Computer Graphics III
Introduction

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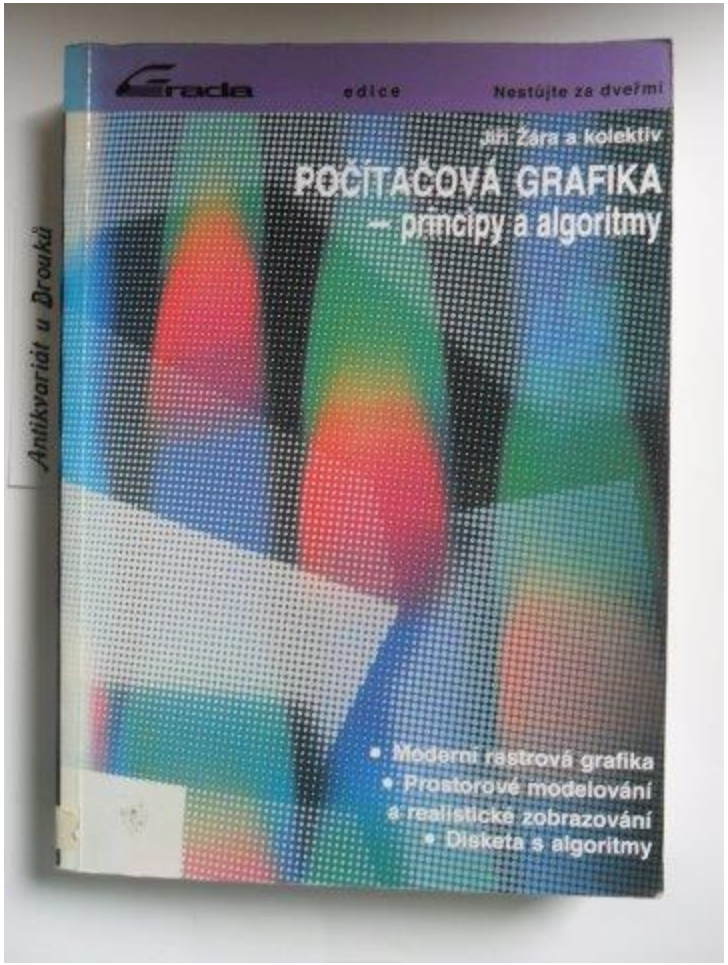
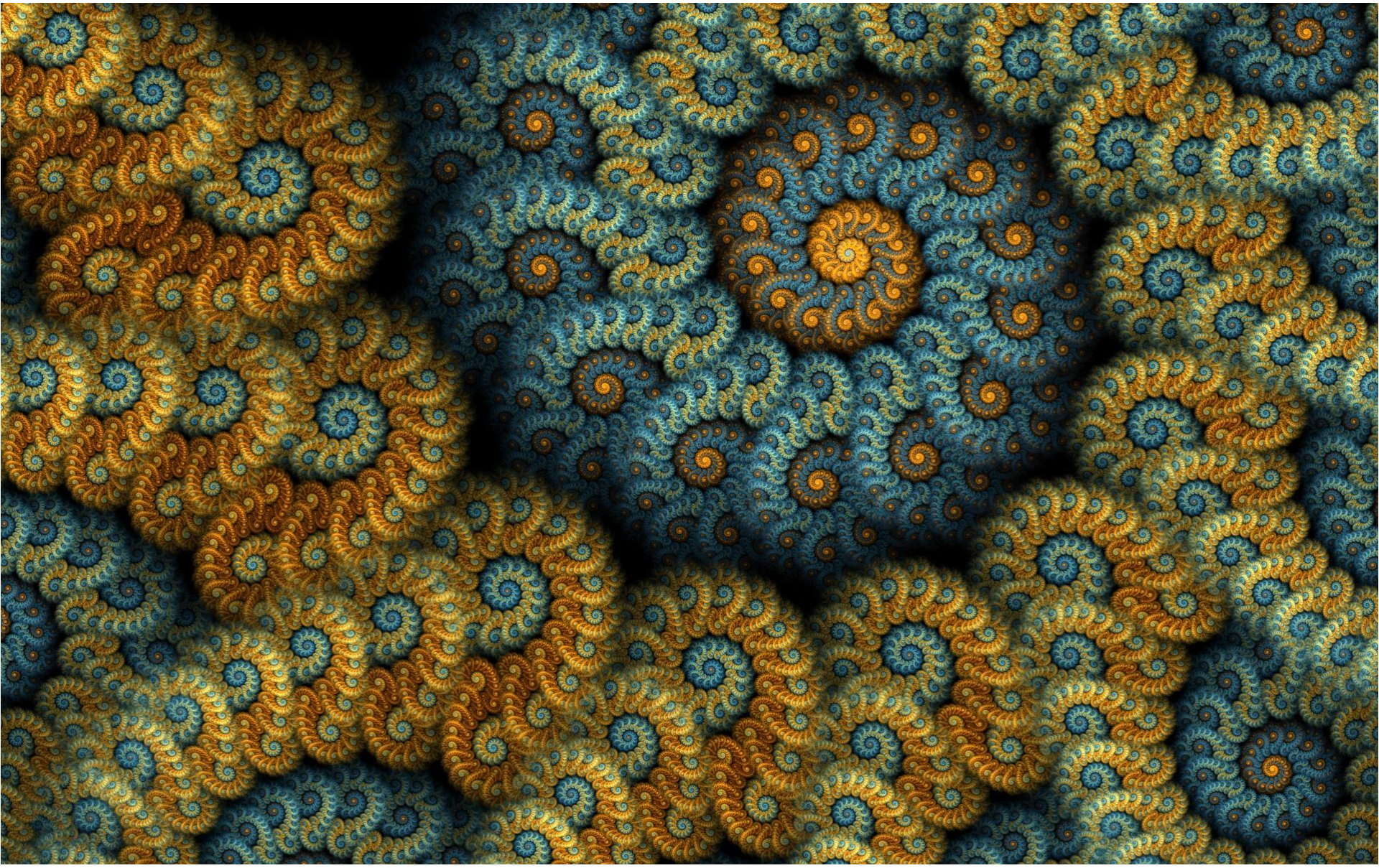

Gracia
edice
Nestůjte za dveřmi
Jiří Žára a kolektiv
POČÍTAČOVÁ GRAFIKA
– principy a algoritmy
• Moderní rastrová grafika
• Prostorové modelování
a realistické zobrazování
• Disketa s algoritmy
Antikvariát u Brouků



$$L_o = L_e + \int_\Omega L_i \cdot f_r \cdot \cos\theta \cdot d\omega$$

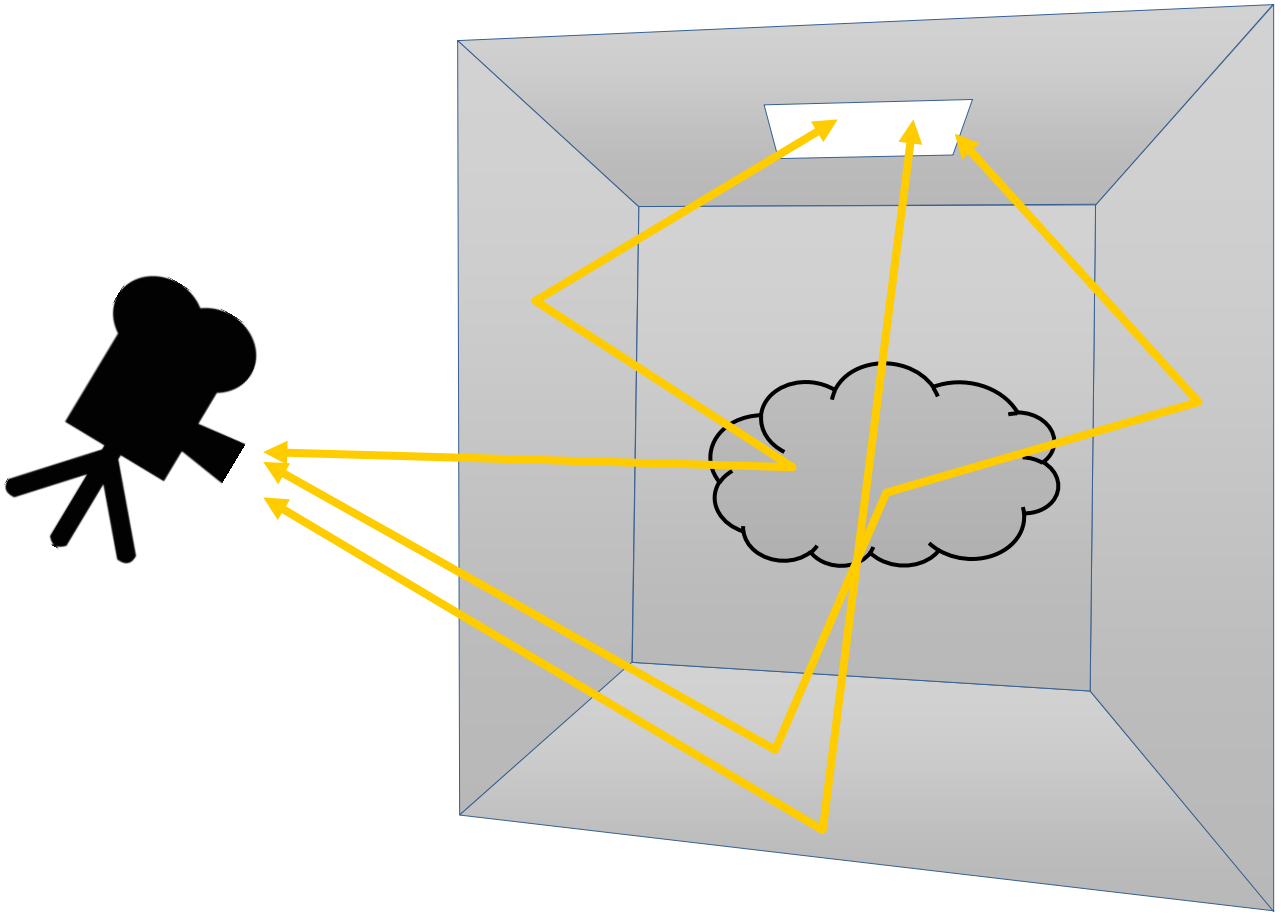
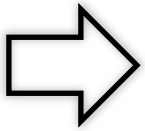


Image synthesis (rendering)



Given a scene description

Create an image
(that looks like reality)

Barts Square by The Boundary in association with Iain Banks | www.the-boundary.com & www.iainbanks.com

rendered with Corona Renderer | www.corona-renderer.com

A room with a view

Put a rocking chair in front of your favourite window and experience how relaxing it is to get away from it all by just coming home. Life is in full swing outside, but you feel totally calm.

01 EKTORP three-seat sofa $749 Seat cushions filled with high resilience foam and polyester fibre wadding; provide comfortable support for your body when seated and easily regain their shape when you rise. Cover: 53% linen, 47% viscose/rayon. W218×D88, H88cm. Risane natural.

02 New FABRIKÖR glass-door cabinet $399 The shelves in the cabinet are adjustable – makes it easy to adjust the height to suit what you want to store. May be completed with DIODER LED lighting strip. Powder coated steel and tempered glass. Designer: Nike Karlsson. W57×D47, H150cm. Light green 702.422.94

03 VÄRMDÖ rocking-chair $169 Wooden furniture that is suitable for both indoor and outdoor use. Solid pine. Designer: Nike Karlsson. W65×D74, H106cm. Black 002.059.59

04 BJÖRNLOKA rug, flatwoven $199 The durable, soil-resistant wool surface makes this rug perfect in your living room or under your dining table. The rug is machine-woven. User surface: 100% pure new wool. W170×L240cm. Beige/black 402.290.05

05 HEMNES coffee table $229 Stained, clear lacquered solid pine. Designer: Carina Bengs. L90×W90, H46cm. Grey-brown 402.579.51

Show products (3)

Jaguar F-Type by Jeff Patton | www.jeffpatton.net

rendered with Corona Renderer | www.corona-renderer.com

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Image created by *Bertrand Benoit*
Rendered in *Corona Renderer*

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VR Scene by Recent Spaces

Computer Graphics Charles University

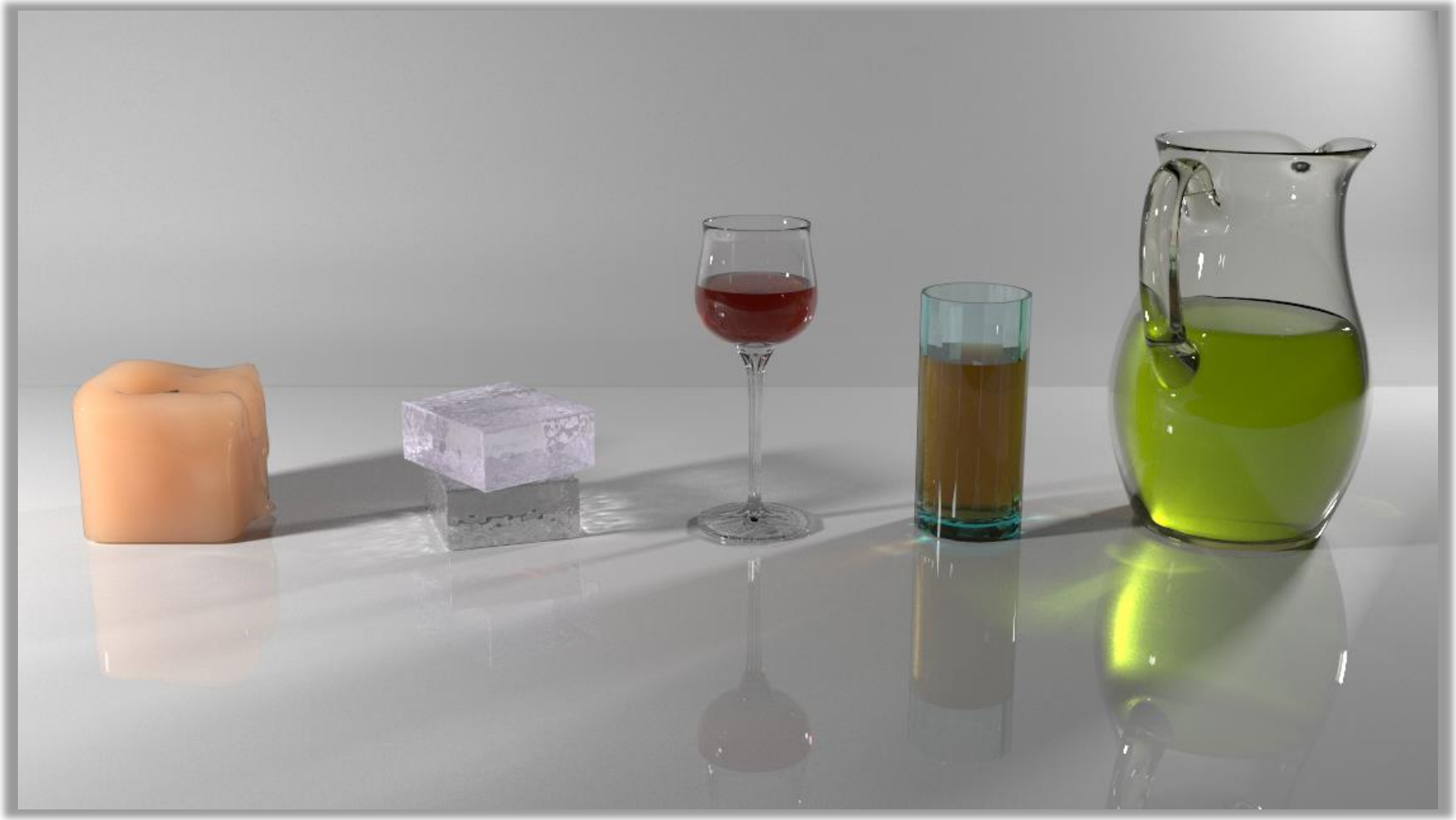

PIXAR
ANIMATION STUDIOS

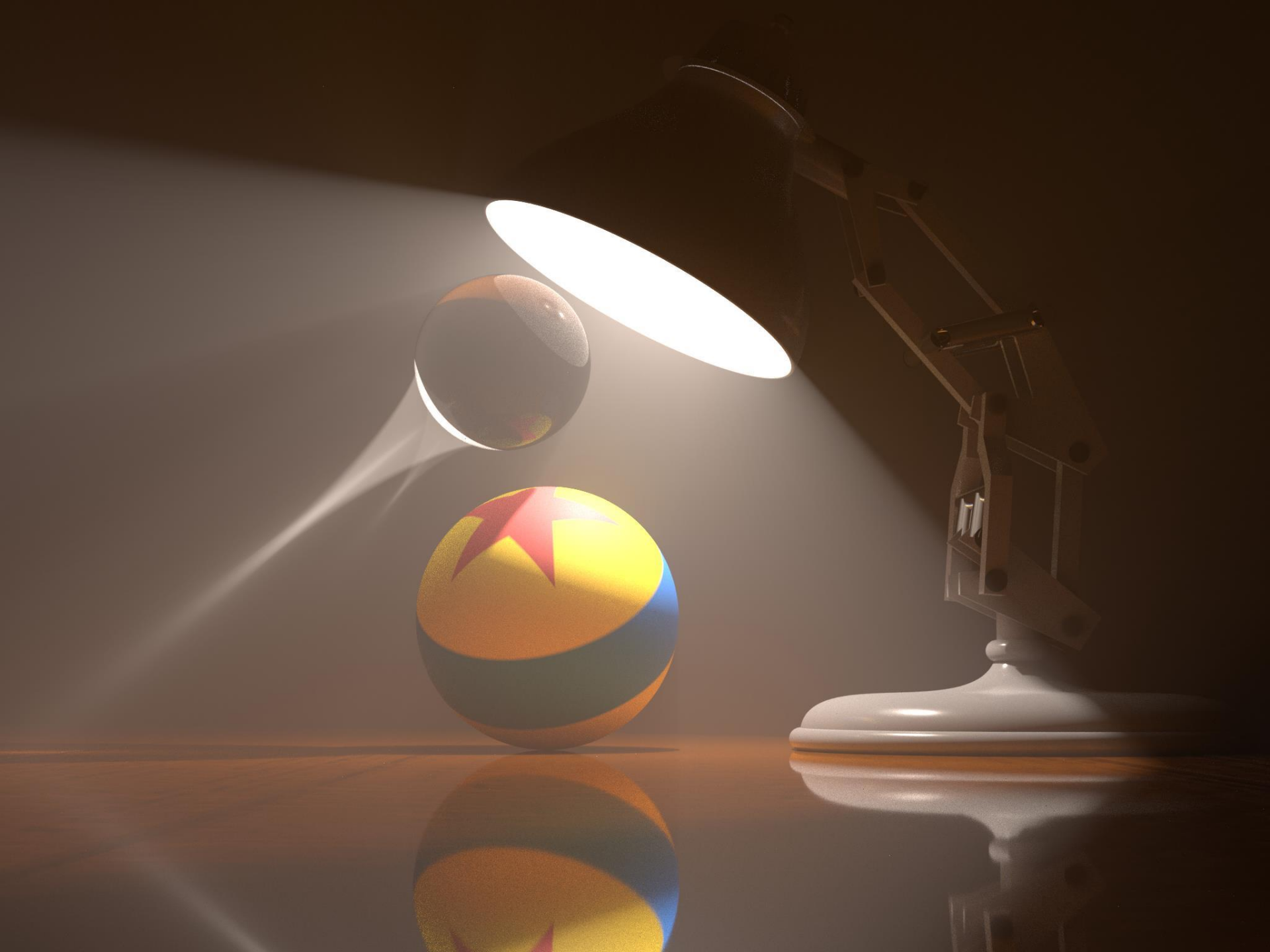
Vertex Connection & Merging (VCM)

SIGGRAPH Asia 2012

Robust rendering of volumetric media

SIGGRAPH 2014






PIXA
ANIMATION S


THE LORD OF THE RINGS
THE MOTION PICTURE TRILOGY


DAWN OF THE PLANET OF THE APES


JAMES CAMERON'S
AVATAR


weta
DIGITAL


June, 2013
HoseinDiba61@yahoo.com


THE LORD OF THE RINGS
THE MOTION PICTURE TRILOGY


DAWN OF THE PLANET OF THE APES


JAMES CAMERON'S
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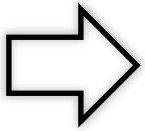
Image synthesis – A gentle intro

Image synthesis (rendering)



Given a scene description

Create an image
(that looks like reality)

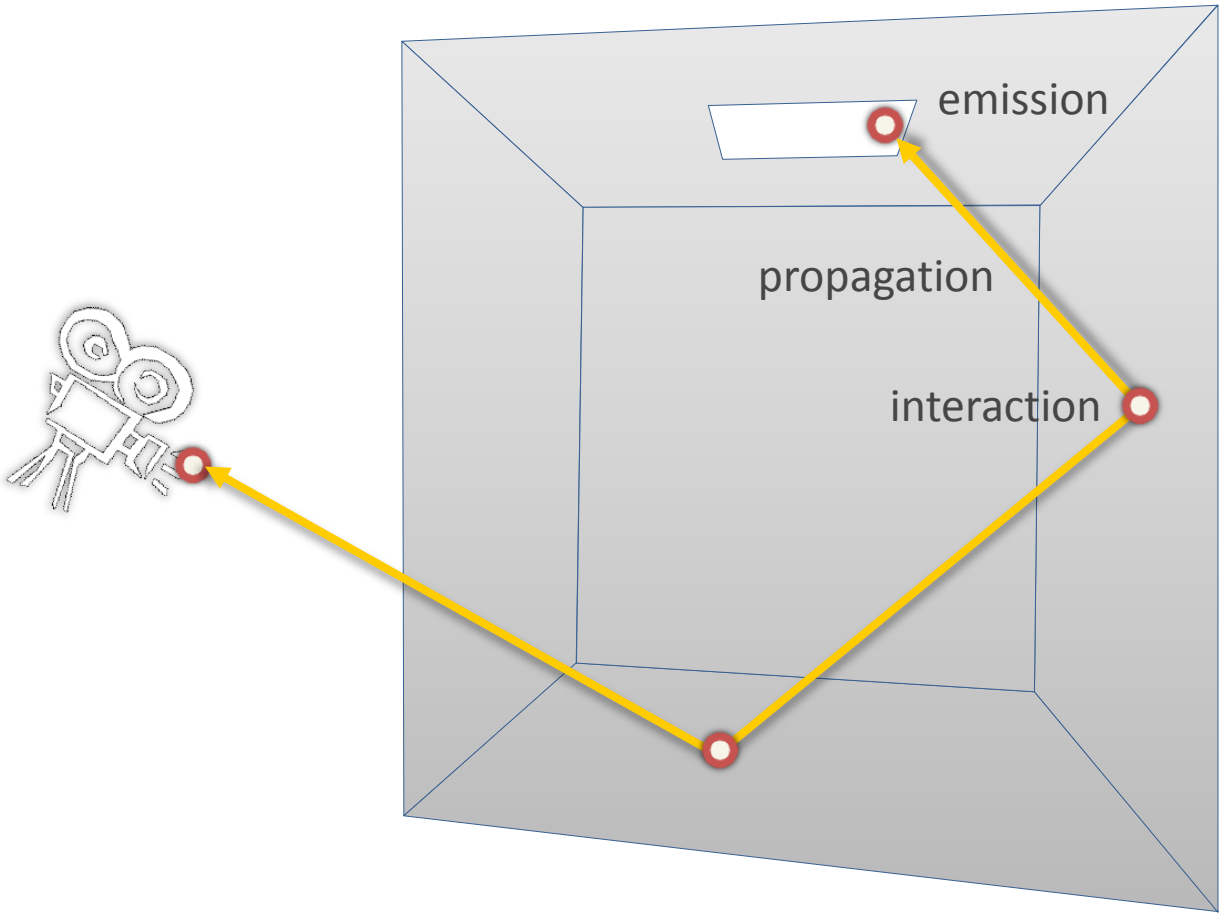
Scene description

- **Geometry**
  - Where is which object and what shape does it have?
  - Usually represented by triangular meshes
  - Accessed via ray casting
- **Surface reflectance**
  - Surface color, glossiness, transparency, etc.
  - Mathematical model: the BRDF
- **Light sources**
  - Spatial and directional distribution of emitted light
  - Radiometric terms are used to describe this
- **Camera (sensor)**
  - Position, orientation, type (perspective, spherical), etc.
  - Mathematical model: the Measurement Equation

Application of realistic image synthesis

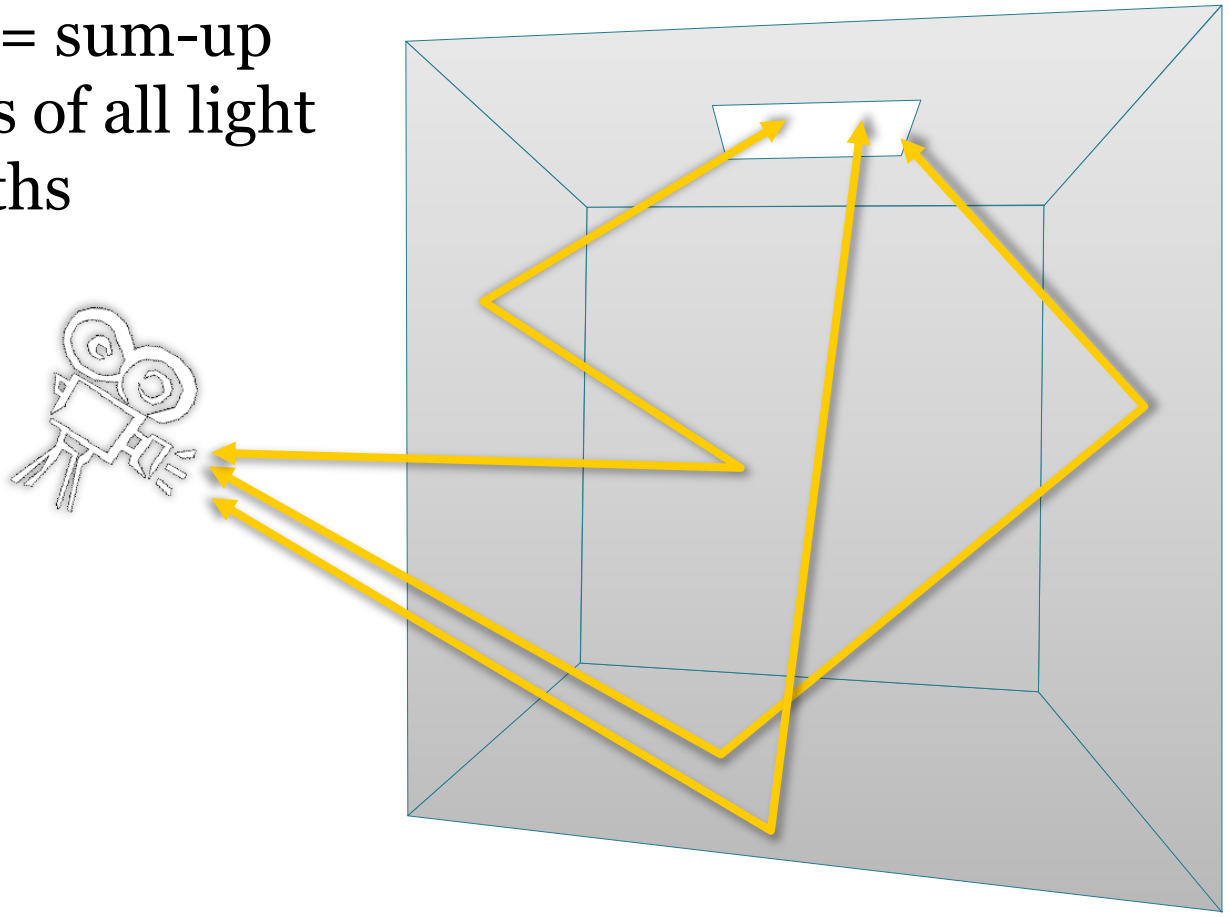
- Movie production
- Entertainment, games
- Industrial design
- Architecture
- Virtual showrooms
- On-line commerce
- Cultural heritage
- Virtual and augmented reality

Light transport simulation

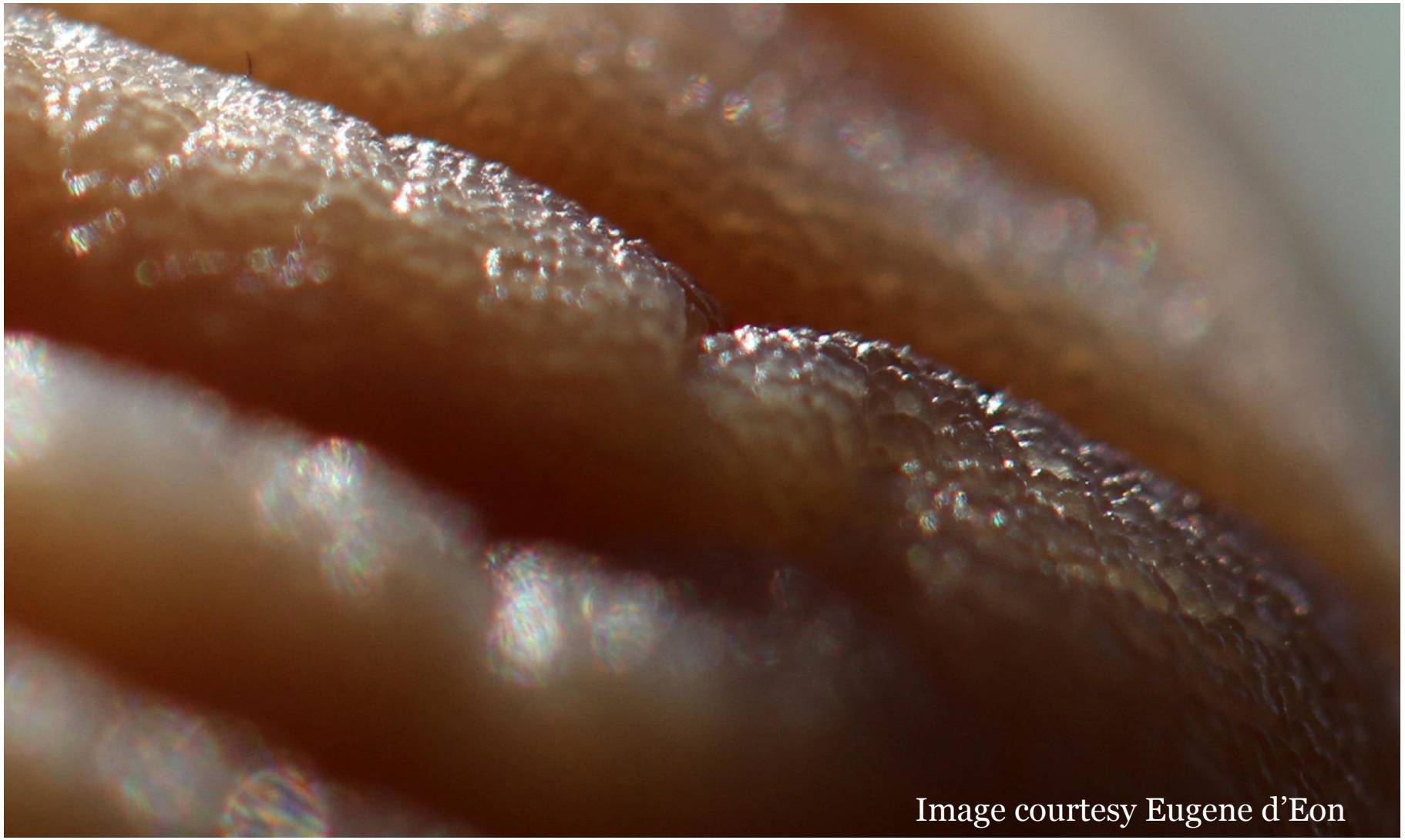


Light transport simulation

- **Rendering** = sum-up contributions of all light transport paths



What's in the image?



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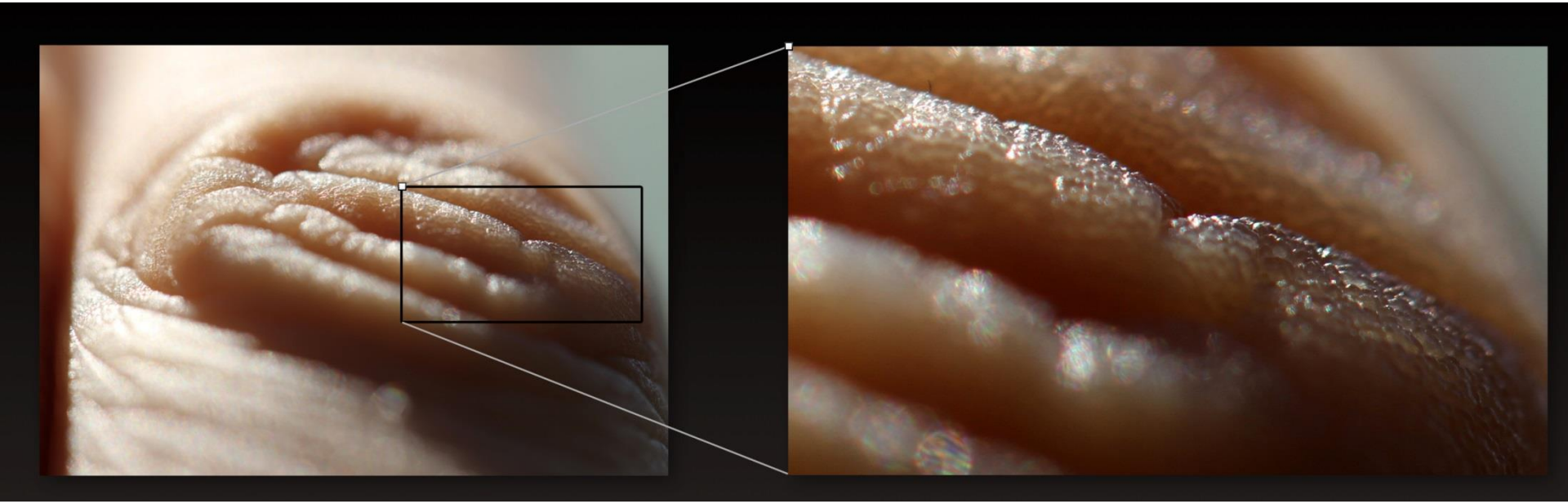
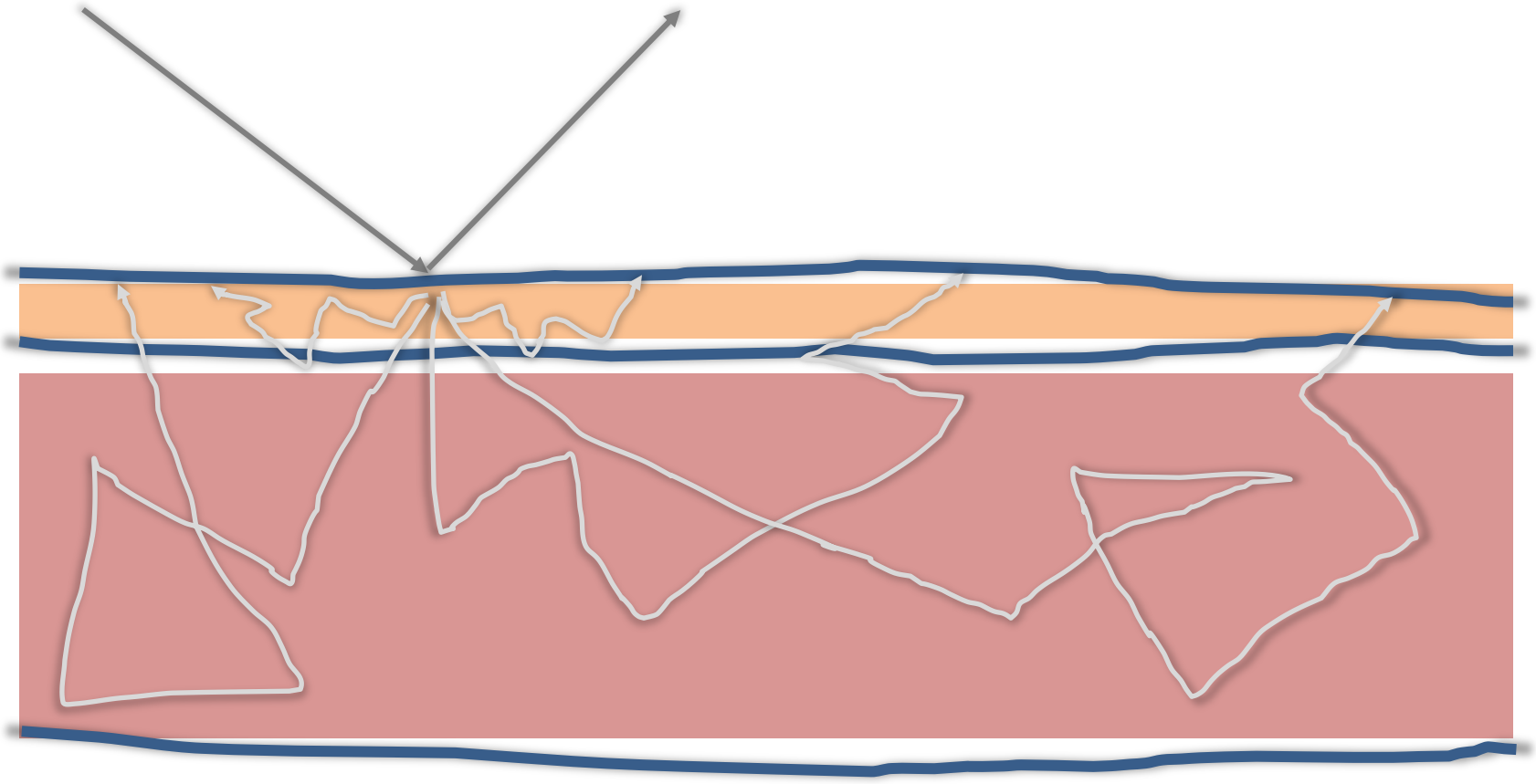
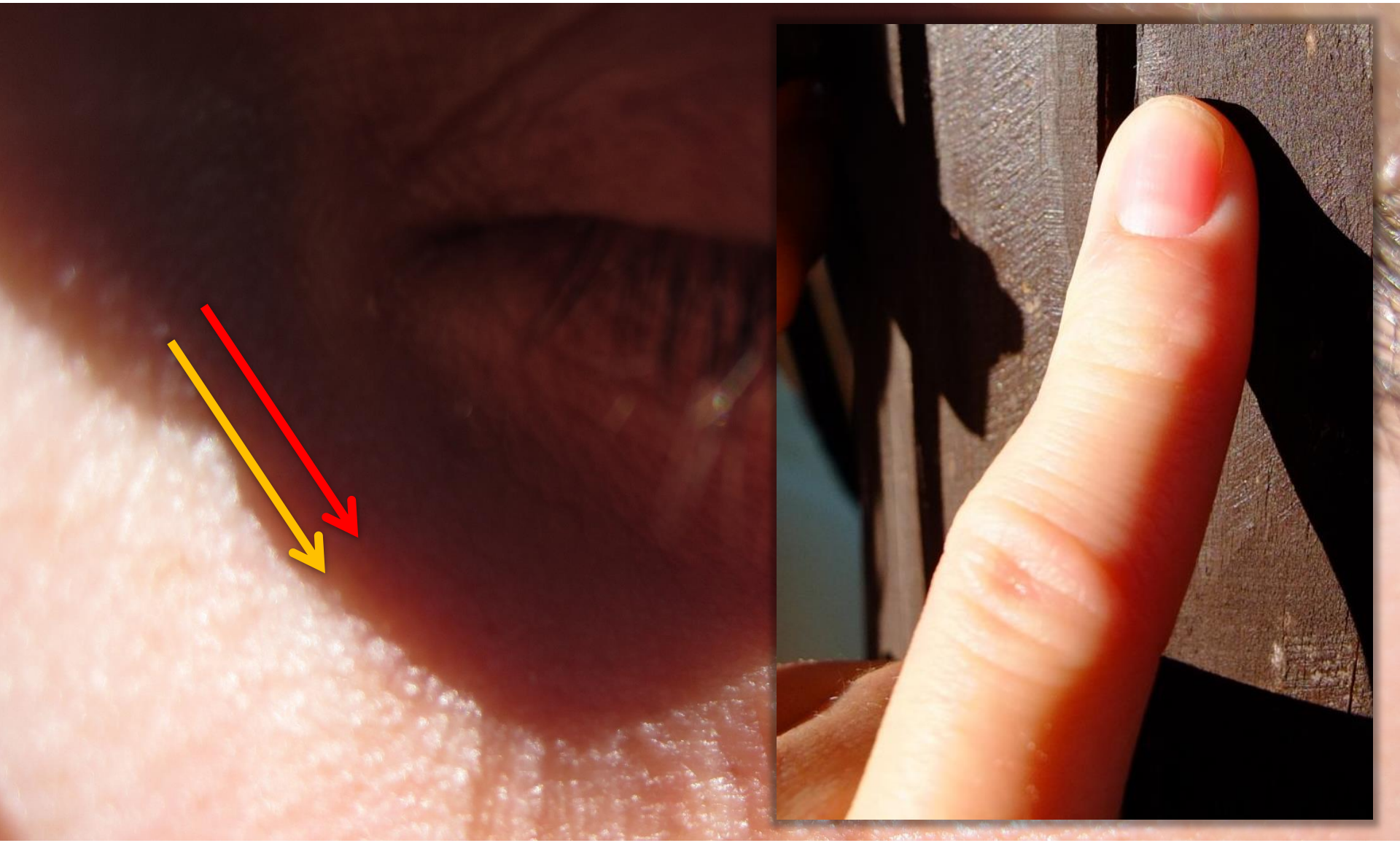


Image courtesy Eugene d'Eon

Why does skin look the way it does?

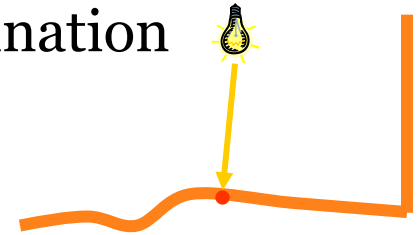


Subsurface scattering effects on skin



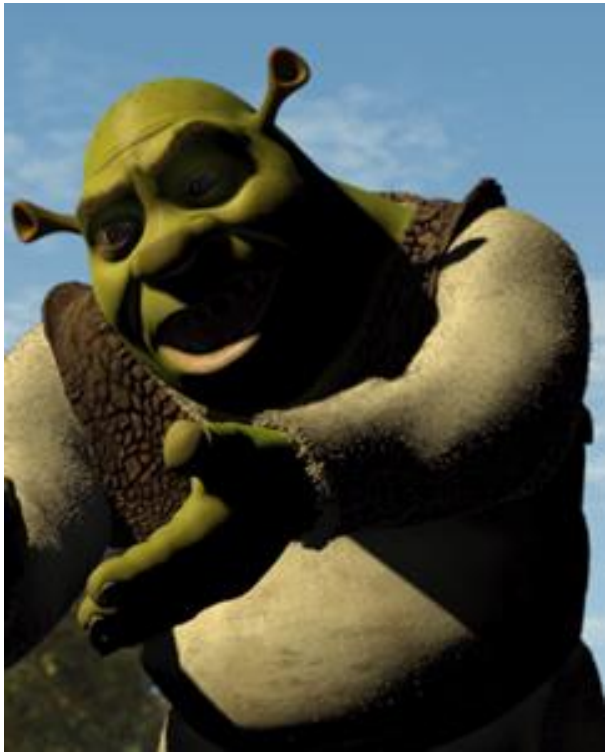
Global illumination – GI

Direct illumination



Globální osvětlení

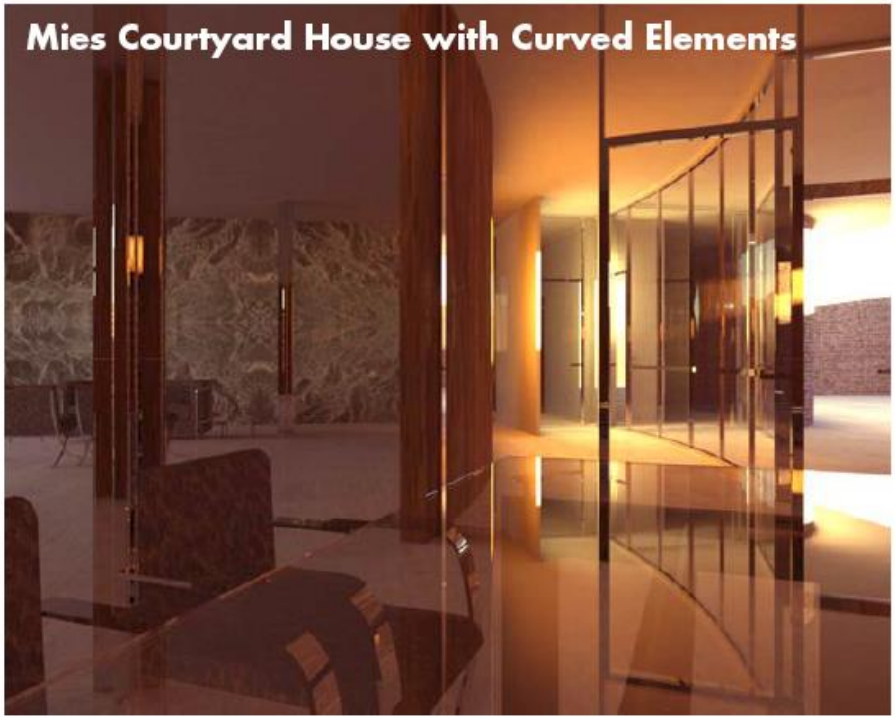
- **Direct illumination**
  - Light reflects only once on its way from the source to the camera



- **Global illumination**
  - Global = Direct + Indirect
  - Light transport between surfaces in the scene
  - Multiple reflections/refractions

Global illumination effects

- Ideal (mirror) reflection / refraction
- Color bleeding
- Caustics

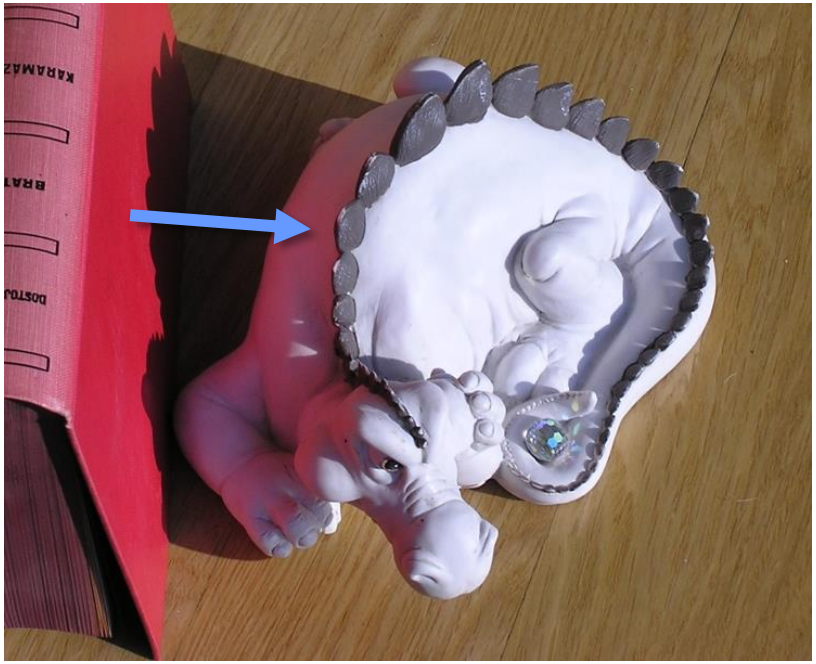


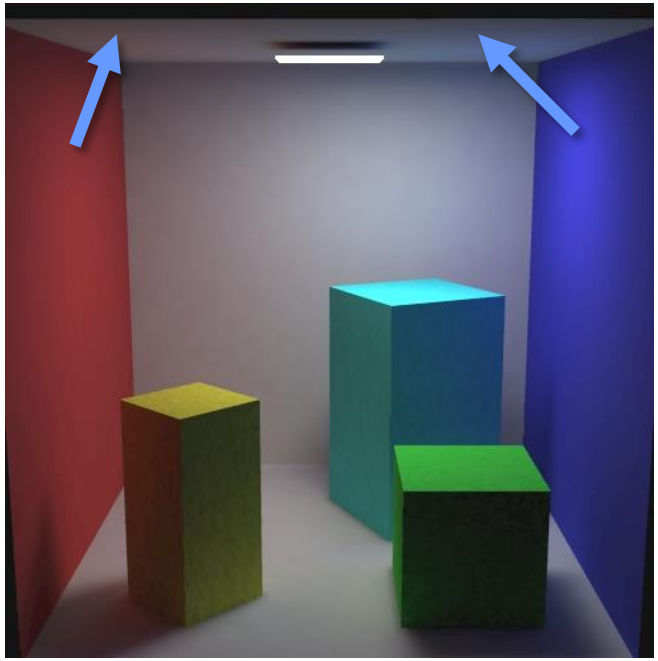
Modeling: Stephen Duck; Rendering: Henrik Wann Jensen

Ideal (mirror) reflection/refraction

- Glass, mirror, water surface
- E.g. the image we see on a water surface is due to light in a completely different part of the scene (bottom, environment, sky, sun)

Color bleeding



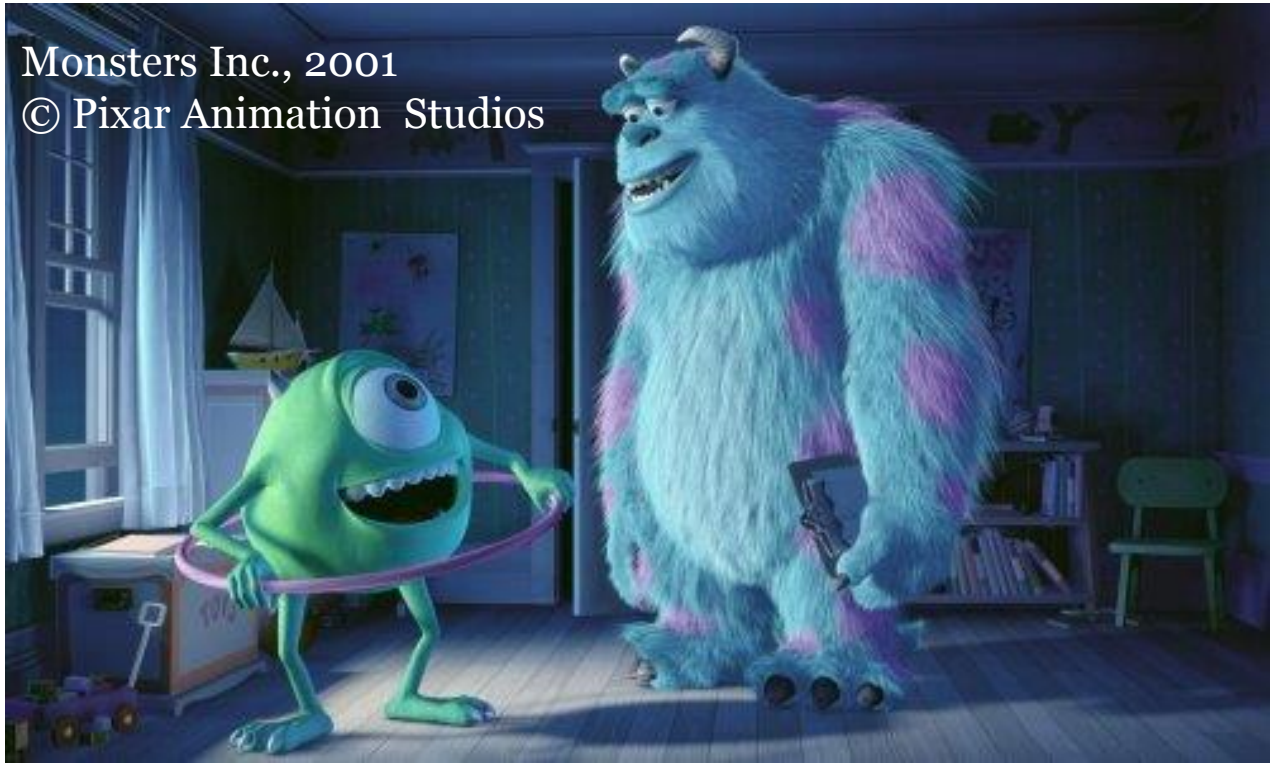


- Light reflected from one diffuse surface onto another
- Important for understanding of the spatial relationships of objects in a given scene (this happens subconsciously)

Color bleeding

Image courtesy Michael Bunnell

“Manual” global illumination



- Manually placed light sources as a proxy for GI
  - E.g. The cyan-ish tint on Mike Wasowski “reflected” from Sulley’s belly
- Was used before full GI simulation started to be feasible

Caustics

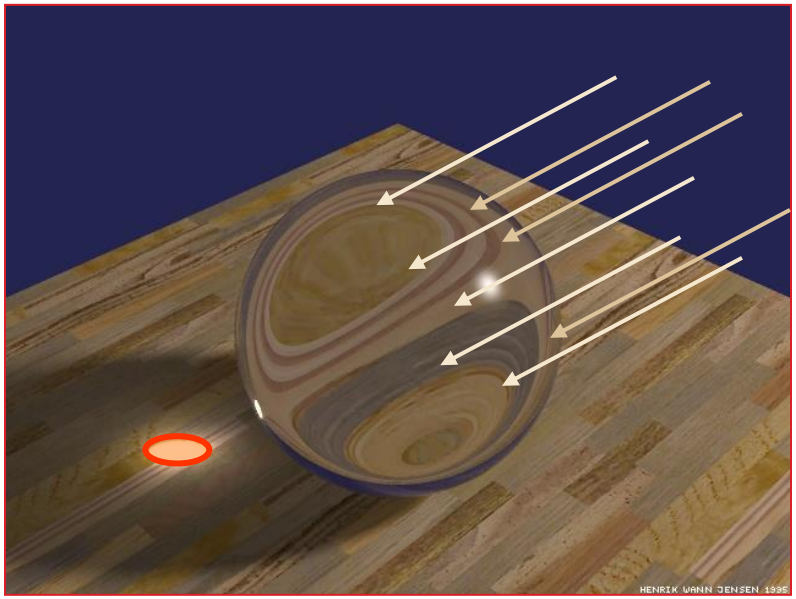
- Focusing of light as it's reflected or refracted, leading to local increase of intensity

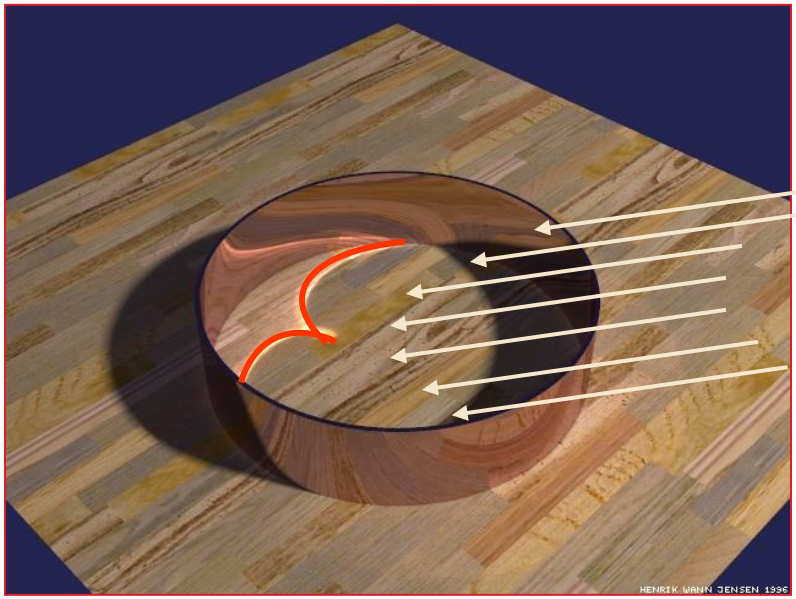
Photograph

Simulation using photon maps

Caustics

- In physics or in computer vision, a caustic refers to a singularity of light intensity (infinite density of light energy)

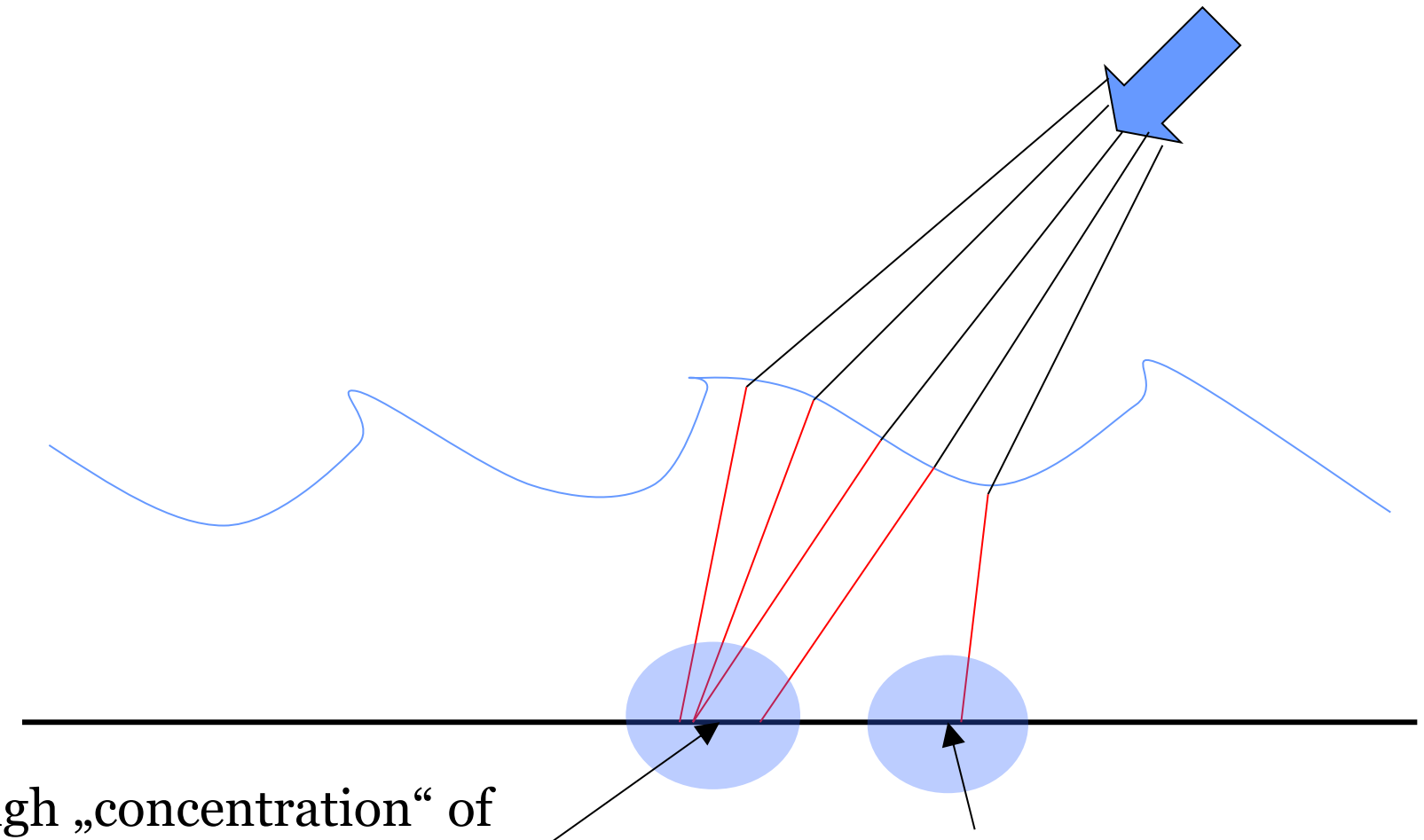




What do we see when we look at a surface of a swimming pool?

- Reflections + refractions on water surface
- Caustics at the bottom

Caustics under water surface



High „concentration“ of photons – high light intensity

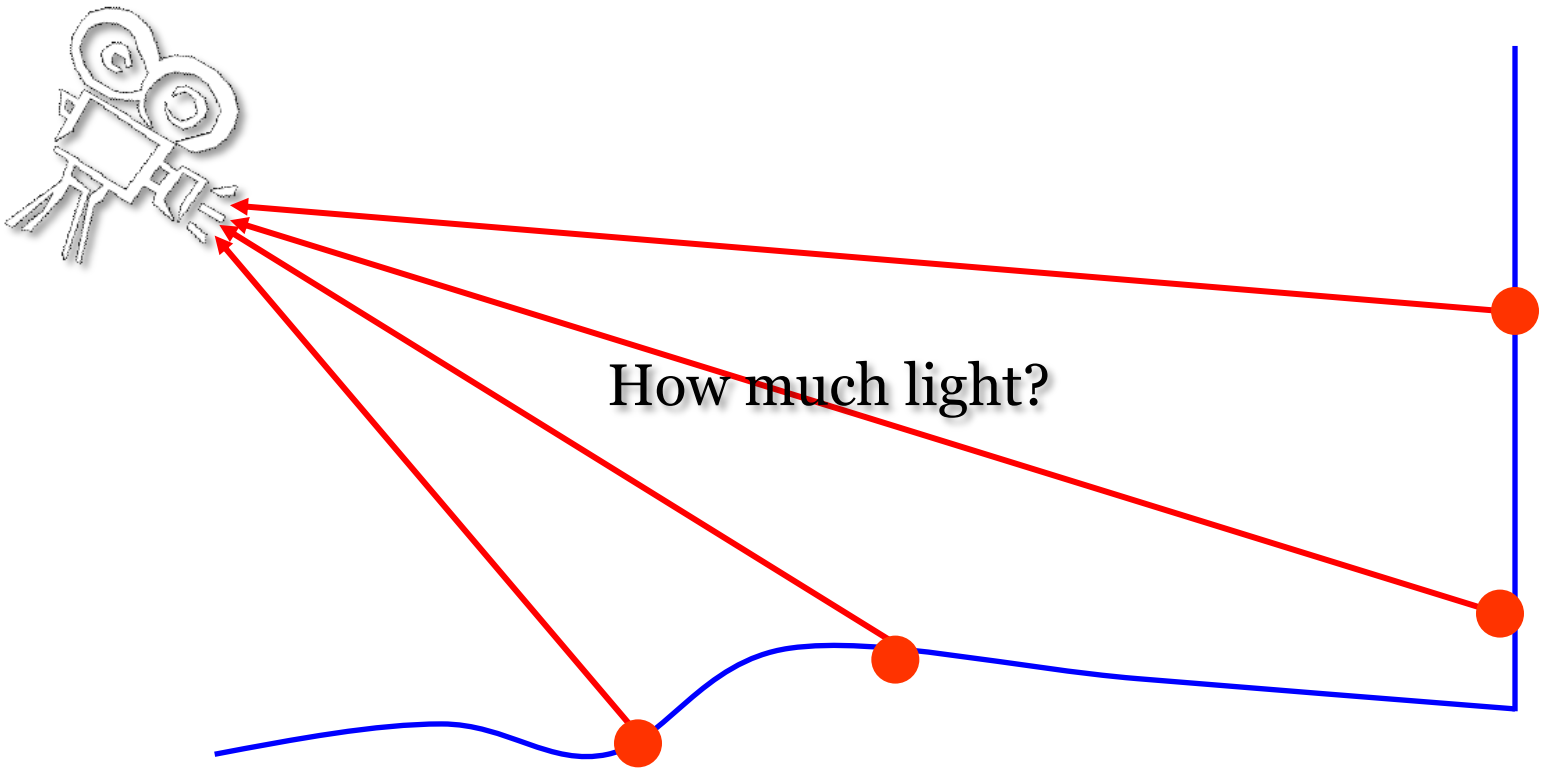
Low intensity

Realistic image synthesis: Ingredients

- Describe the “amount of light” in space – **radiometry**
- Describe light interaction with surfaces – **BRDF**
- Describe equilibrium light distribution – **rendering equation (RE)**
- Image rendering = **numerical solution of the RE**
  - Find the light distribution in a given scene that fulfils
    - The rendering equation
    - The „boundary conditions “ = i.e. the scene model
  - Methods
    - Finite elements (radiosity) – obsolete
    - **Monte Carlo** (stochastic ray tracing) – prevalent

Light

Realistic image synthesis



Different approaches to rendering

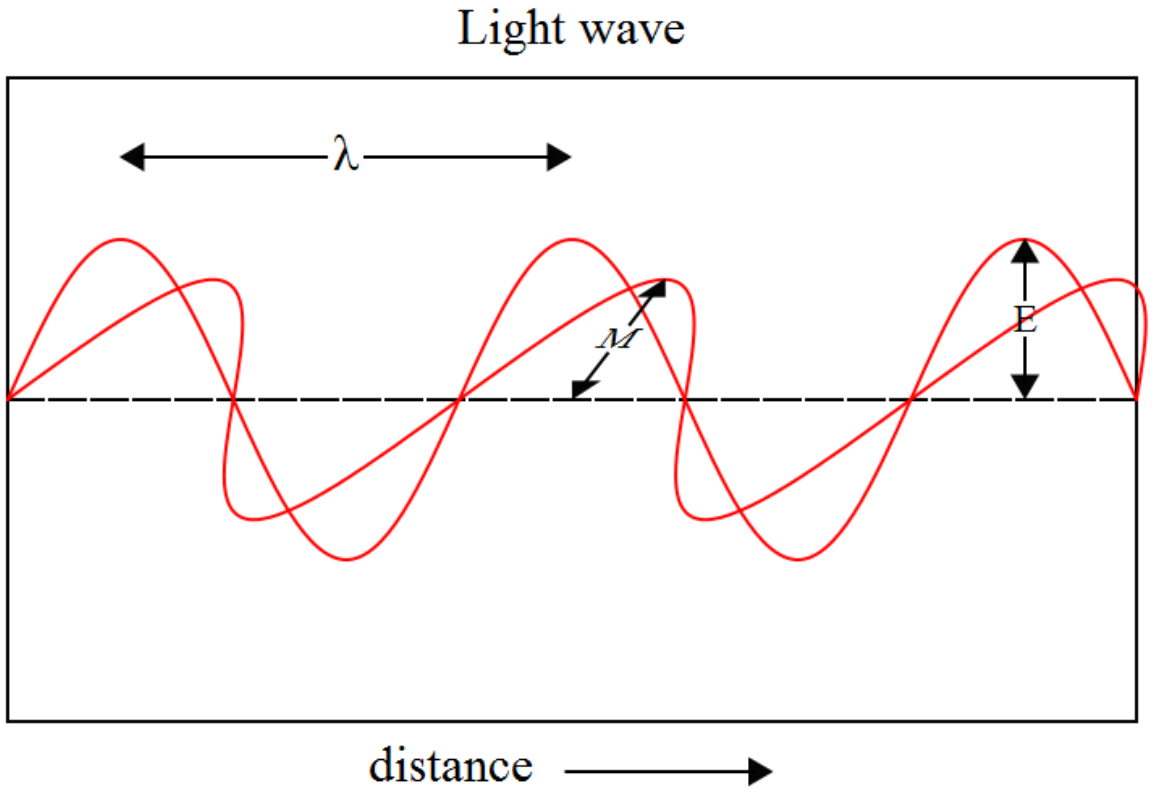
- **Phenomenological**
  - Traditional, “old” computer graphics
  - E.g. Phong shading model, colors between 0 and 1, etc.
- **Physically-based**
  - Based on a proper mathematical formulation
  - Rendering algorithms = numerical methods for solving the rendering equation
  - Radiance values between 0 and infinity

Mathematical model

- Image synthesis (rendering) = light transport simulation
- We need a **mathematical model** for light
- Formulation of the model = choice of level of detail
  - No need to model the behavior of every single photon
  - Need simplifying assumptions

Light

- EM radiation (an EM wave propagating through space)



λ = wave length

E = amplitude of electric field

M = amplitude of magnetic field

Image: Wikipedia

Light

- Frequency of oscillations => wavelength => perceived color

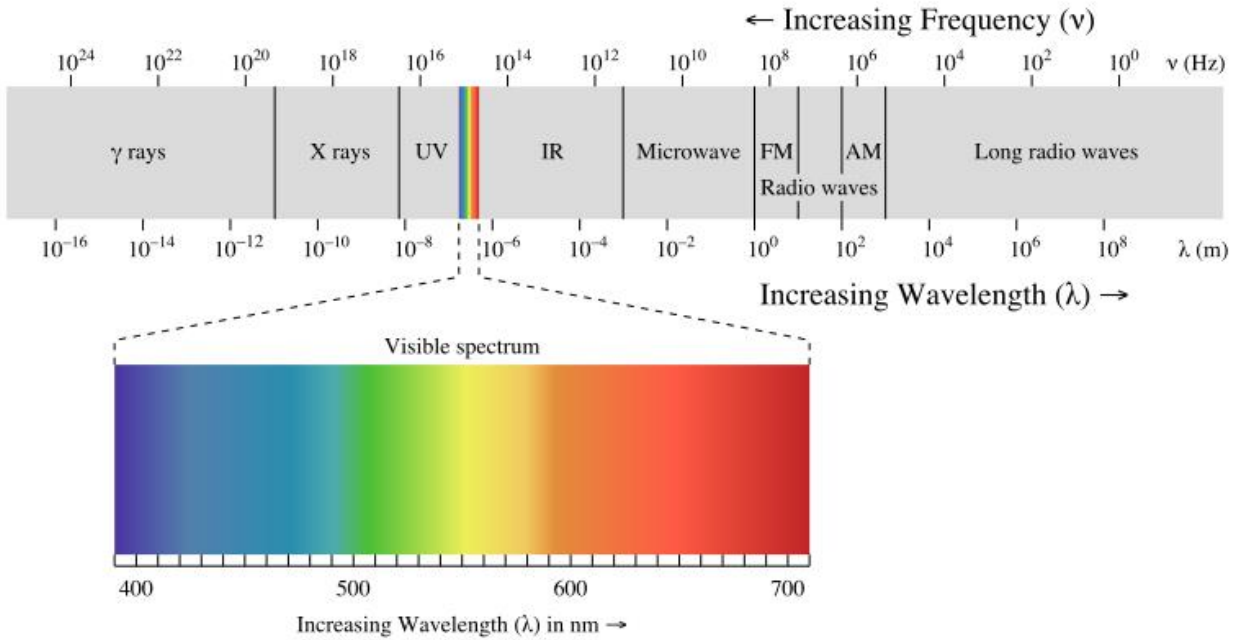


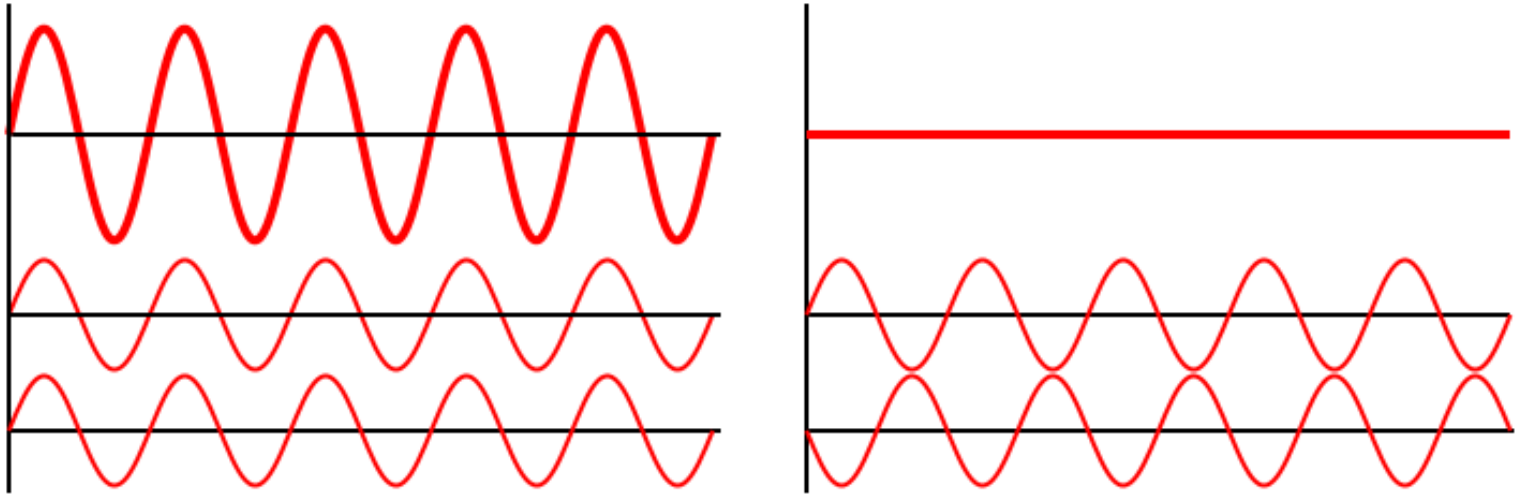
Image: Wikipedia

Various kinds of optics

- **Geometry (ray) optics**
  - Most useful for rendering
  - Describes bulk, macroscopic effects of light
  - It is not a complete theory (Does not describe all observed phenomena, such as diffraction, interference etc.)
- **Wave optics** (light = E-M wave)
  - Important when describing interaction of light with objects of size on par with the light wavelength
  - Interference (soap bubbles), diffraction, dispersion
- **Quantum optics** (light = photons)
  - Necessary to describe interaction of light with atoms

Effects of the wave nature of light

- **Interference**



Constructive

Destructive

  - Causes **iridescence** (structural coloration)

Img: Wikipedia

Iridescence

- Thin-film interference
- Color changes with the observation angle

Img: http://en.wikipedia.org/wiki/Iridescence

Iridescence – Structural coloration

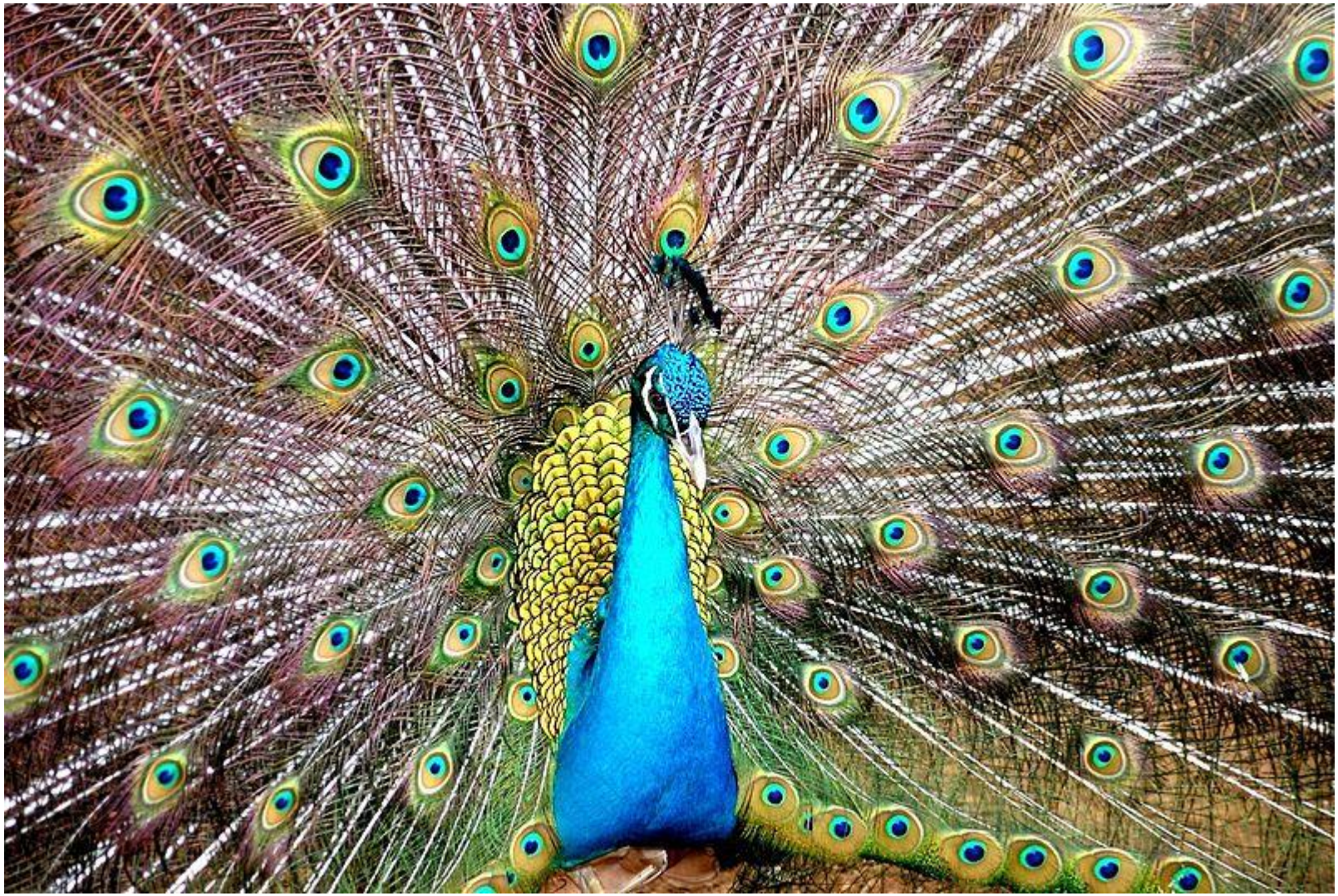
- Biological tissues can have layers causing interferences

Img: http://en.wikipedia.org/wiki/Iridescence

Iridescence – Structural coloration

Img: http://en.wikipedia.org/wiki/Iridescence

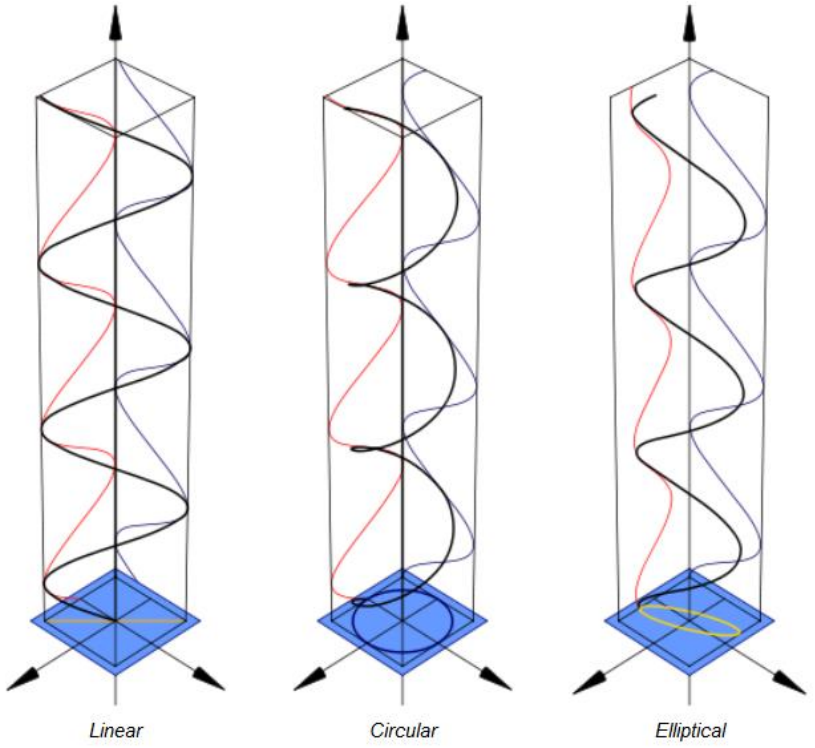
Iridescence – Structural coloration



Img: http://en.wikipedia.org/wiki/Iridescence

Polarization

- Preferential orientation of the E-M waves with respect to the direction of travel
- Unpolarized light – many waves with different polarization
- More in the “Predictive rendering” class



Polarization

- Skylight is partially polarized

- Specular reflections are polarized