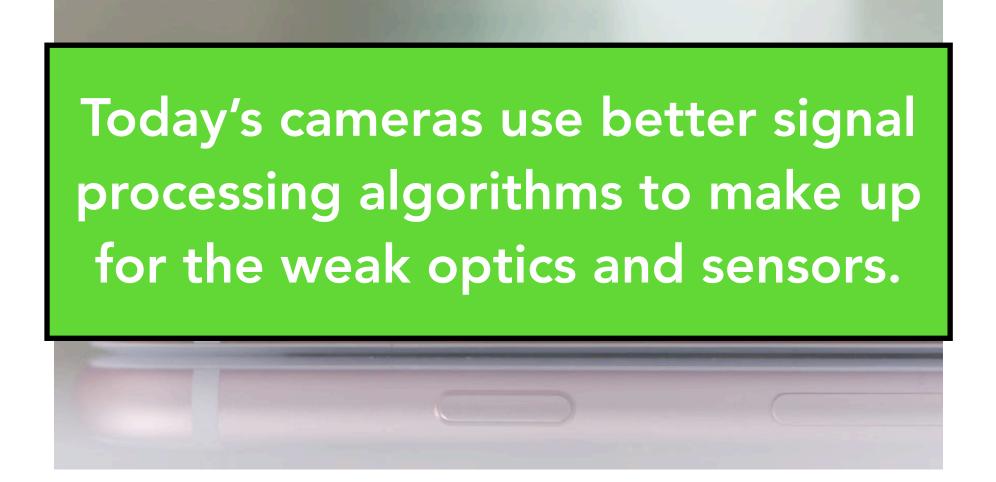










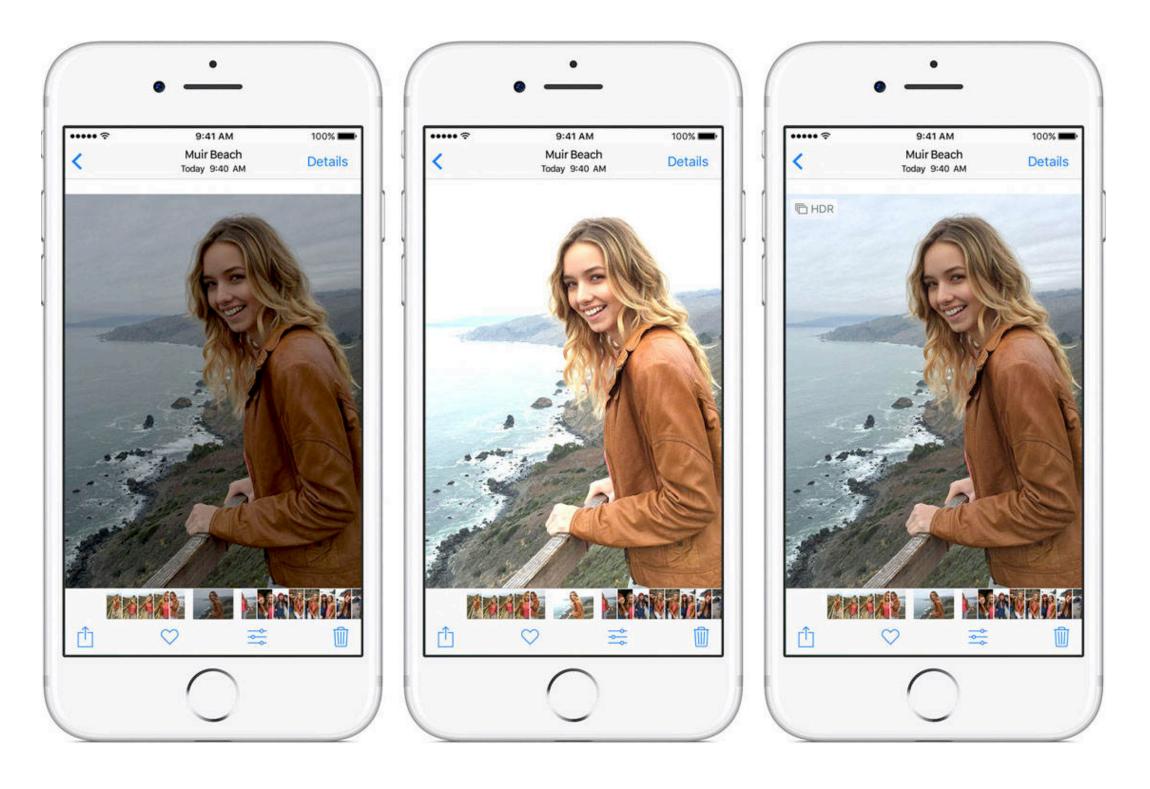


Computational Photography

Use computational algorithms to simplify optics and sensors







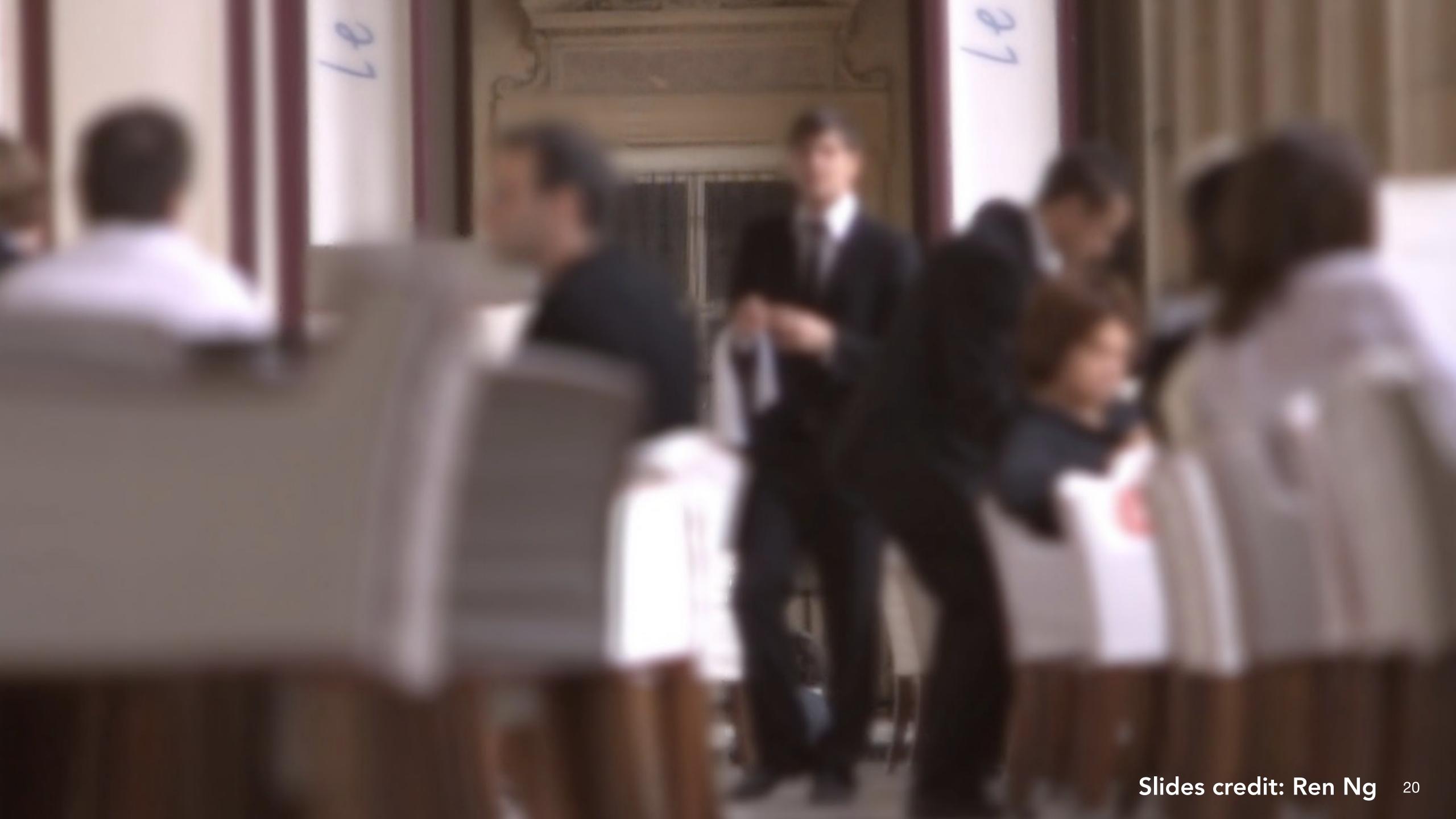
HDR mode: simulate a high dynamic range sensor

Computational Photography

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



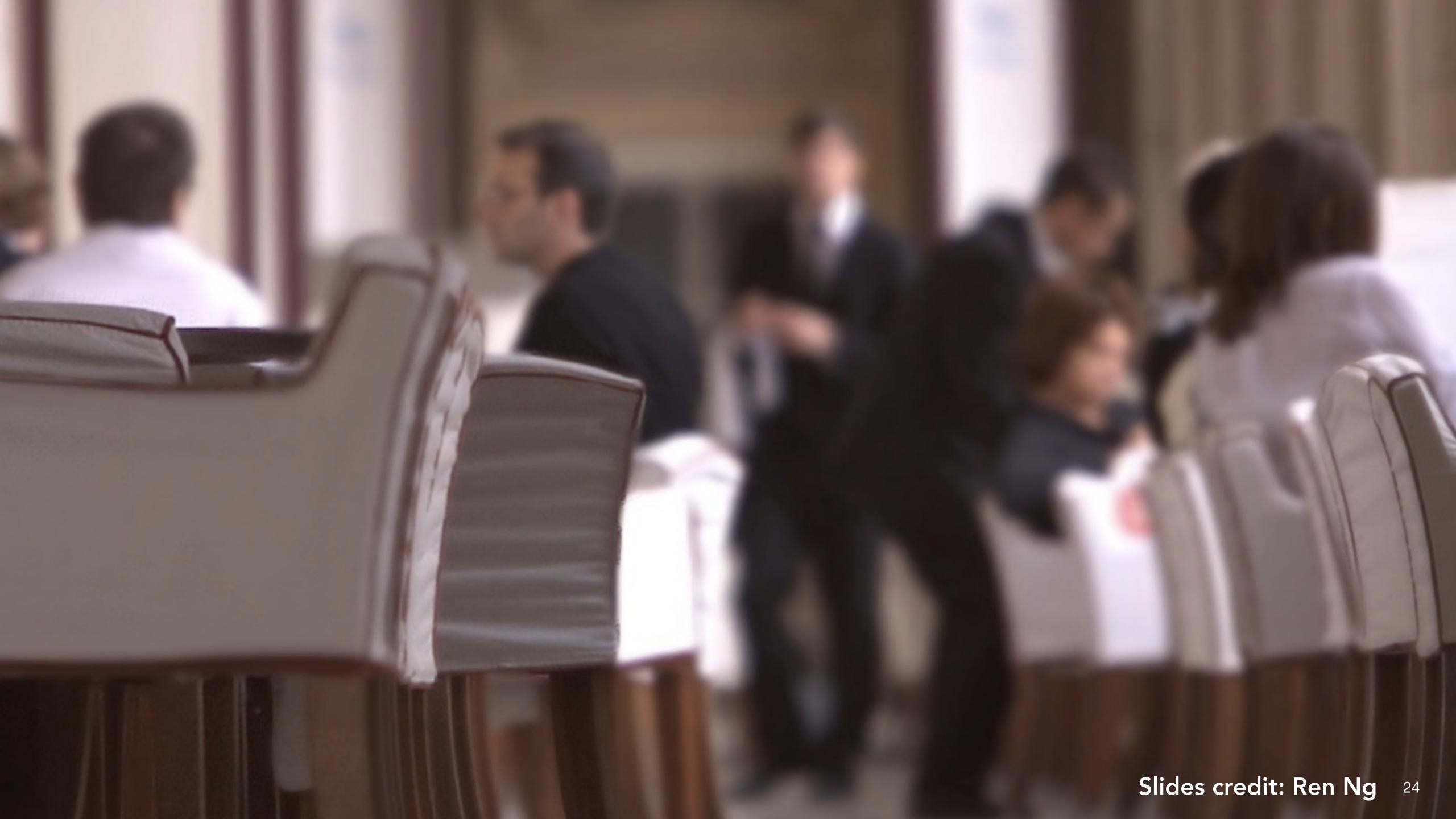










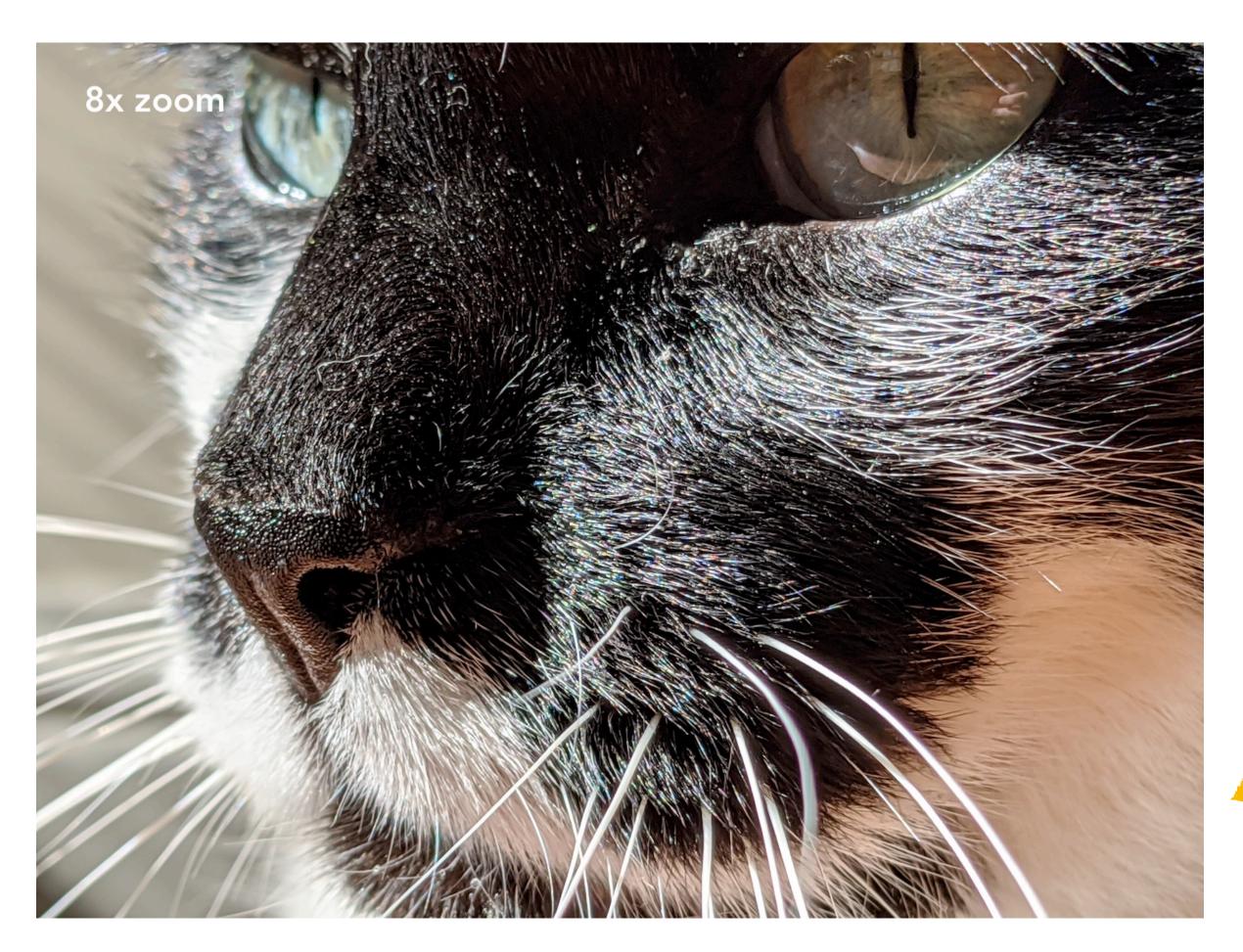


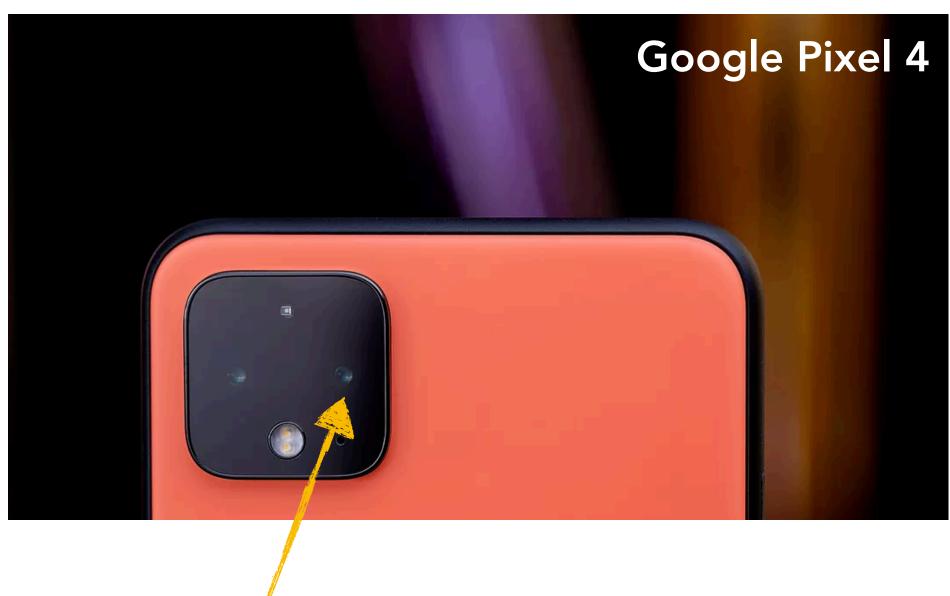


Traditional Telephoto (Long-Focus) Lens



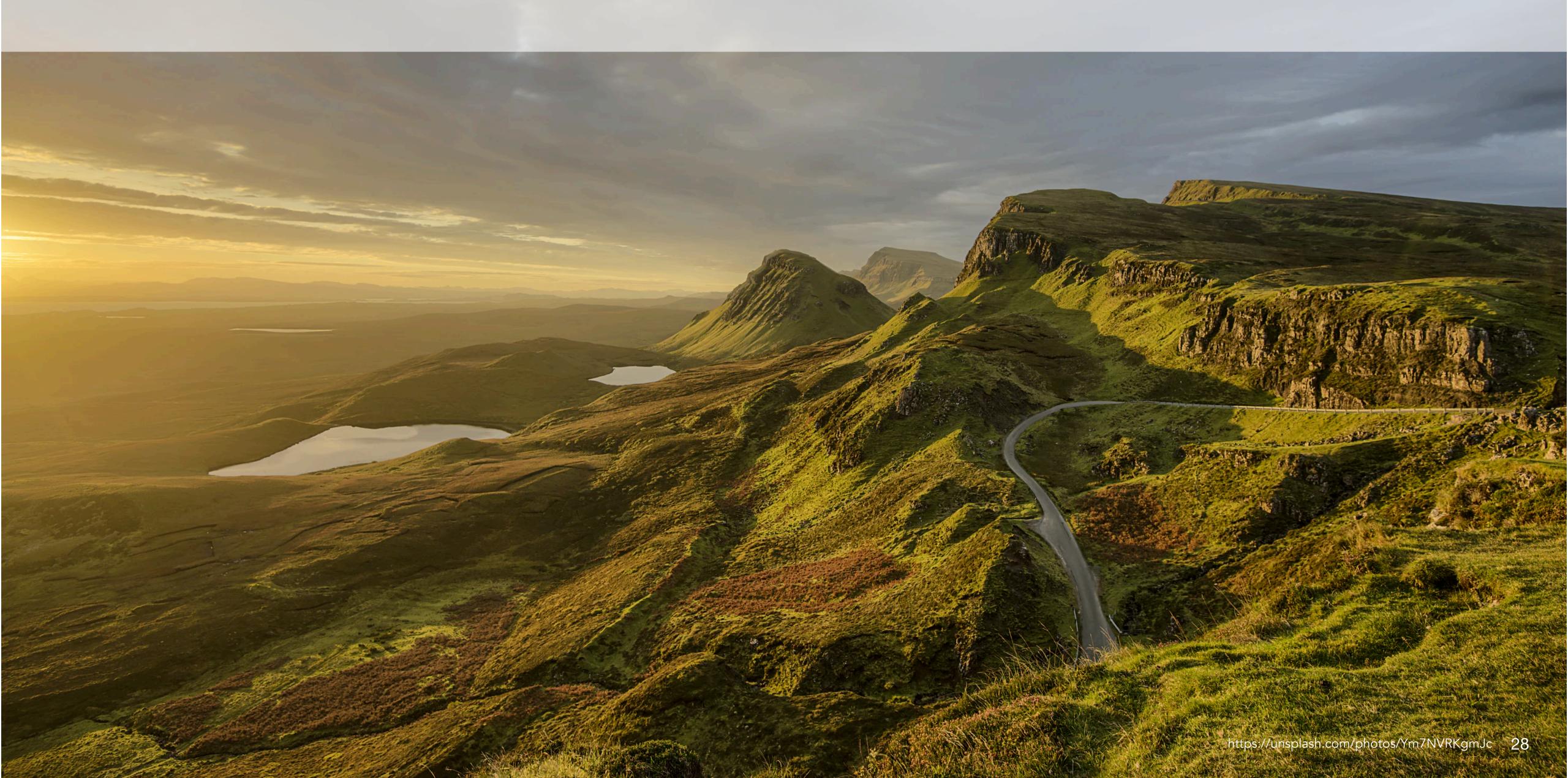
Telephoto (Long-Focus) "Lens" in Smartphones





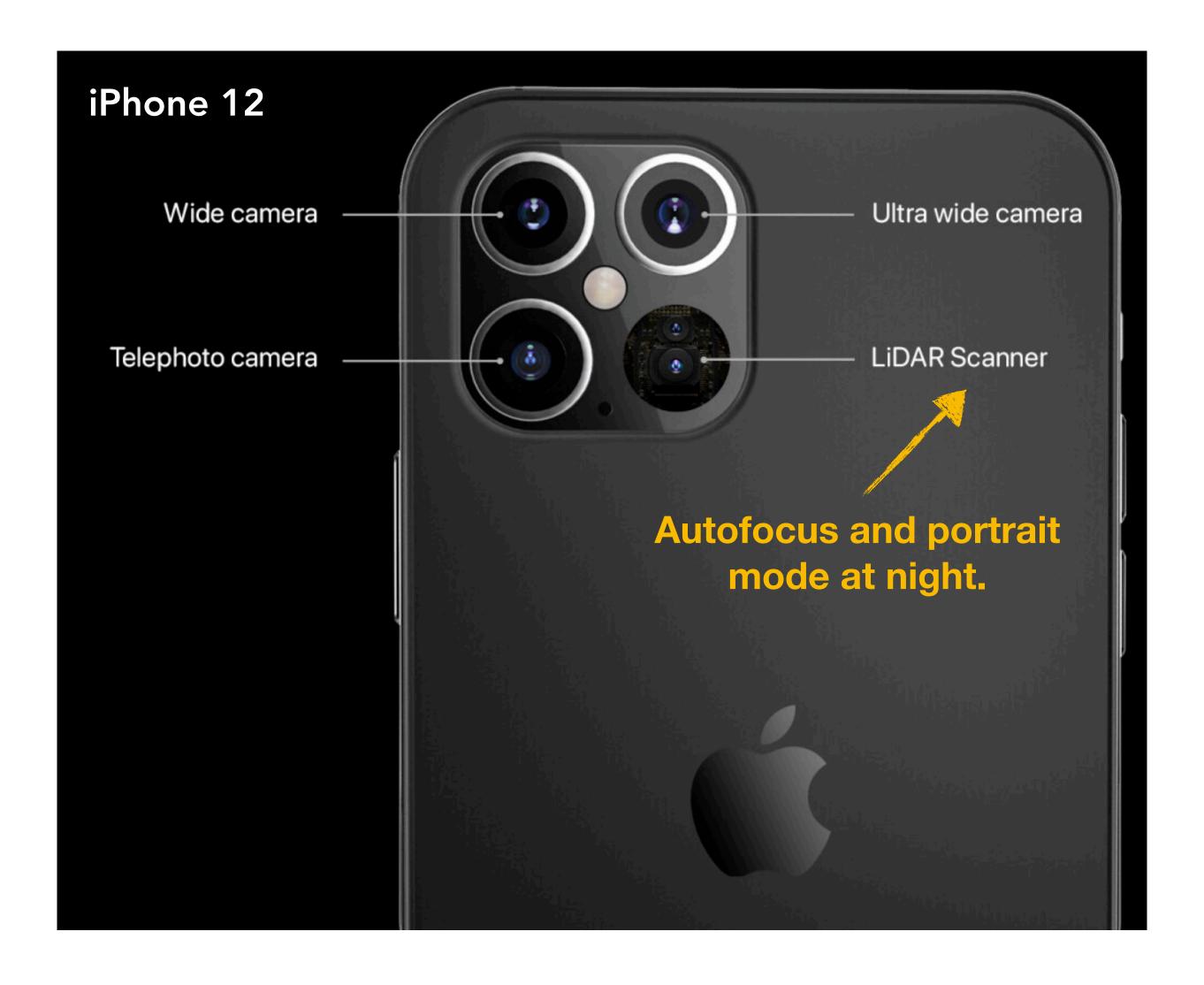
Telephoto lens (f = 48 mm) + computational photography algorithm for super resolution

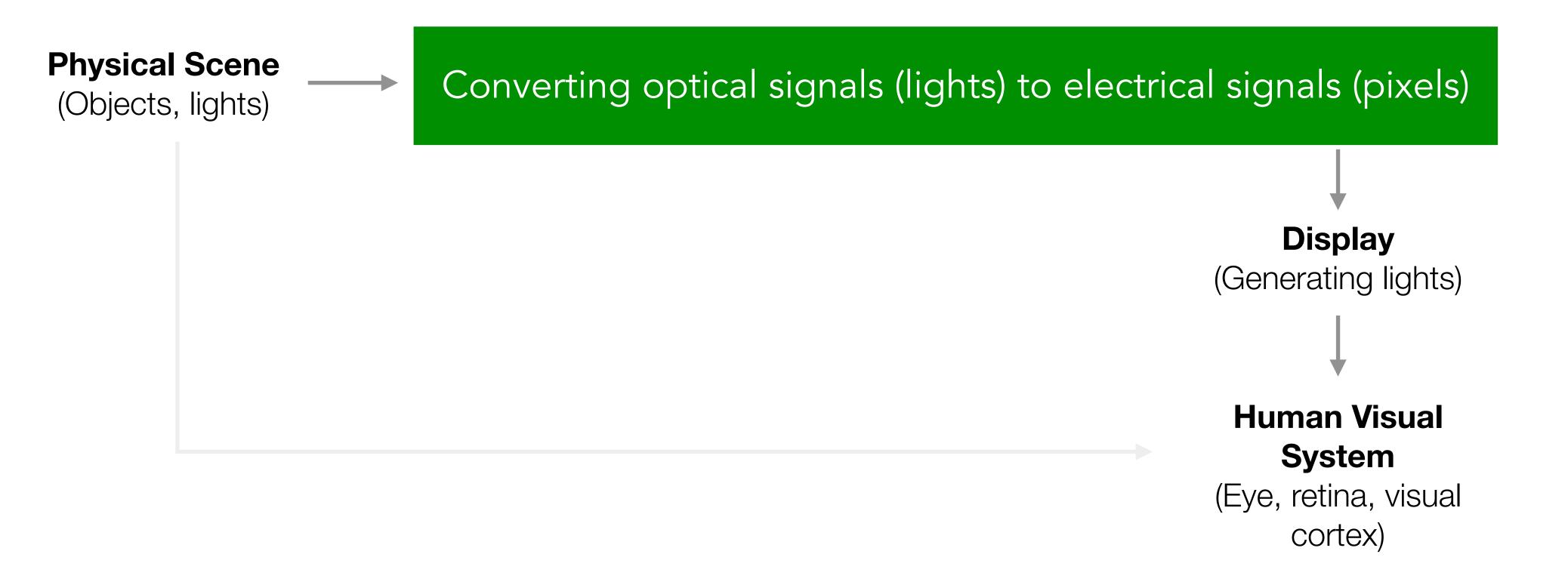
Wide Field-of-View





Cameras in Modern Smartphones





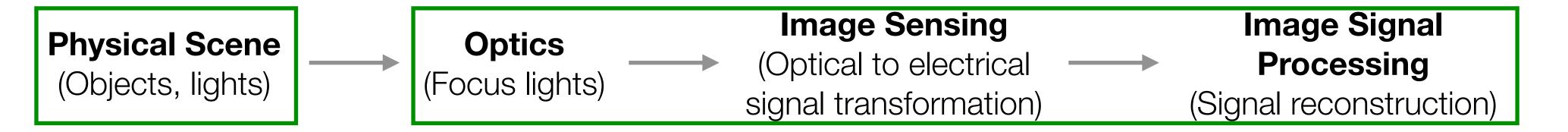




Real-Time Photorealistic Rendering (e.g., Gaming)



Graphics and Rendering



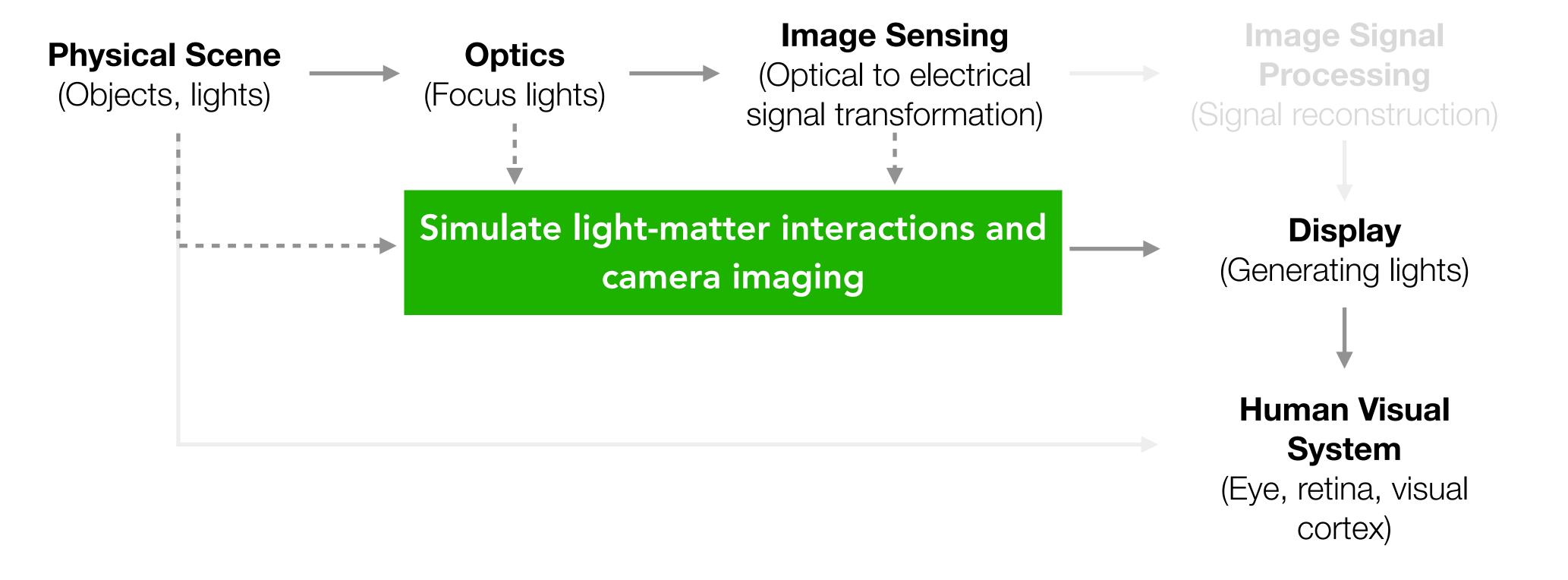
Why do those images look "real" to you?

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

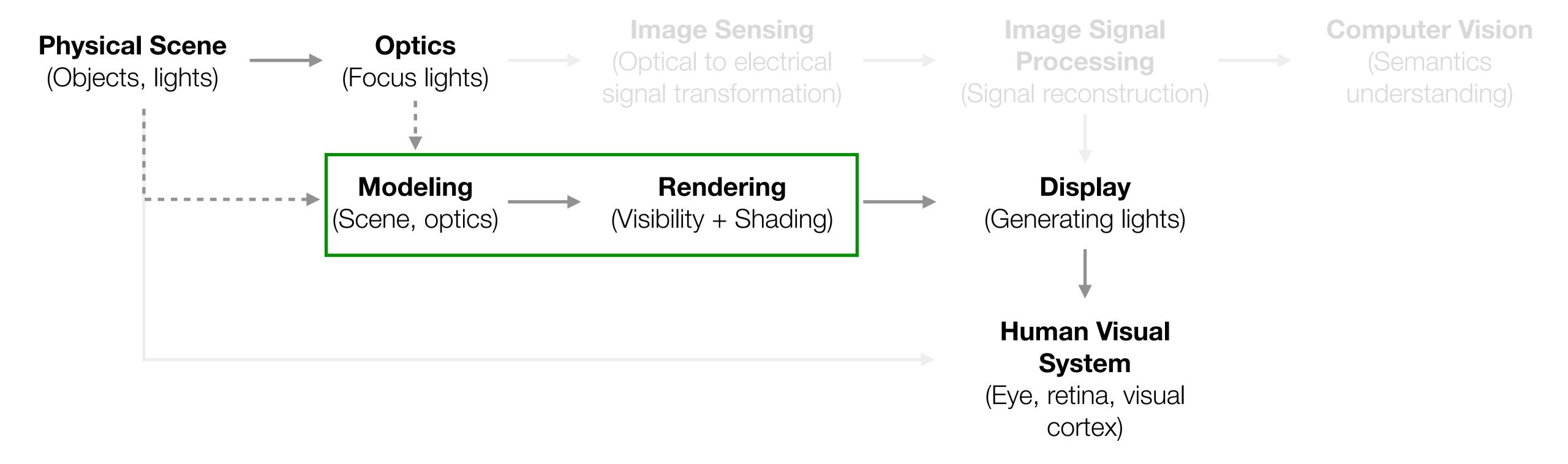
Photorealistic rendering is a simulation of:

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

Graphics and Rendering



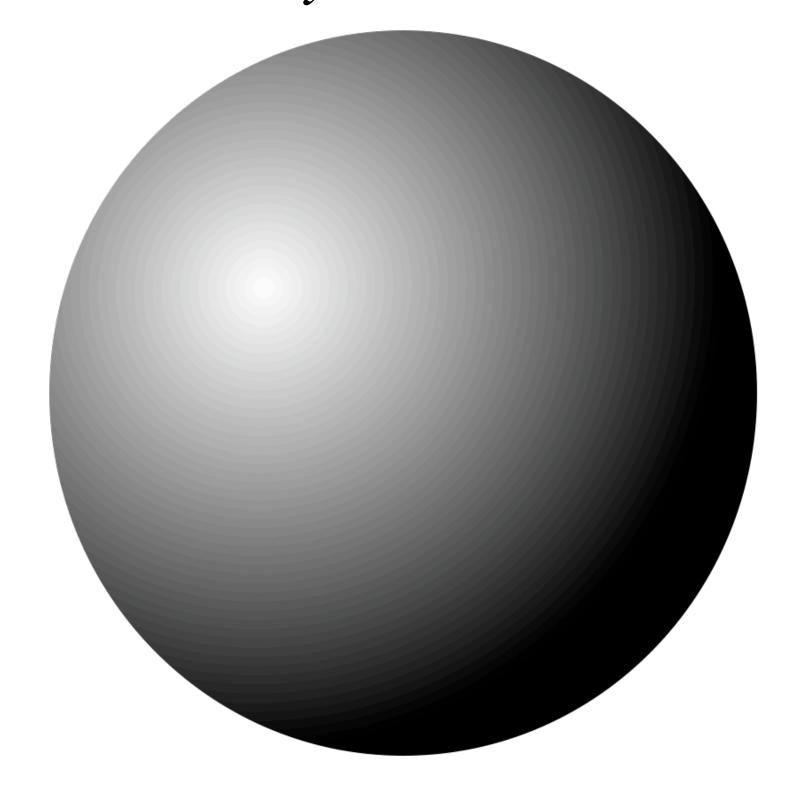
Graphics and Rendering



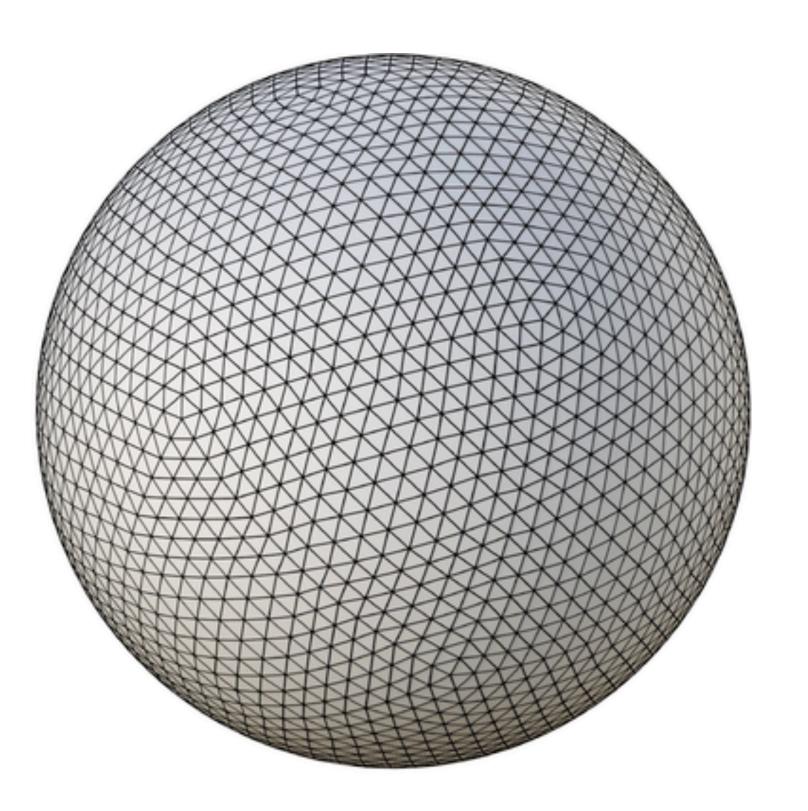
3D Modeling

Parametric surface

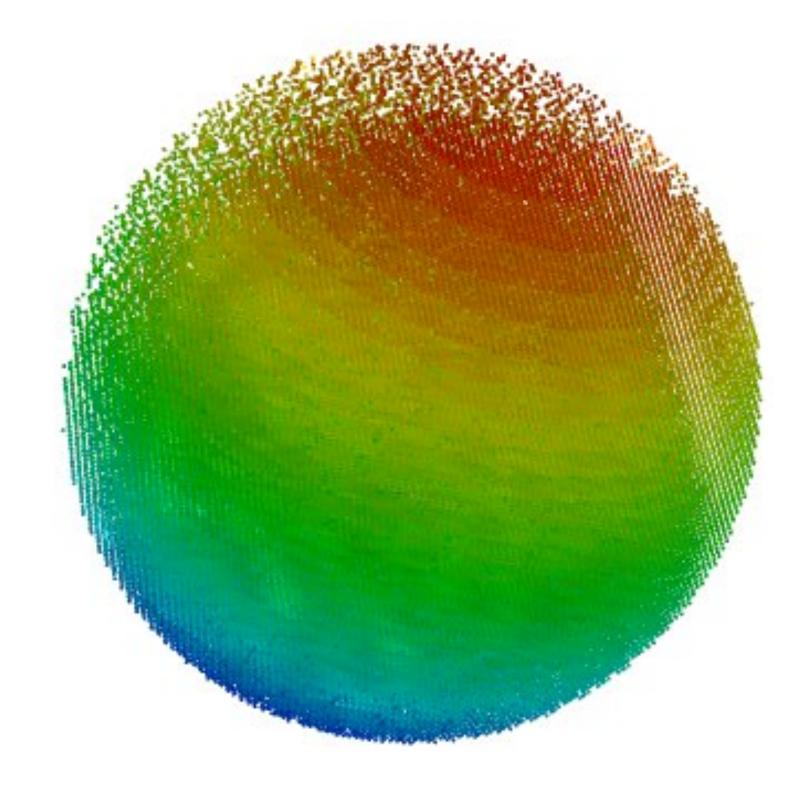
$$x^2 + y^2 + z^2 = R^2$$



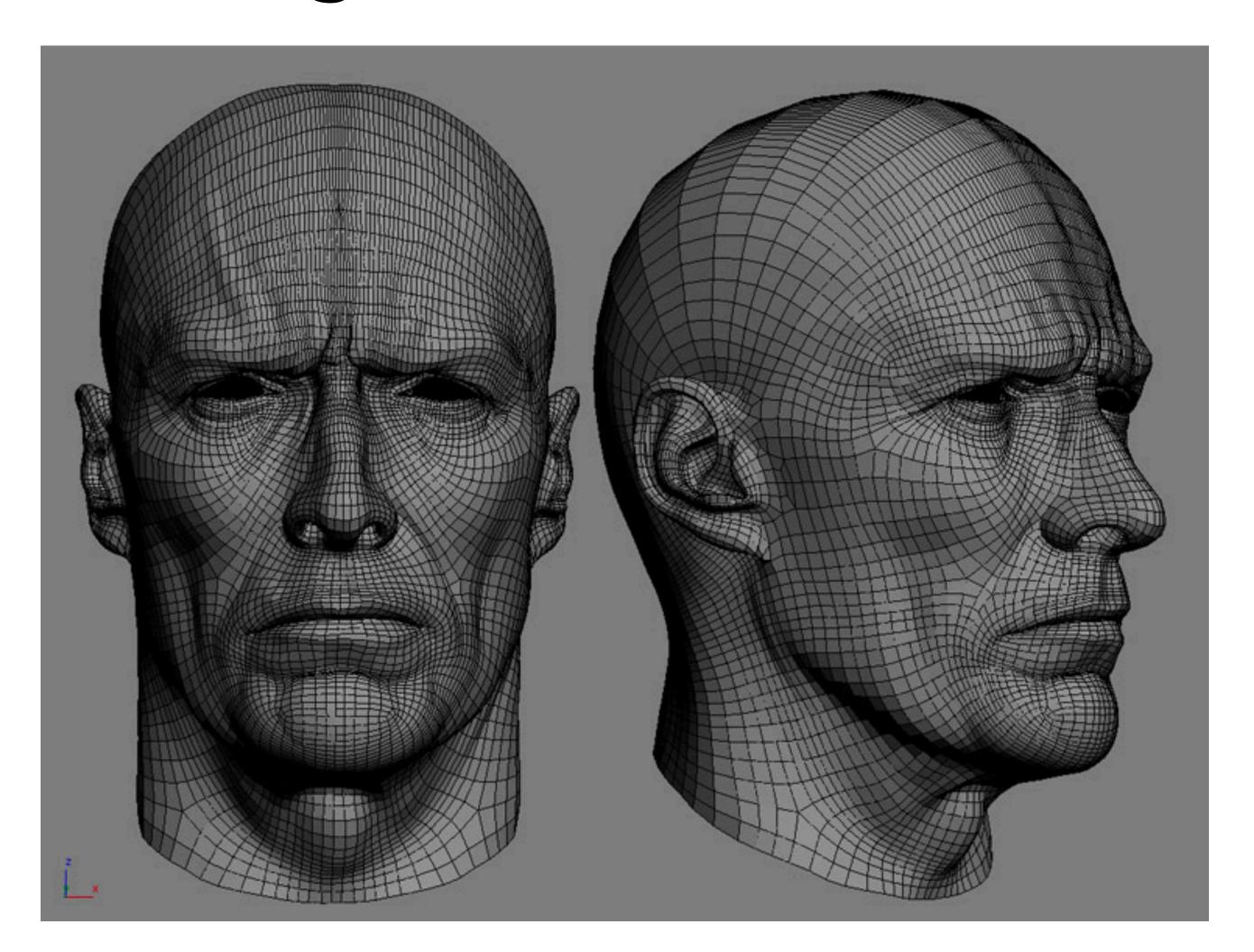
Polygon mesh

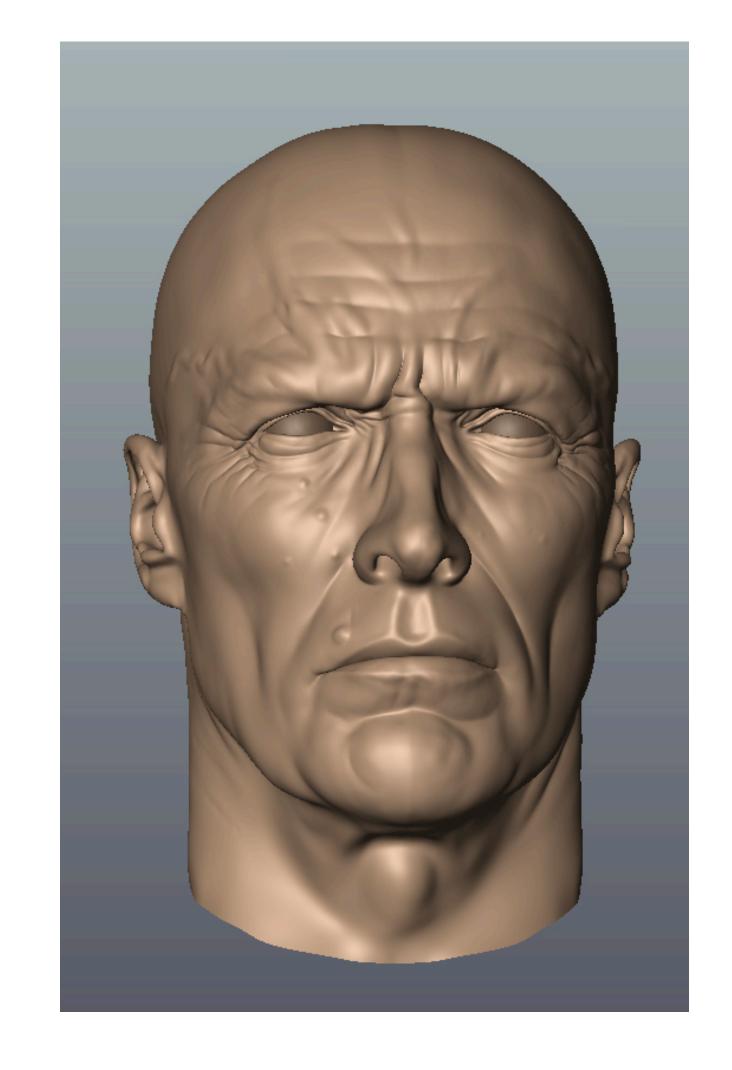


Point cloud

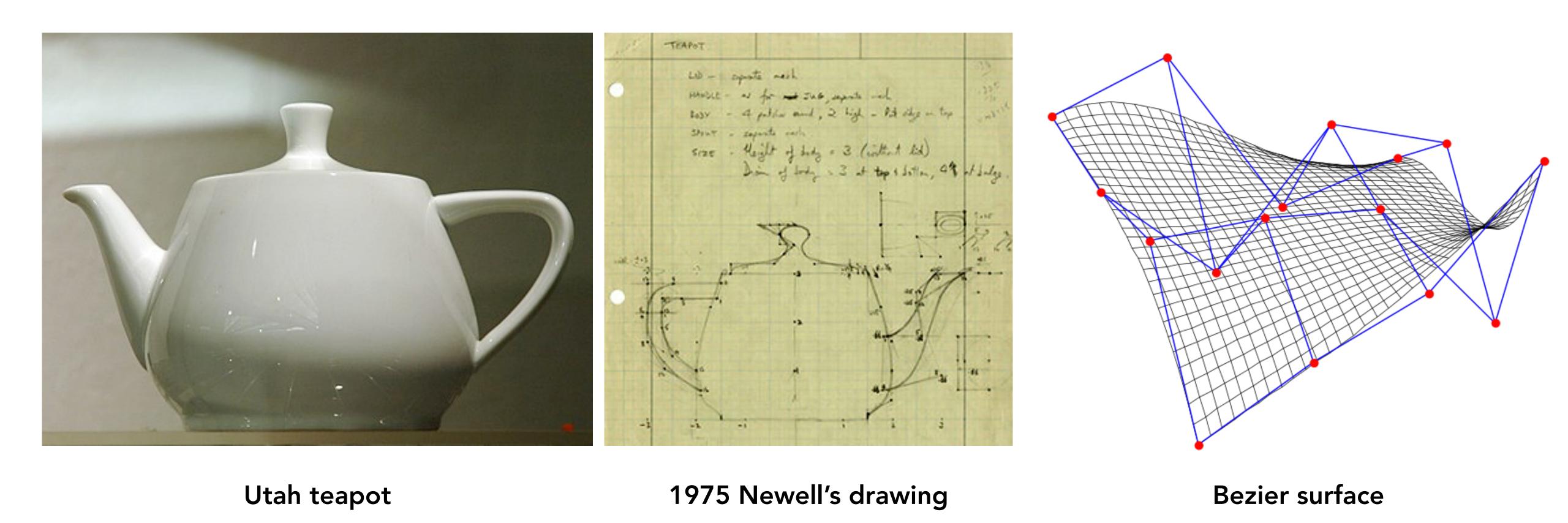


Modeling: Mesh

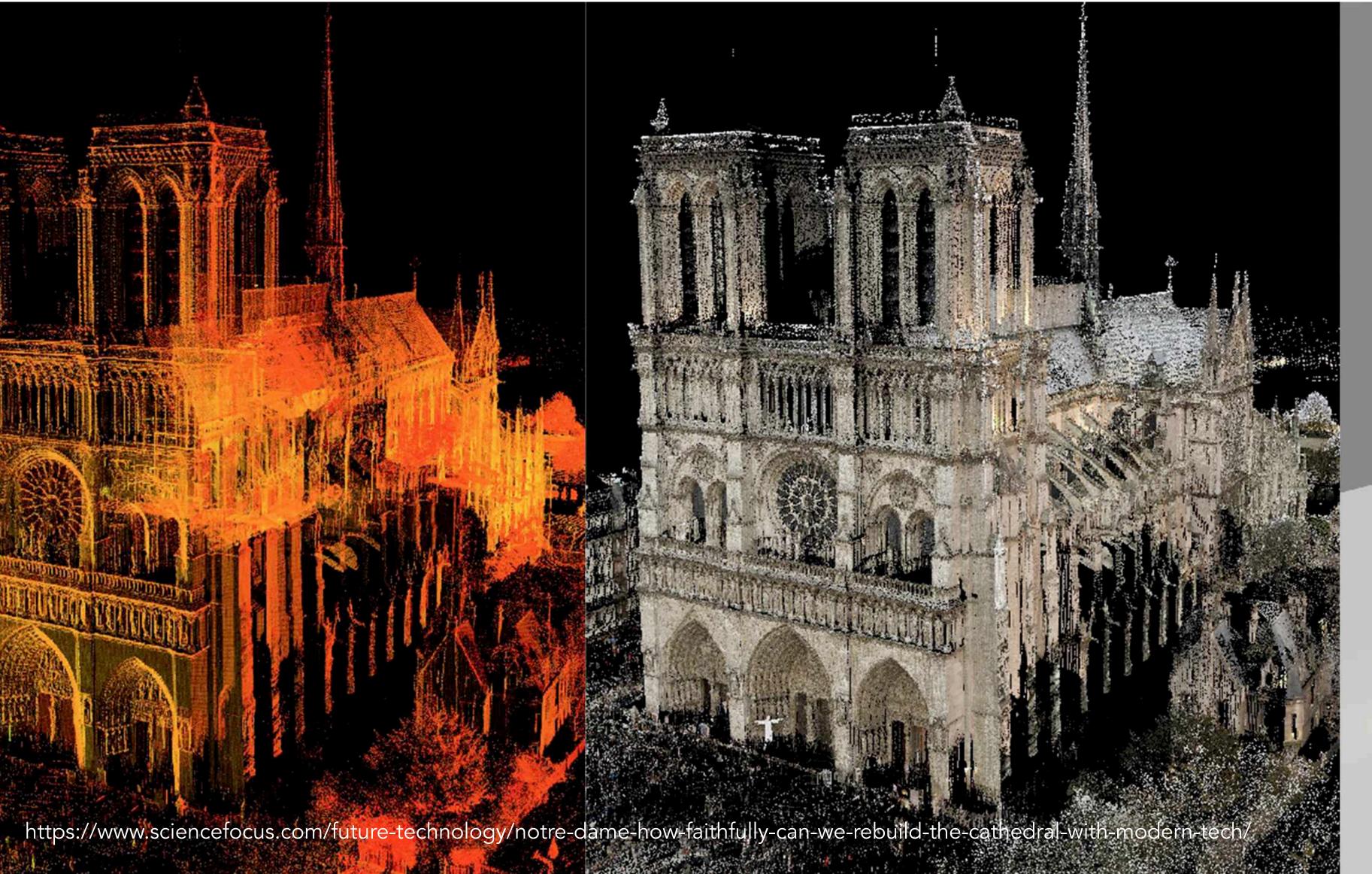


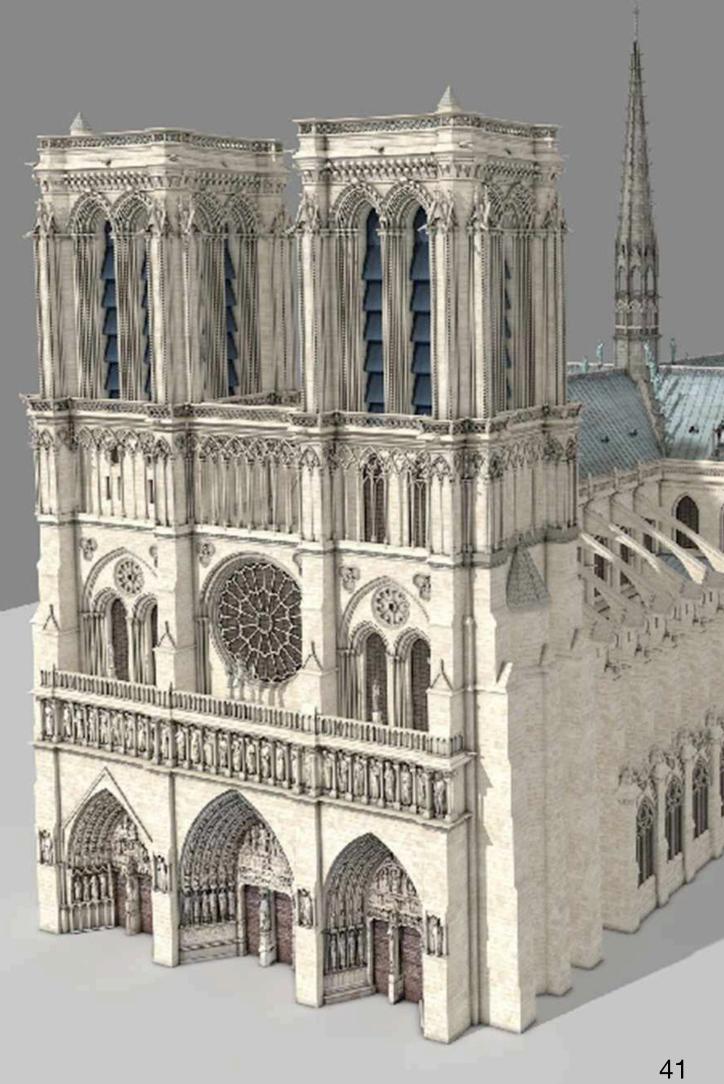


Modeling: Parametric Surface



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)**

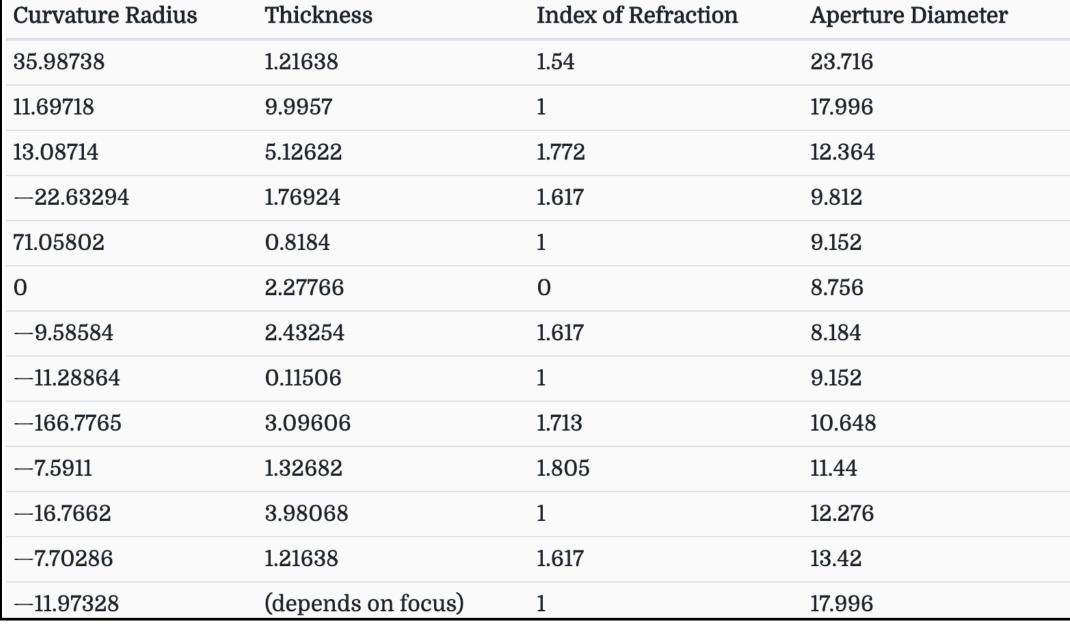


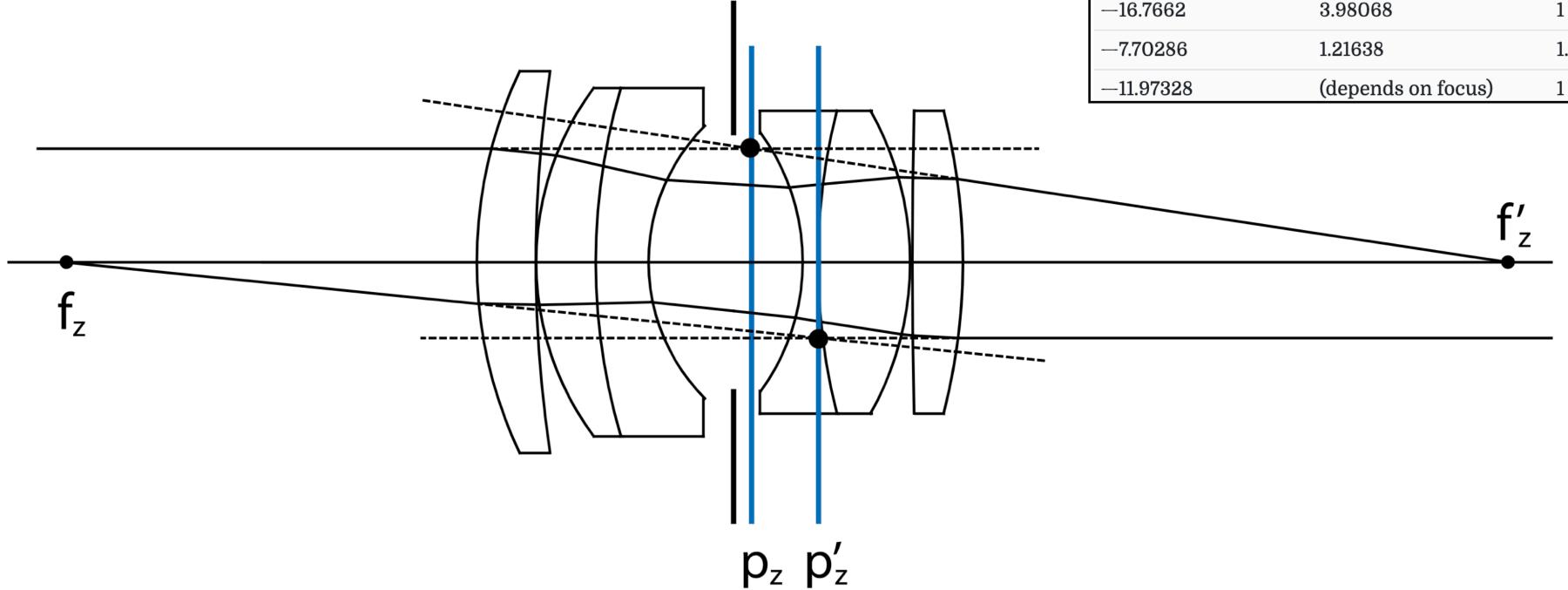




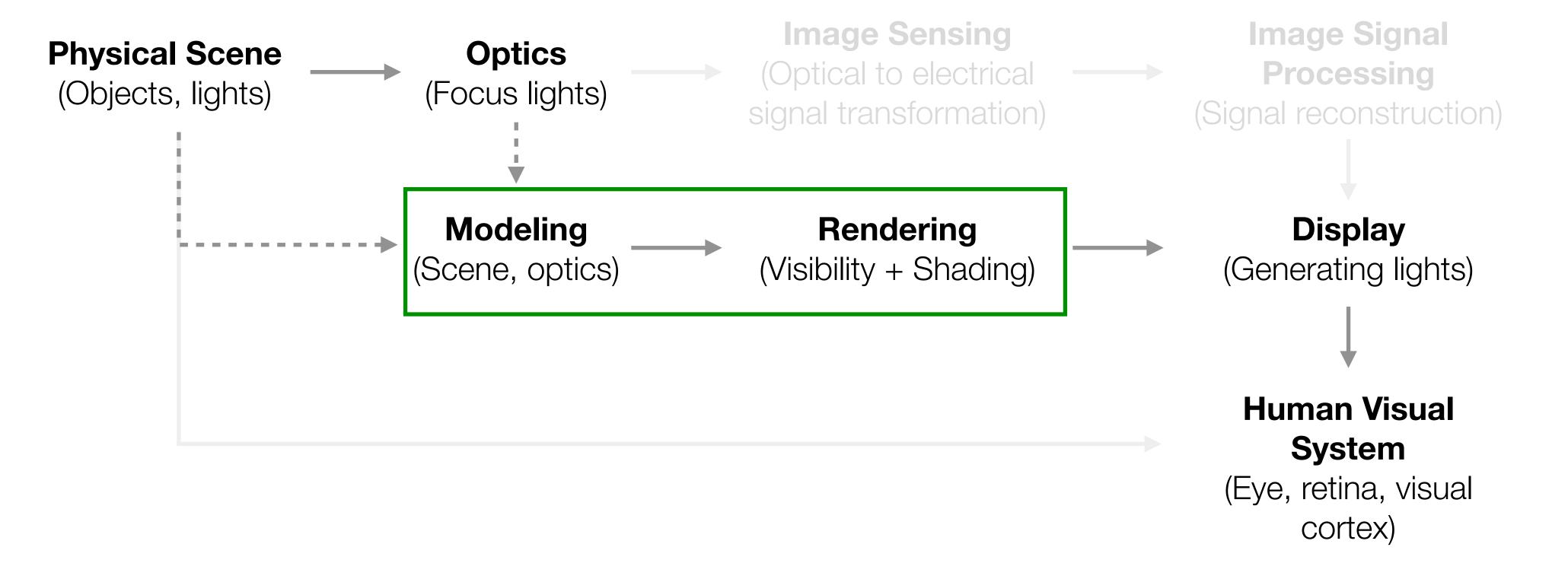


Modeling Optics



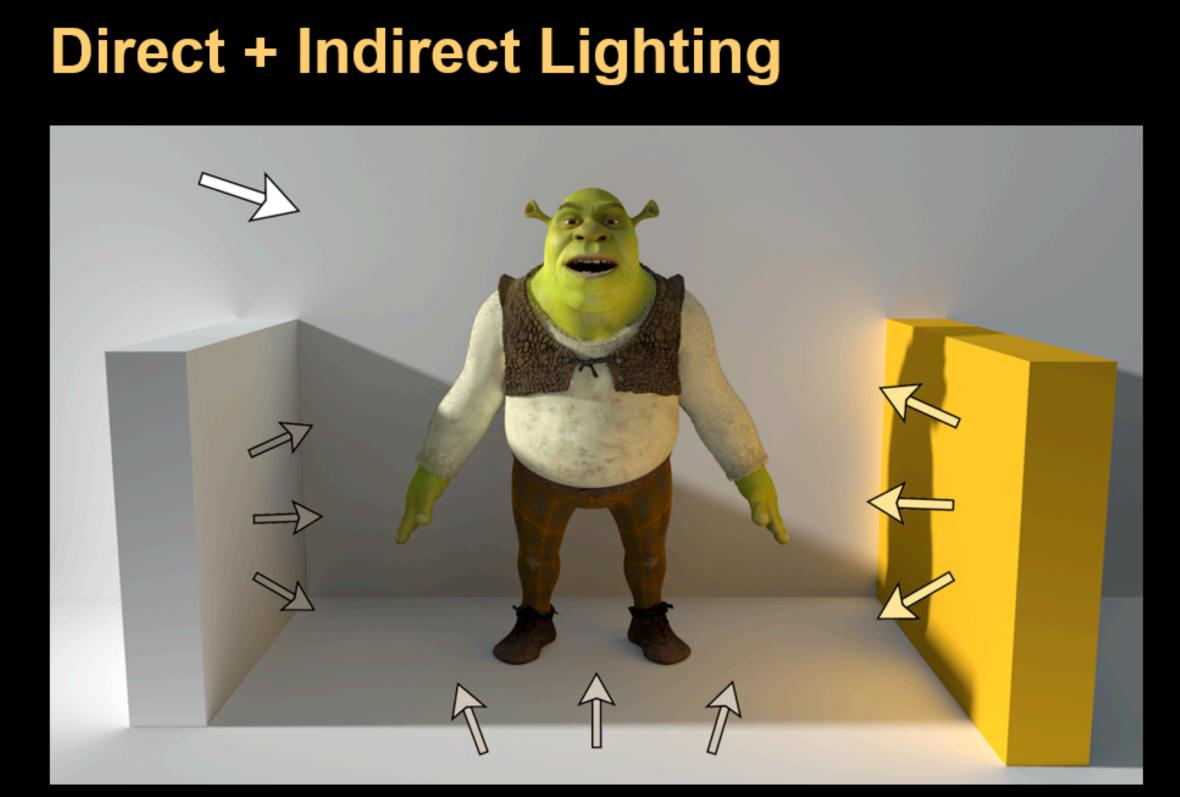


Graphics Rendering



Modeling Light Transport









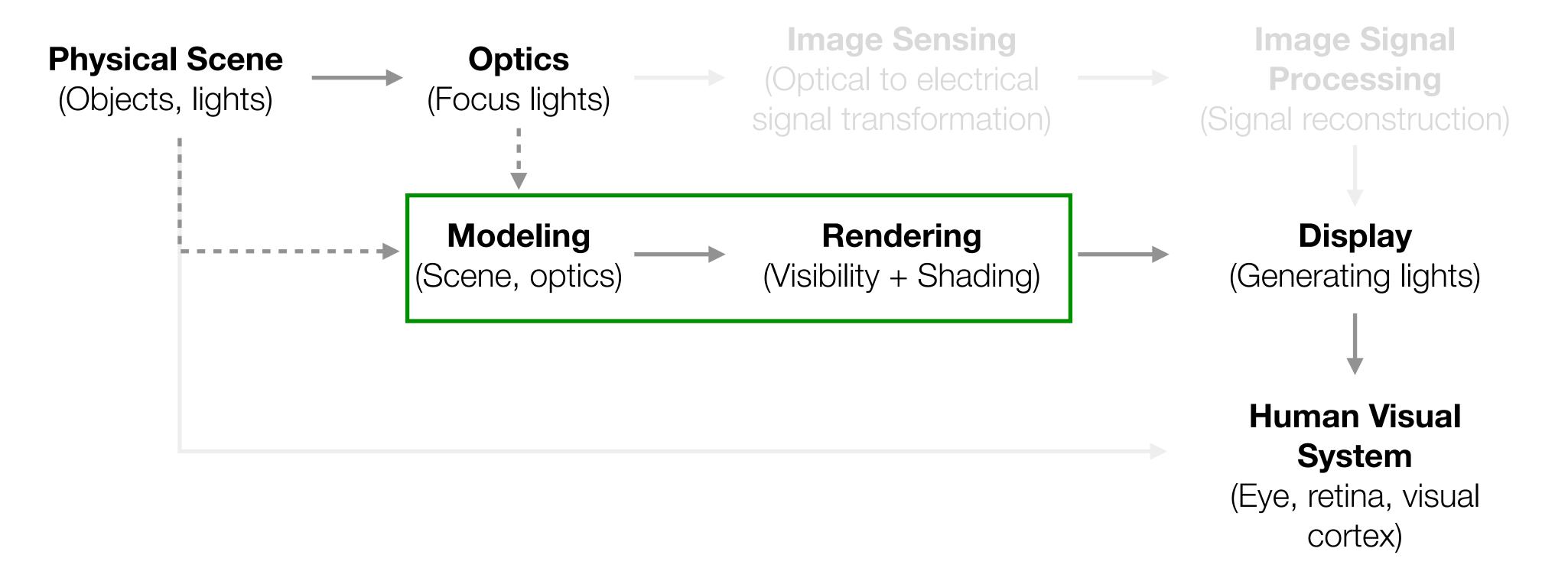








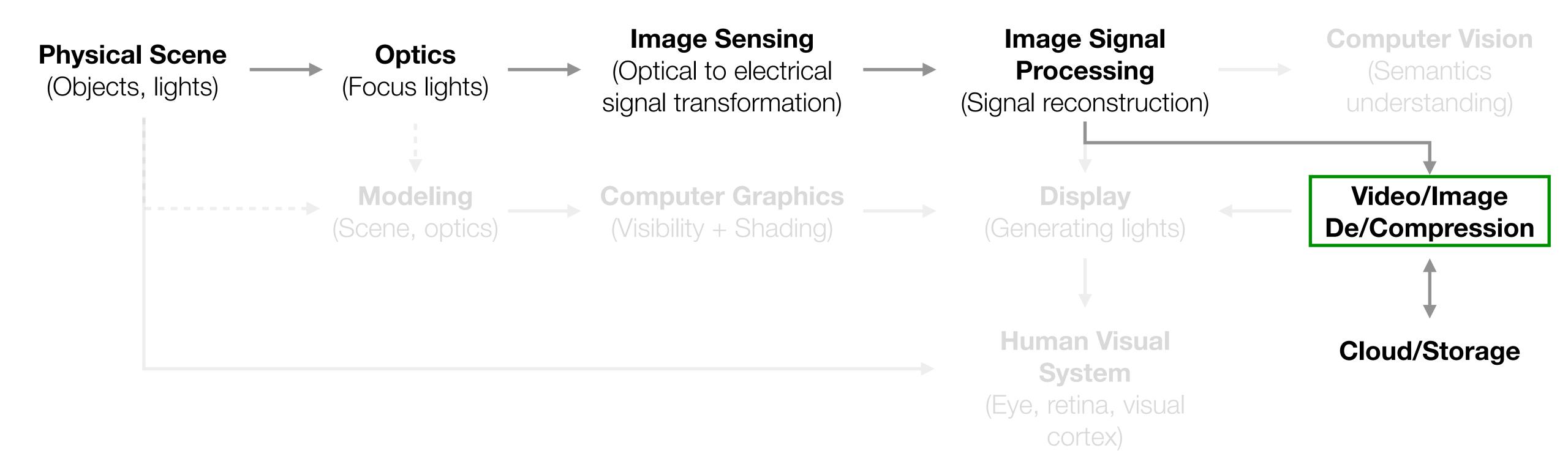
Graphics Rendering: Not All About Photorealism







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).

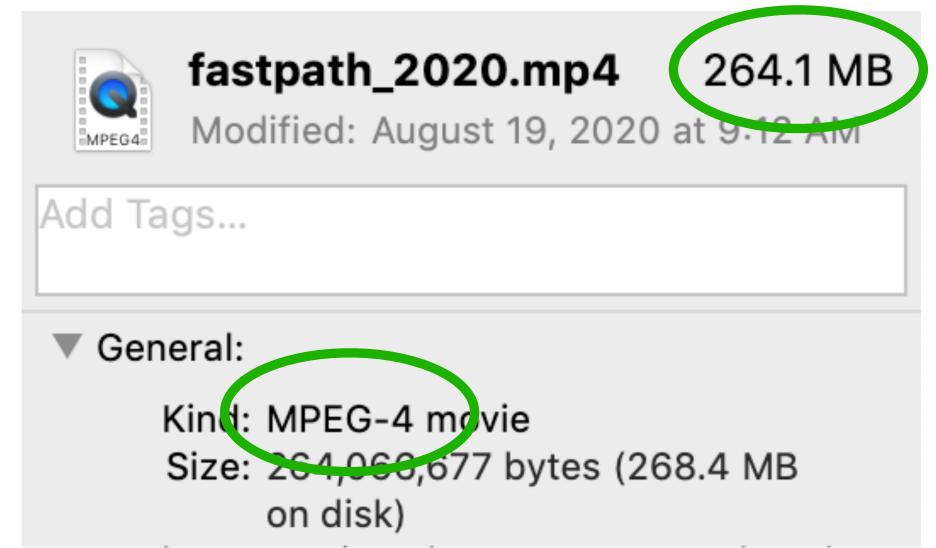
Compression/encoding done in real-time without you even realizing it!

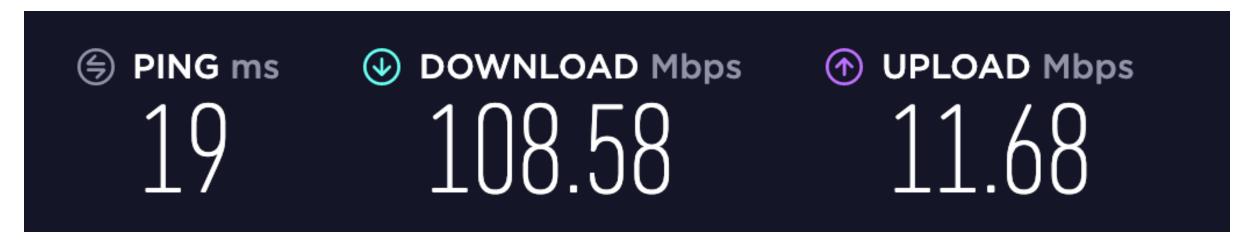




Video Compression



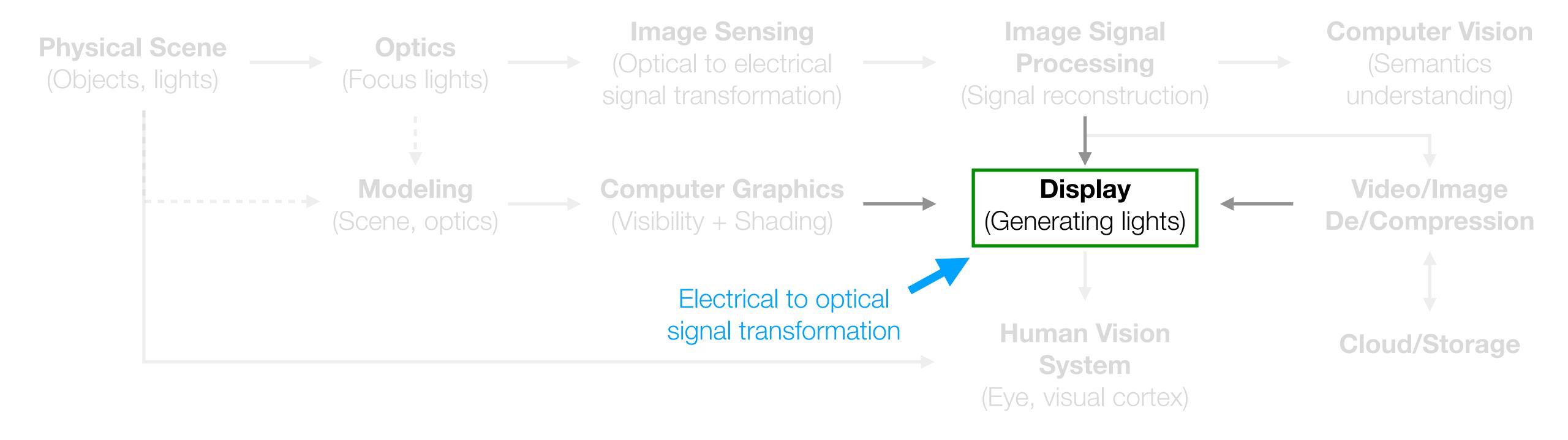




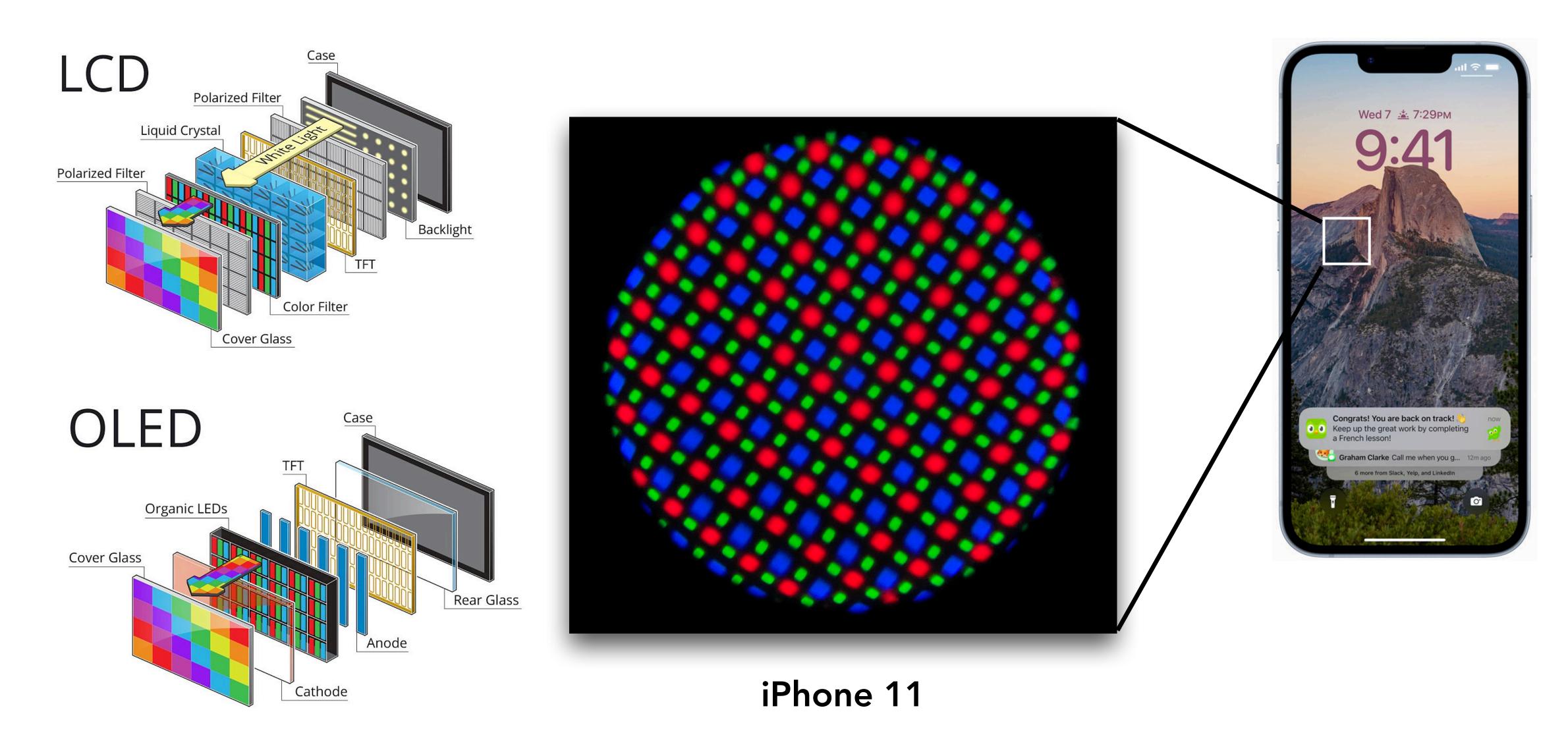
WiFi bandwidth test at my home



Scope of the Course



Display: Transform Electrical Signals to Optical Signals



Holographic Display

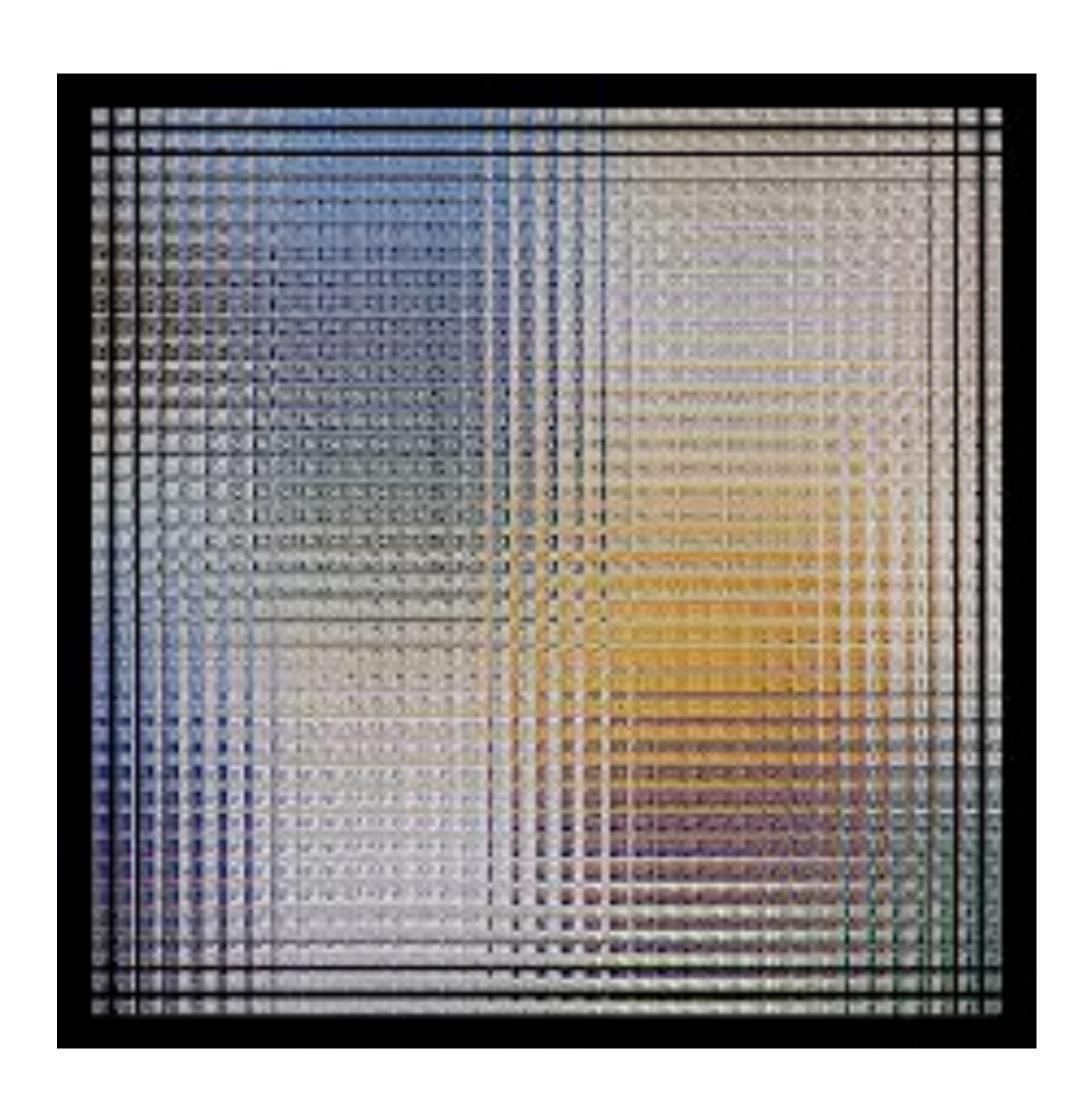


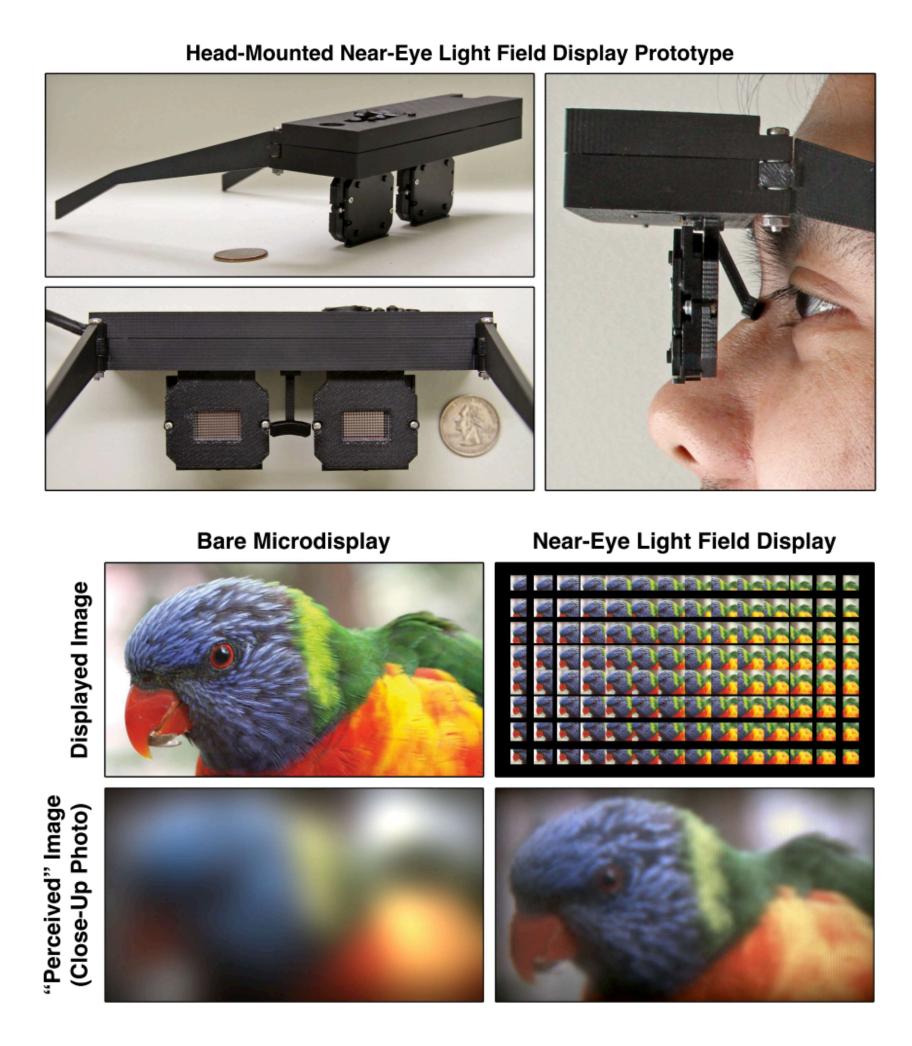


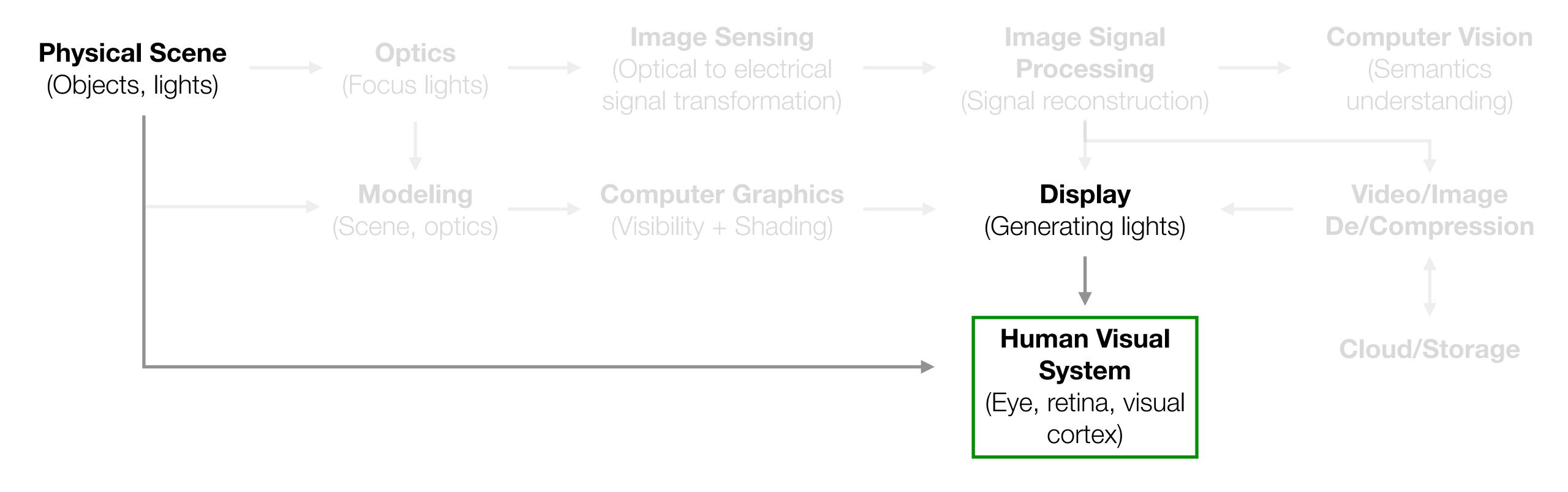
Sequence filmed with 4DViews' volumetric capture technology



Light-Field Display: One Way Toward Holography



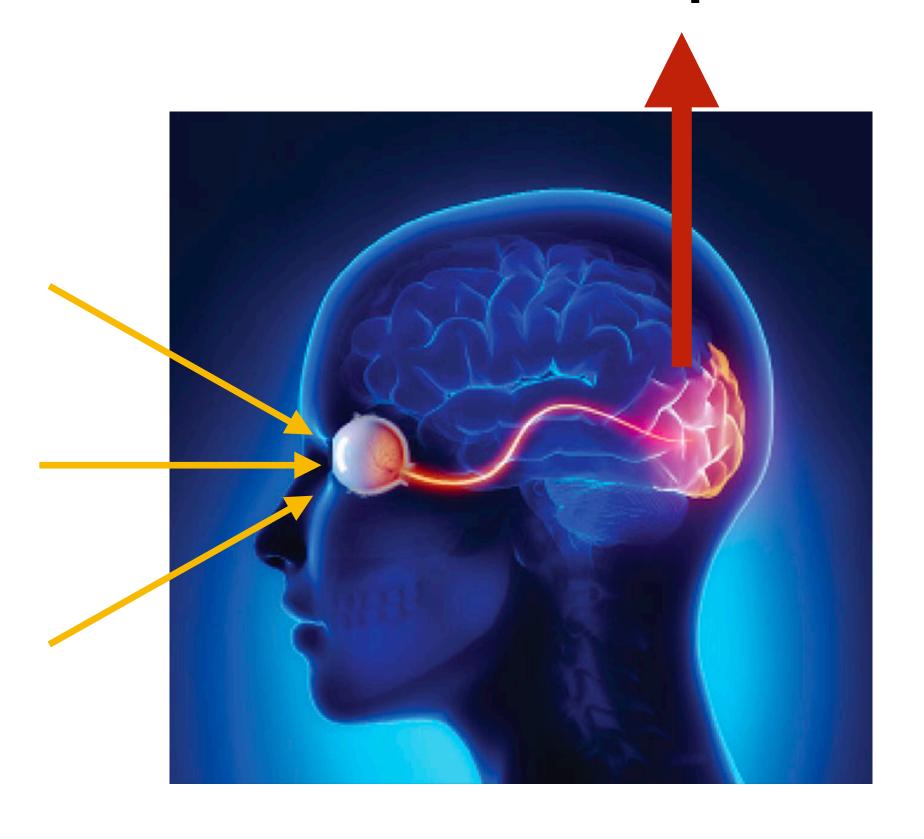




Another sequence of signal transformations

- 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

Perception

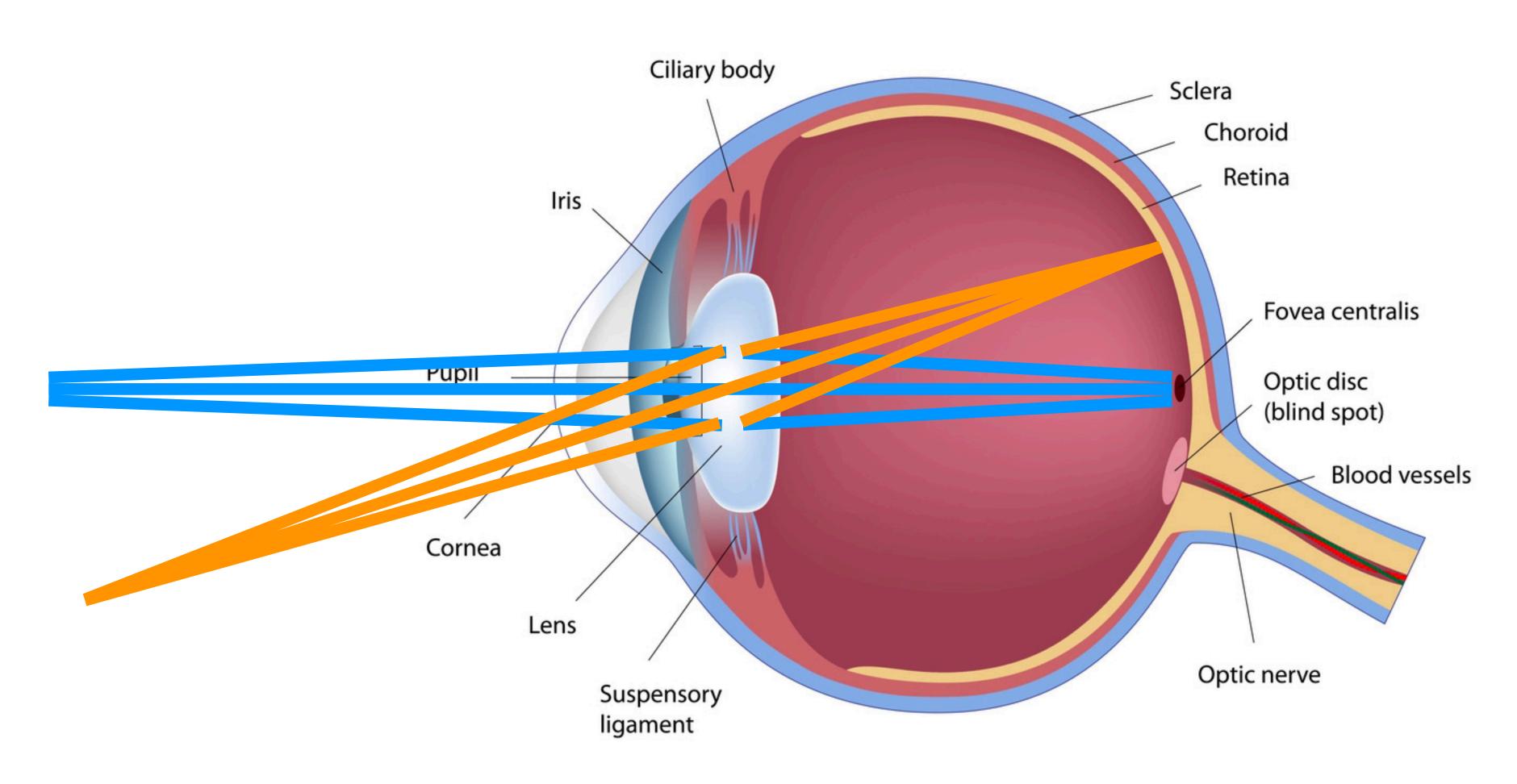


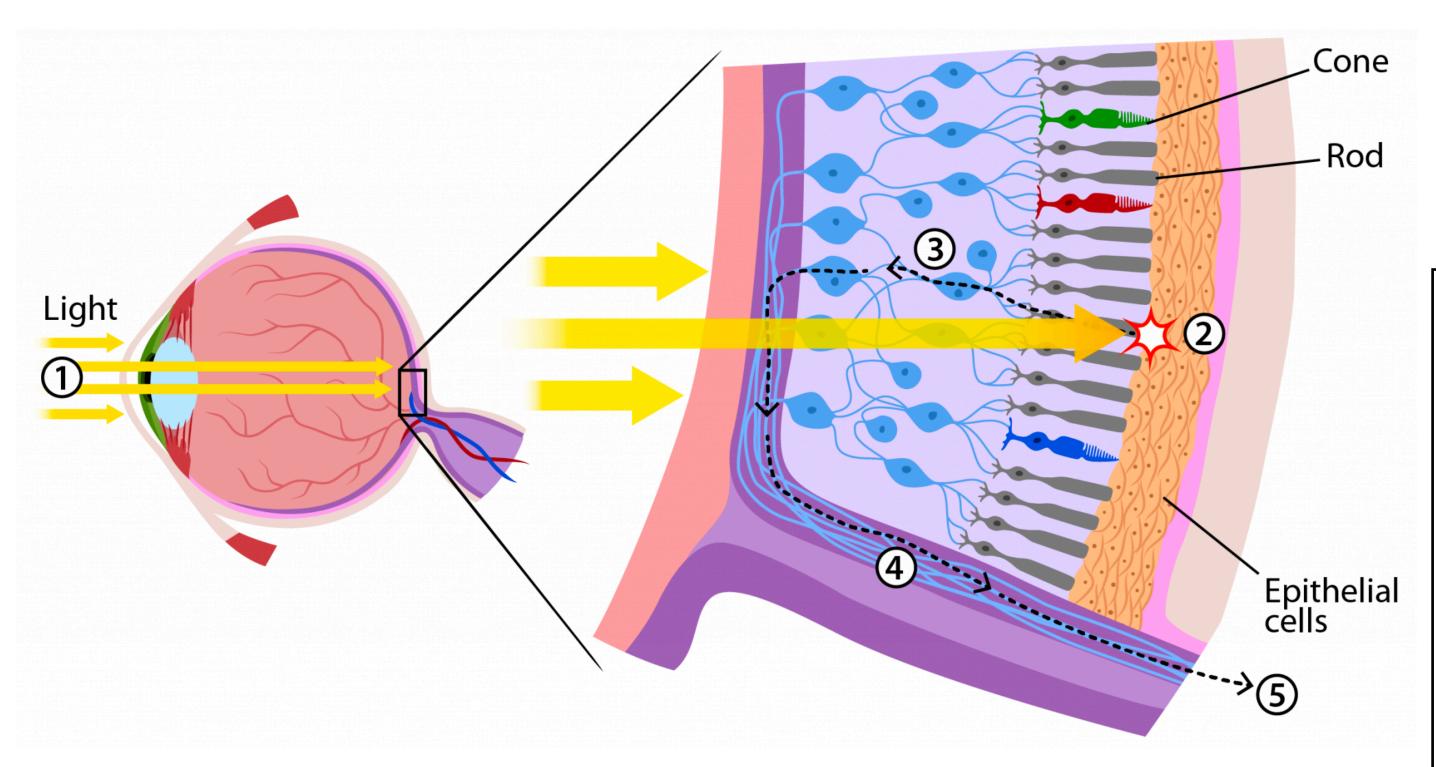


Post-receptor Processing

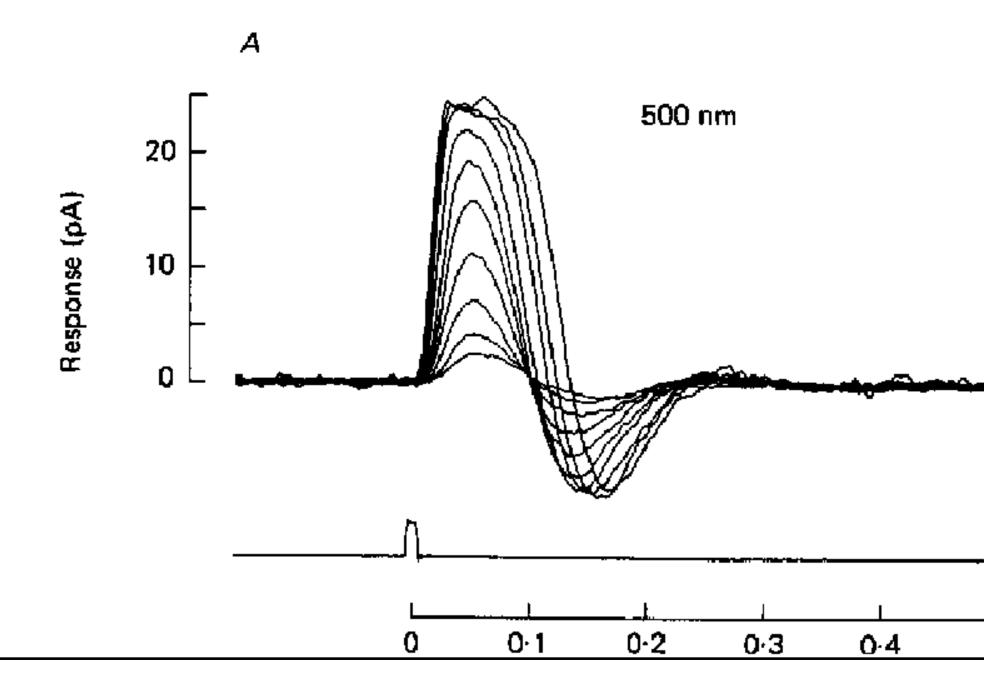
(Electrical to semantics transformation)

Human Eye Anatomy



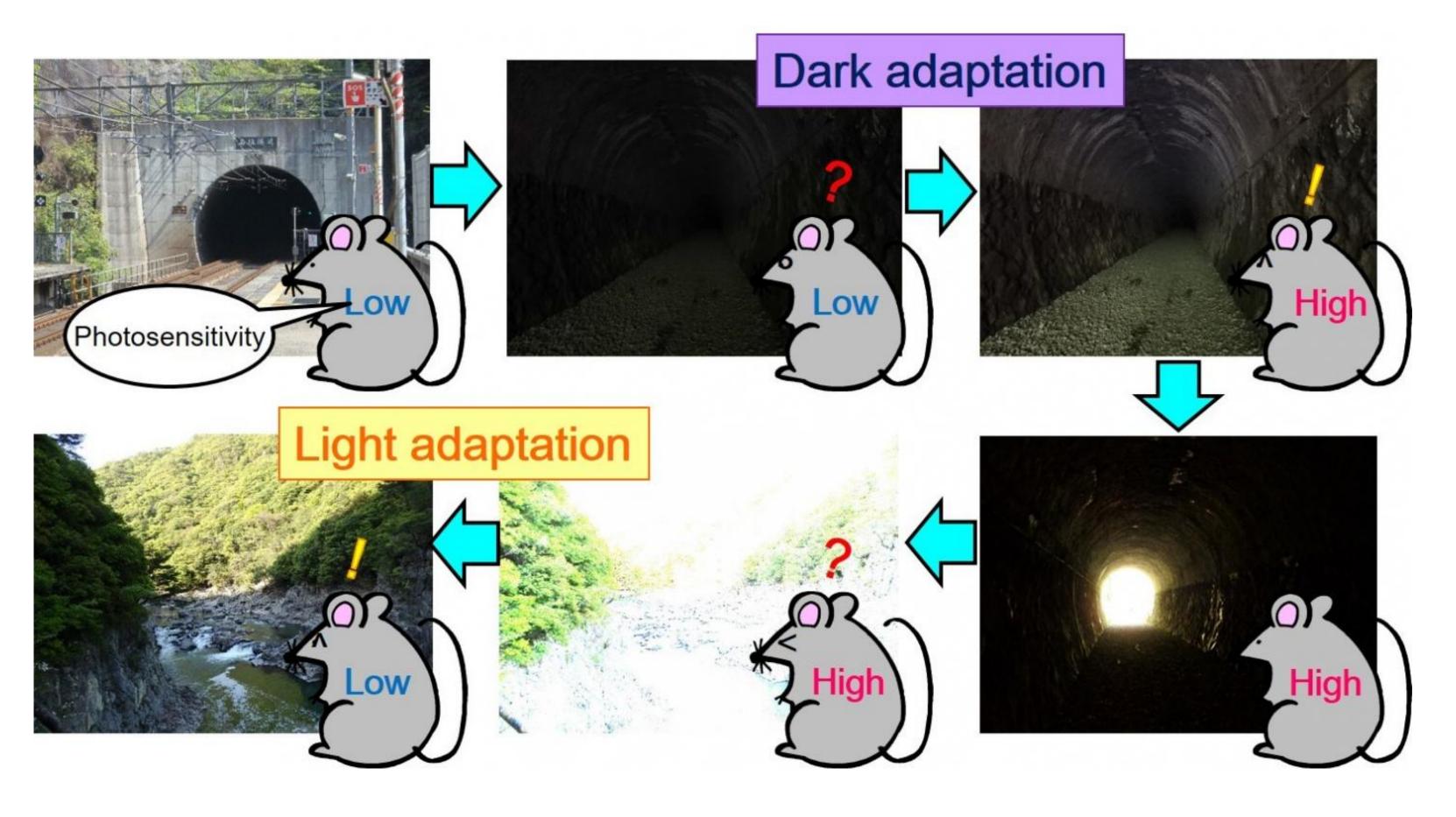


Photocurrents in response to photon absorption



Baylor Nunn and Schnapf, 1987

Light and dark adaptation



Light and dark adaptation

How do we see color?

Why do things have colors anyways?





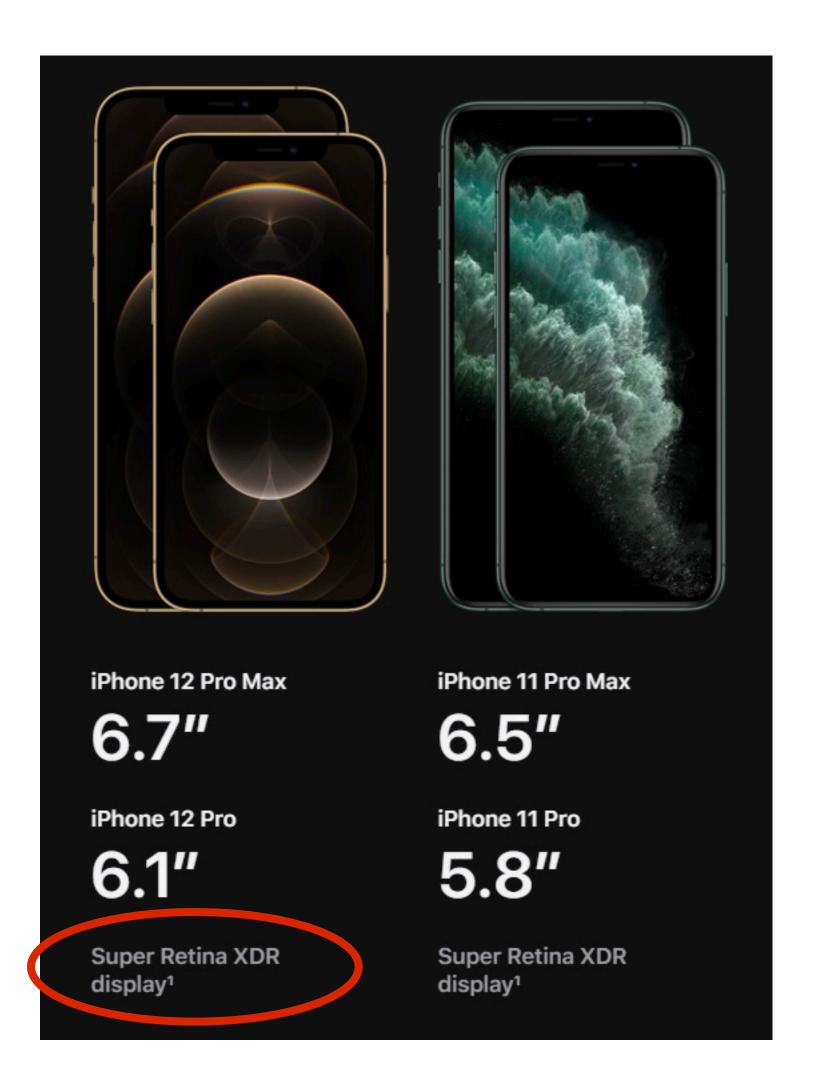
Light and dark adaptation

How do we see color?

Why do things have colors anyways?

What are the limits of human vision?

• Spatial resolution, temporal resolution, etc.



Light and dark adaptation

How do we see color?

Why do things have colors?

What are the limits of human vision?

• Spatial resolution, temporal resolution, etc.

What do color blind people see?



Light and dark adaptation

How do we see color?

Why do things have colors?

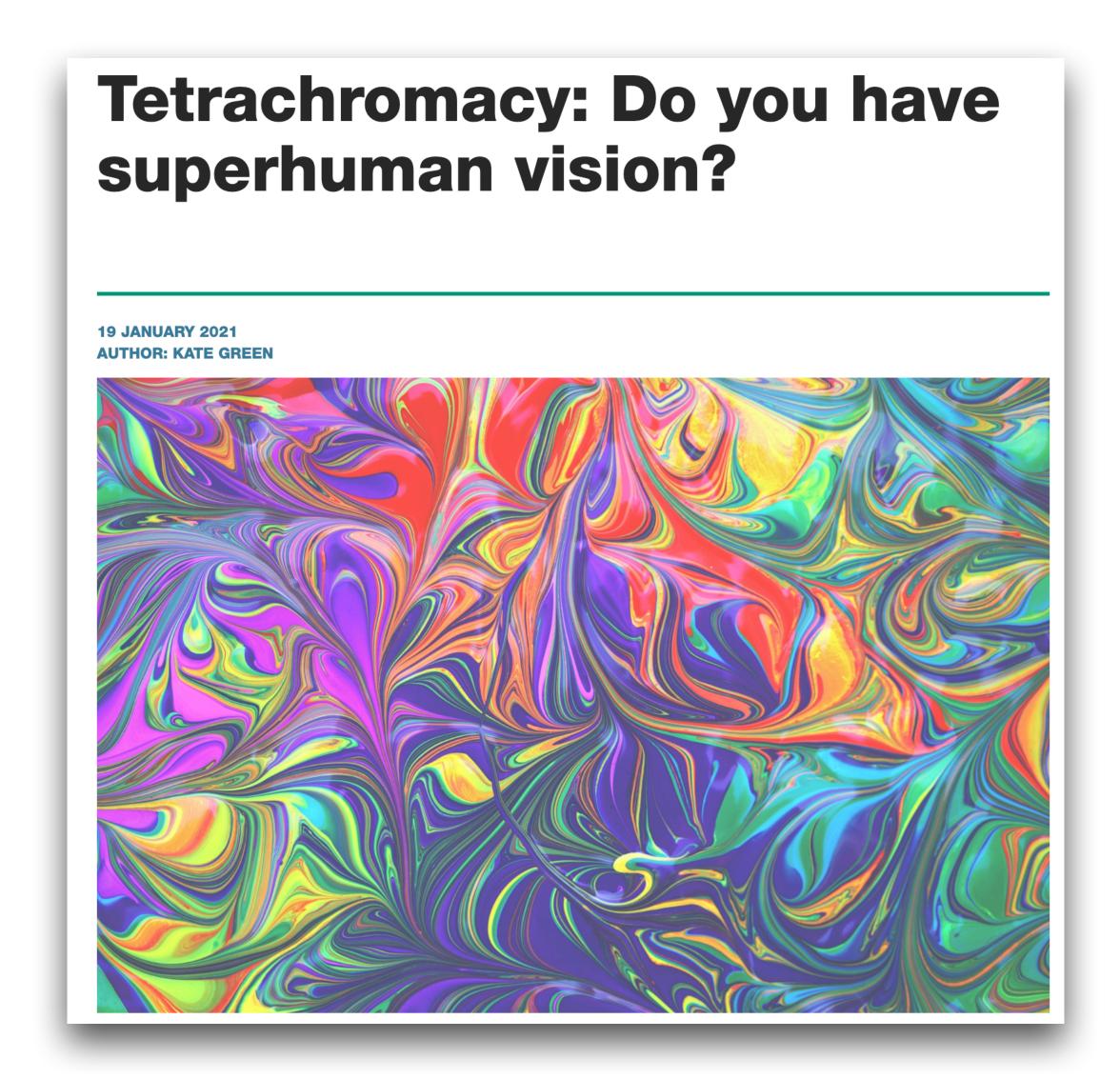
What are the limits of human vision?

Spatial resolution, temporal resolution, etc.

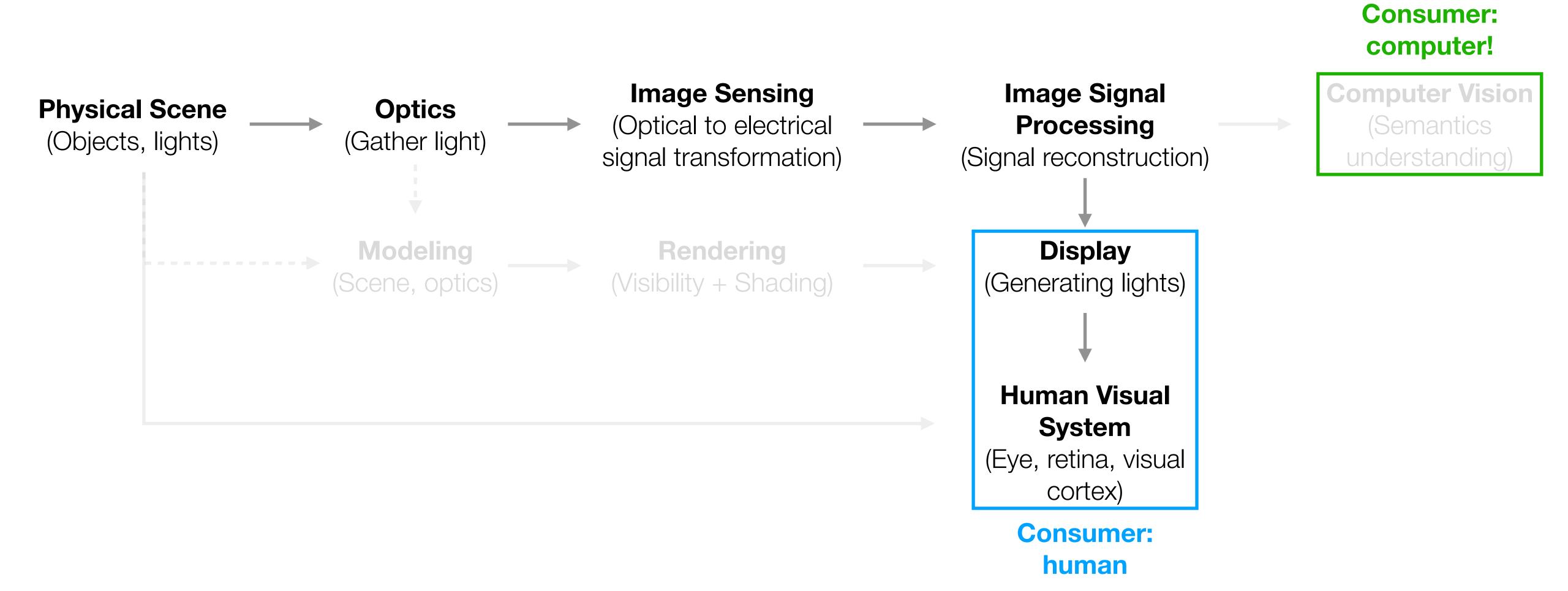
What do color blind people see?

Super-human color vision?

Tetrachromacy, "Imaginary colors"?



Computer Vision: Semantics Understanding



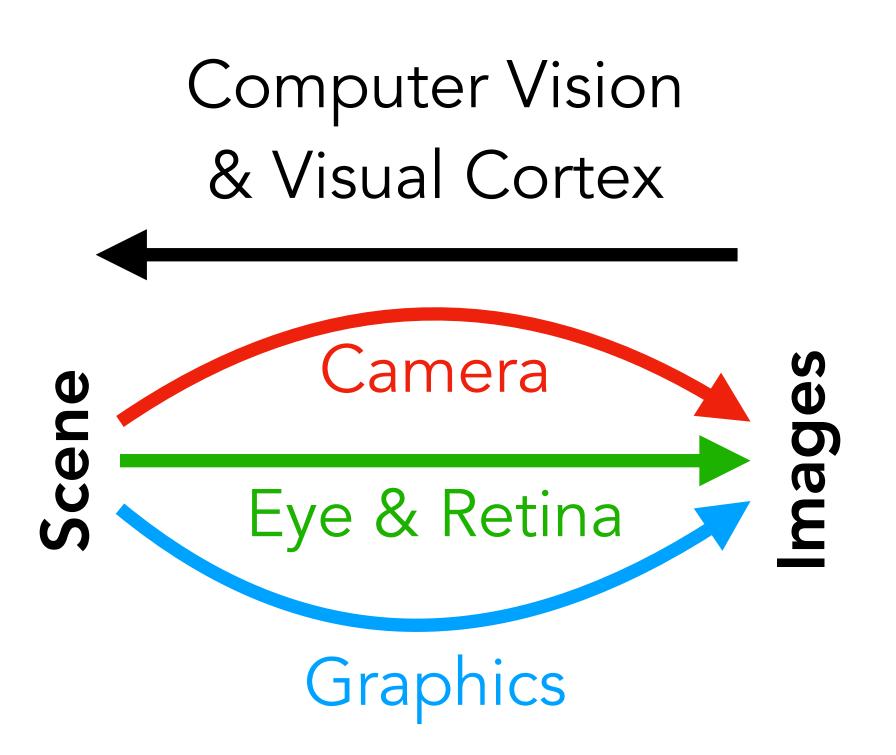
Not a Computer Vision Course

Computer vision is concerned with understanding scene from images.

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

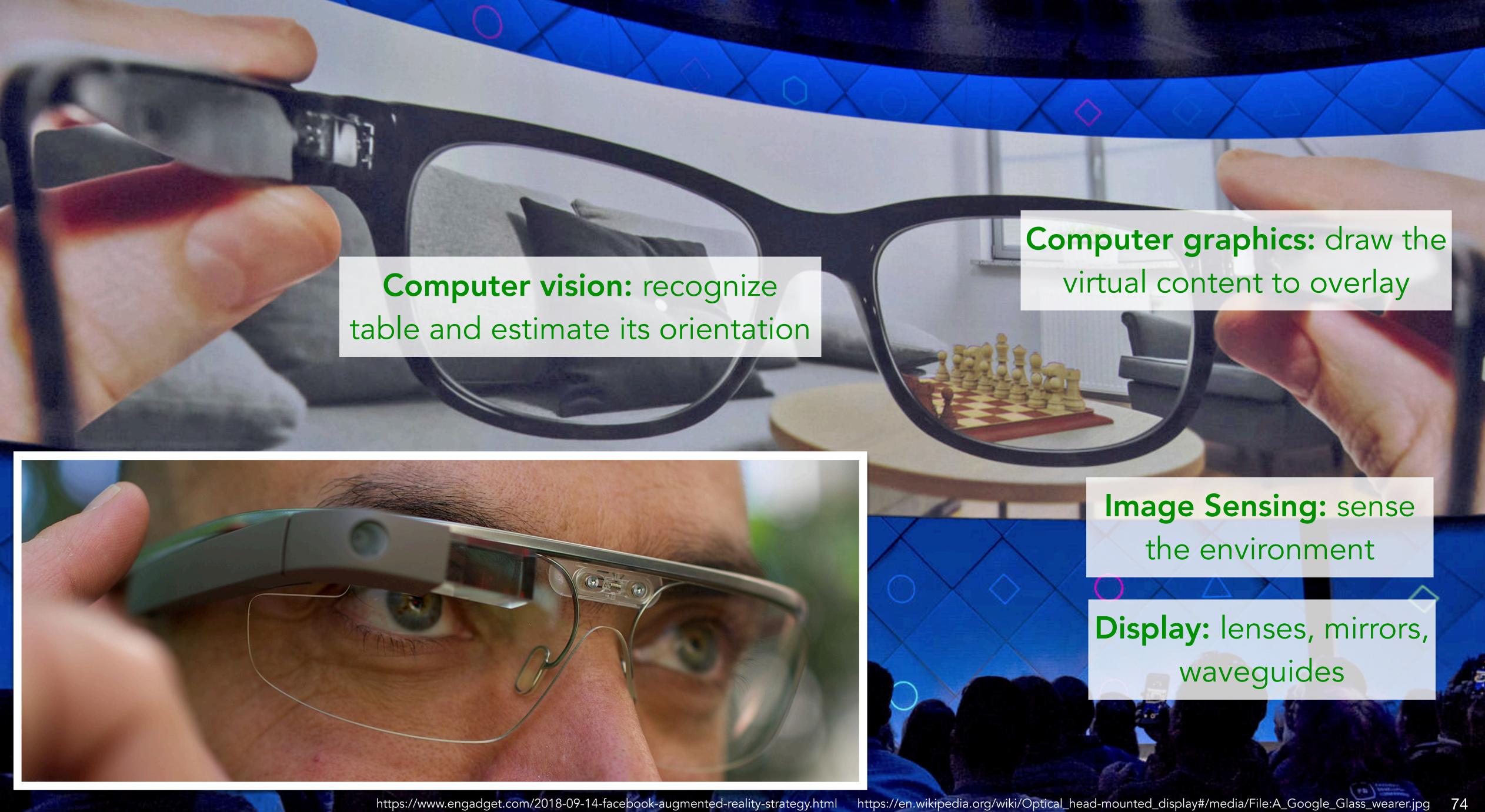
 Both in biological systems and in engineered systems (cameras, rendering, etc.)

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.





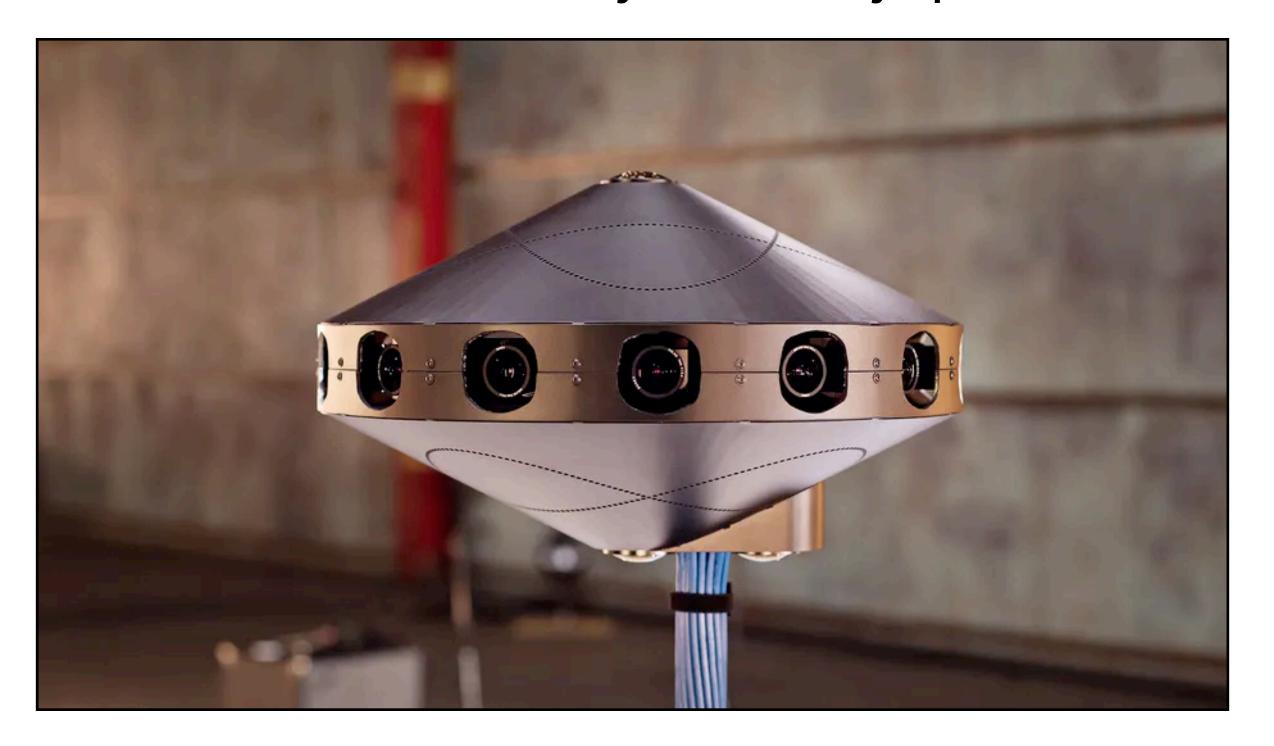


360° (VR/Panoramic) Videos and Photos



VR Video Capturing Device

Facebook Surround 360 System (mostly open-source)



A Google Jump rig built by Yi Halo



Cultural Heritage Preservation



Cultural Heritage Preservation

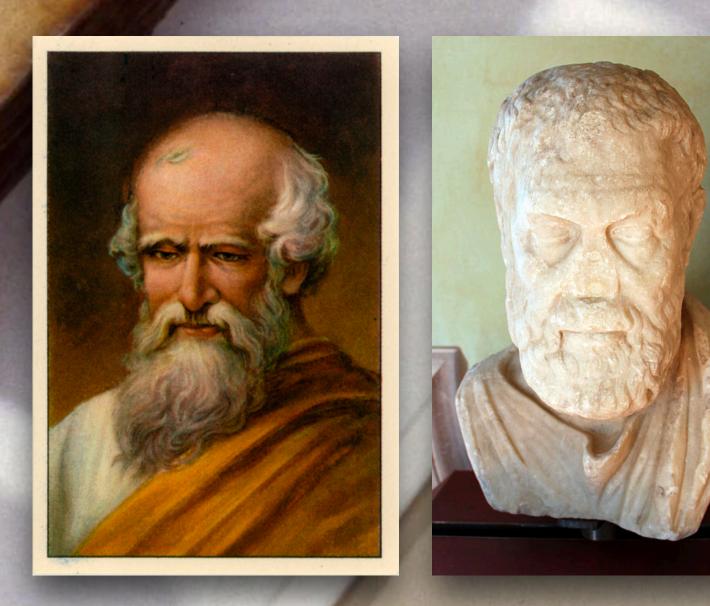




Medieval manuscript made from parchments used for other writings.

The over-text is a Byzantine prayerbook (1229).

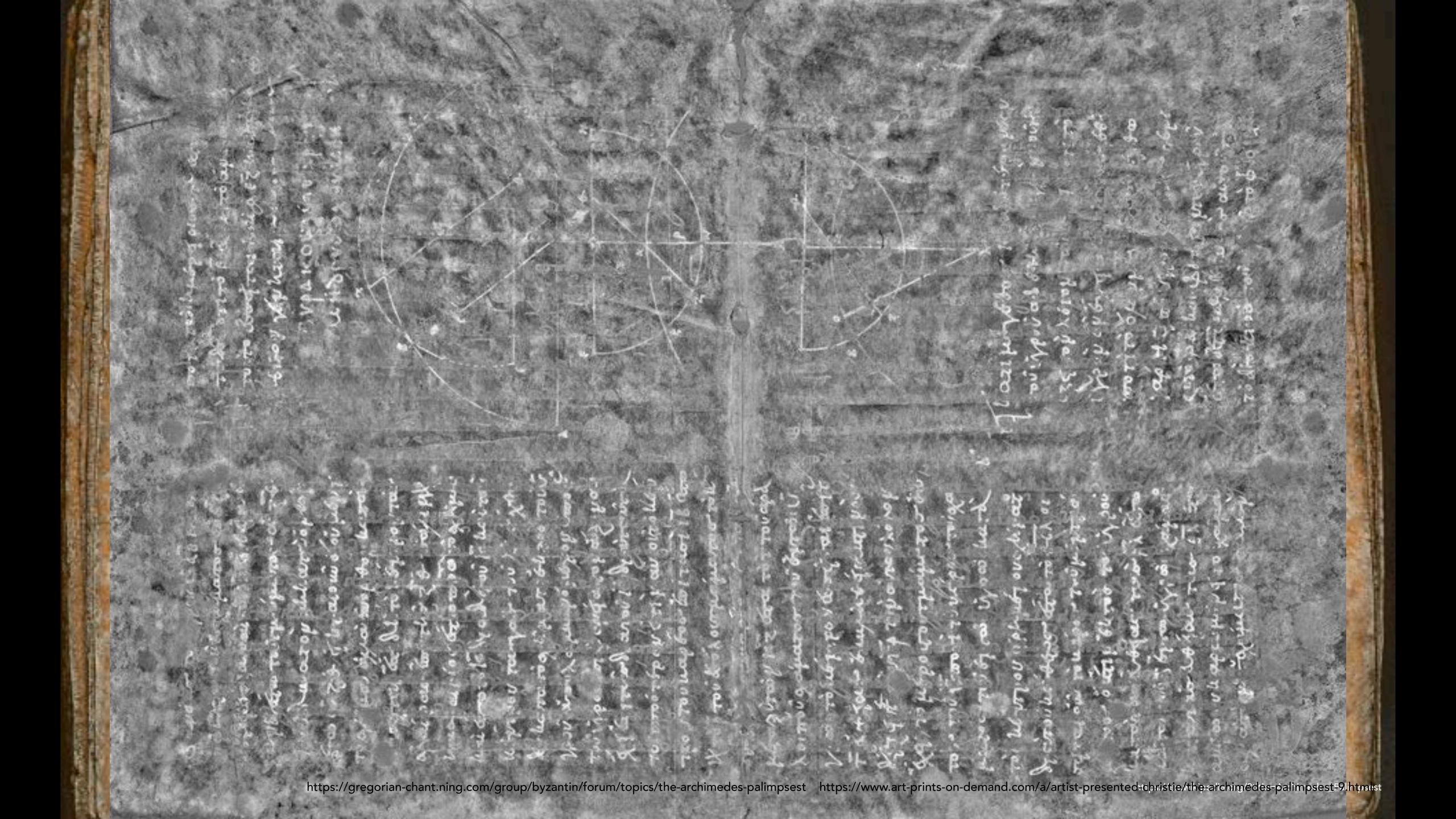
The under-texts are mainly from Archimedes and Hyperides; some are unidentified.



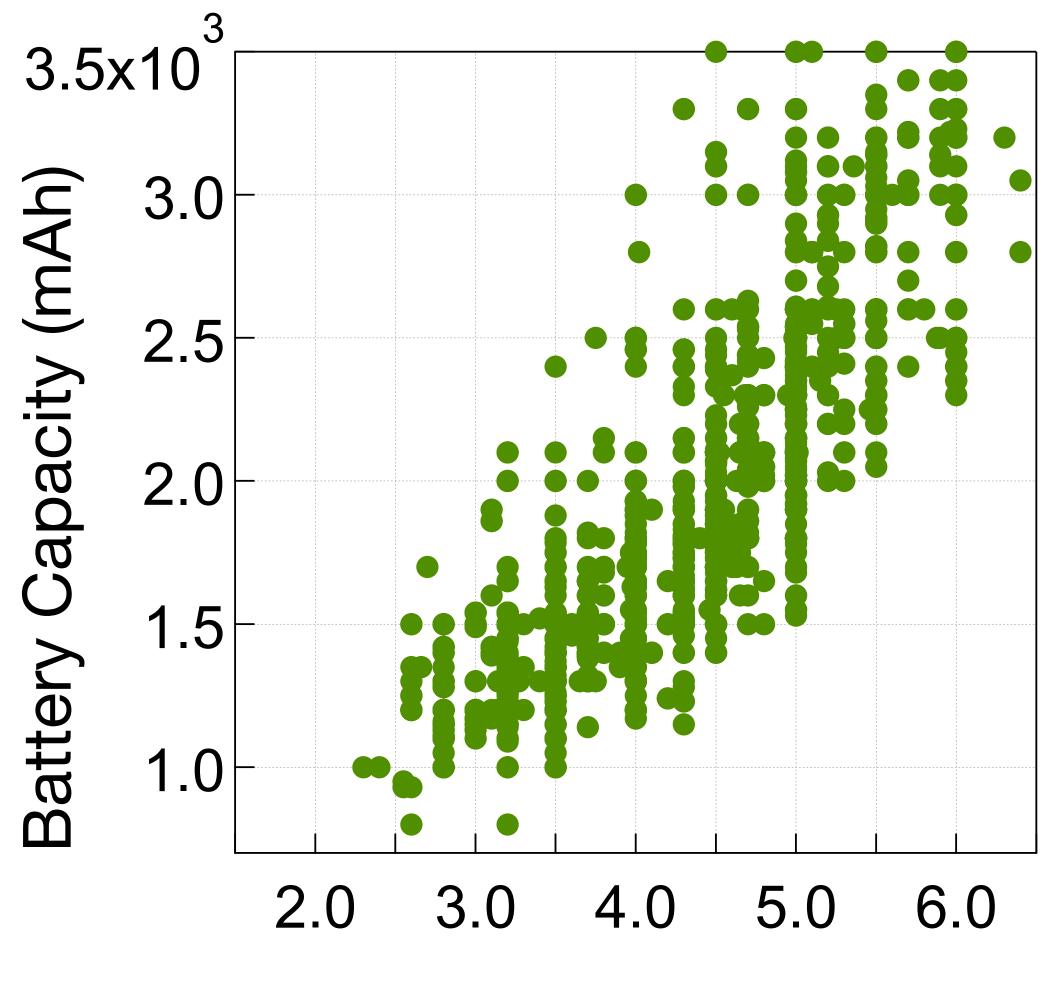
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https://cudl.lib.cam.ac.uk/view/MS-ADD-01879-00023/2



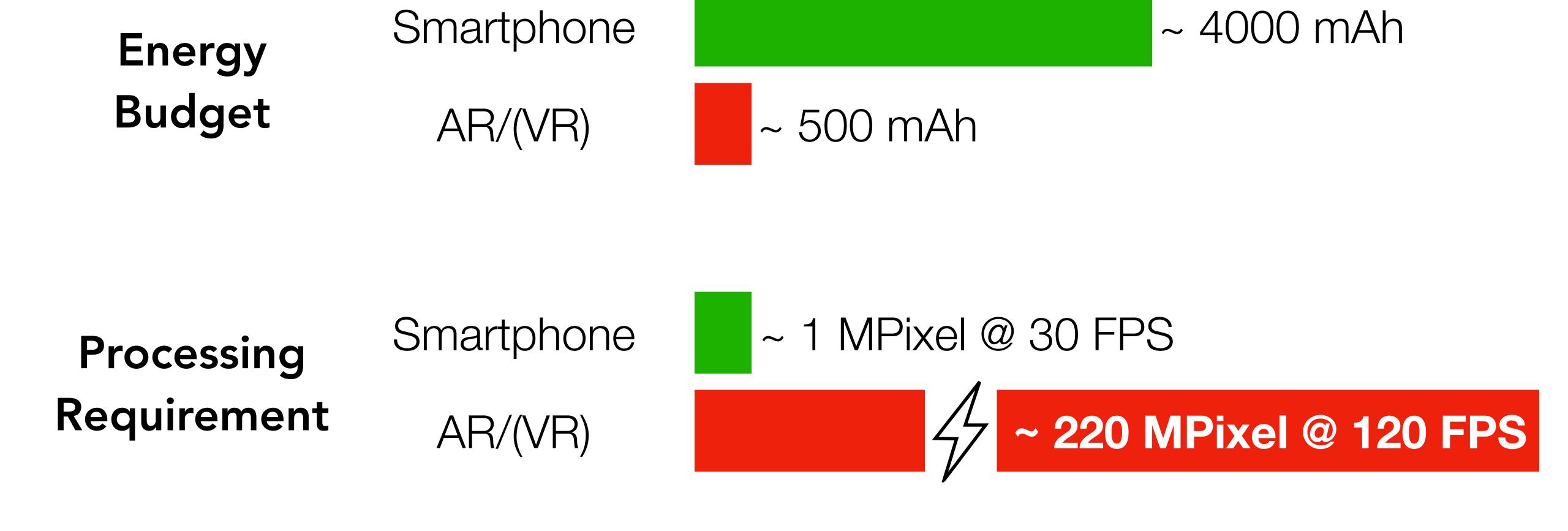
What Challenge?







What Challenge?

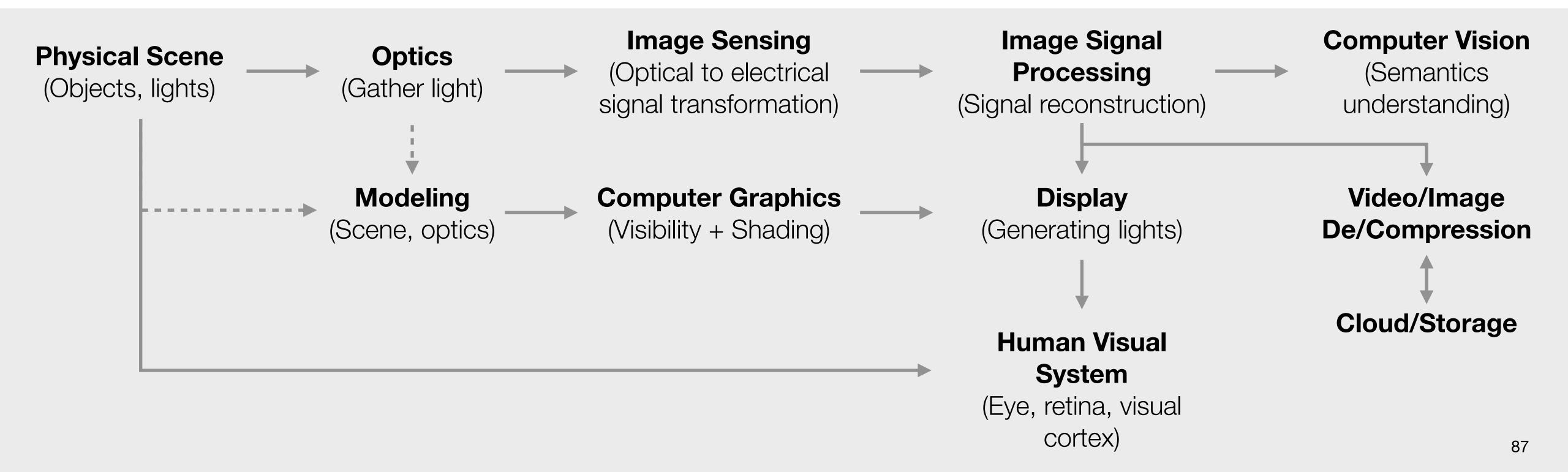


How Do I Teach (and How You Should Learn)?

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

Necessarily Inter-Disciplinary

Your goal is **NOT** to understand everything in one semester (no one does). Your goal is to understand the basic **principles** so that you can learn things on your own when need to.



Rochester is a Great Place for Visual Computing Research

Augmented/Virtual Reality Initiative

• https://www.rochester.edu/augmented-virtual-reality/

AR/VR National Research Traineeship (NRT) Program:

• https://www.rochester.edu/augmented-virtual-reality/education/index.html

Digital Scholarship Library

https://digitalscholar.rochester.edu/

Studio X:

https://www.rochester.edu/advancement/studiox/

Center for Visual Science

https://www.cvs.rochester.edu/

Logistics

Course website: https://cs.rochester.edu/courses/259/fall2024/

We meet on Wednesdays and Fridays (11:50 — 13:05).

All announcements will be made through blackboard.

Feel free to send me emails.

Office hours by appointment.

TA: Ethan Chen (echen48 [at] cs [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

There is no definitive textbook. The course material is self-contained.

The syllabus page has links to many references that I think are helpful: https://cs.rochester.edu/courses/259/fall2024/syllabus.html

• Most of them are either PDFs online made available by the authors or are accessible through UR digital library (login required).

There will be readings assigned (my lecture notes and other sources; some are required and others are recommended).

How You Will Be Evaluated

3%: finish the student information sheet

• Ideally, come to my office hours to introduce yourself.

33%: written assignments; mostly every 2—3 weeks.

24%: mini programming assignments; probably 2.

40%: a final project of your choice that fits your interests and background; could be programming, systems, art, design, etc.

Need approval. Must finalize within the first 2 months. Could be team of up to 2.