# Computer Graphics III
# Introduction

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# Image synthesis (rendering)

Given a scene description

Create an image
(that looks like reality)


HosseinDiba61@yahoo.com
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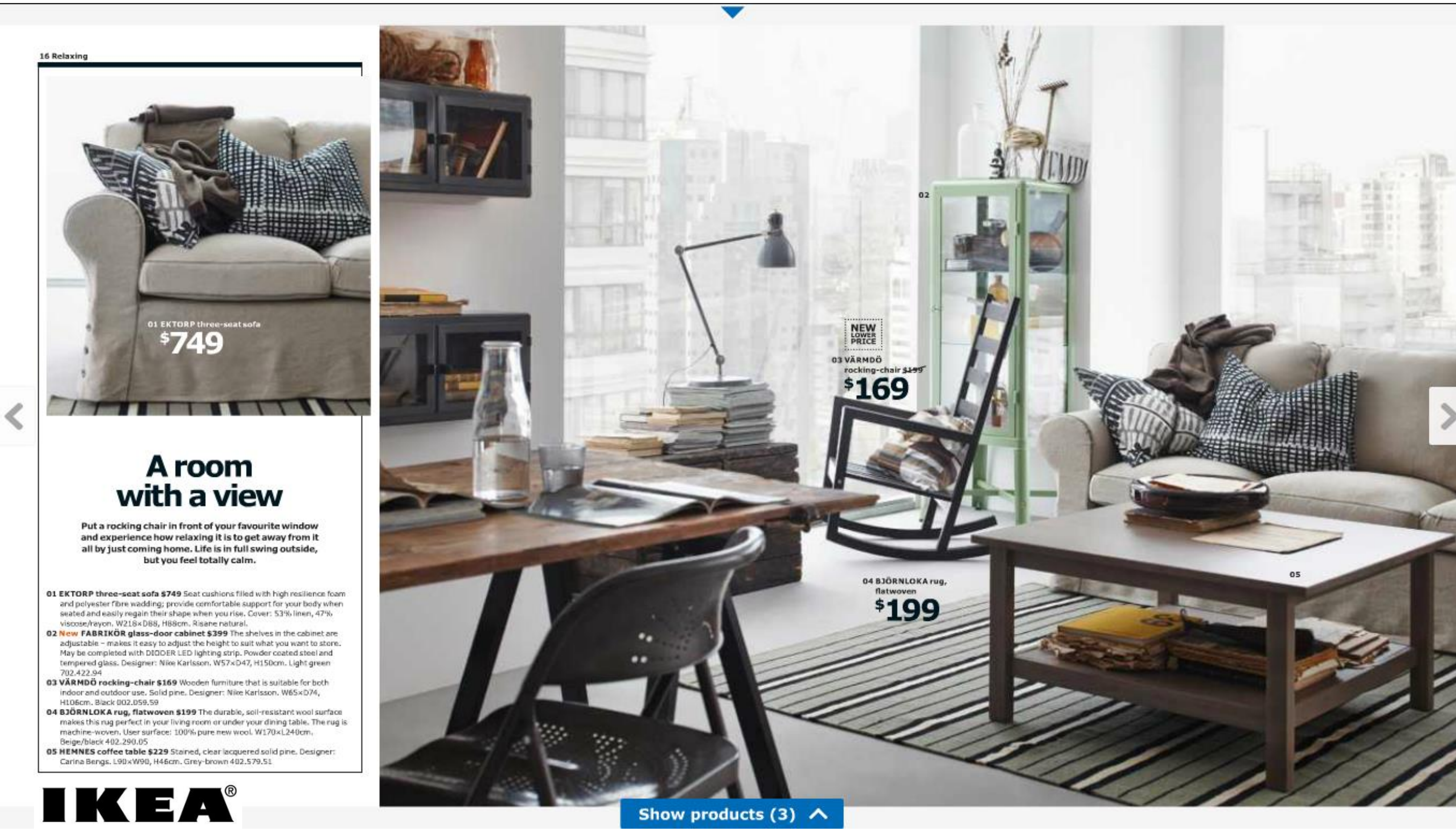
Image created by *Bertrand Benoit*
Rendered in *Corona Renderer*


Image created by *Jeff Patton*
Rendered in *Corona Renderer*


2SA 8801
ŠKODA Rapid Catalogue



16 Relaxing

01 EKTORP three-seat sofa
$749

# 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

IKEA®

02

NEW LOWER PRICE
03 VÄRMDÖ rocking-chair ~~$199~~
$169

04 BJÖRNLOKA rug, flatwoven
$199

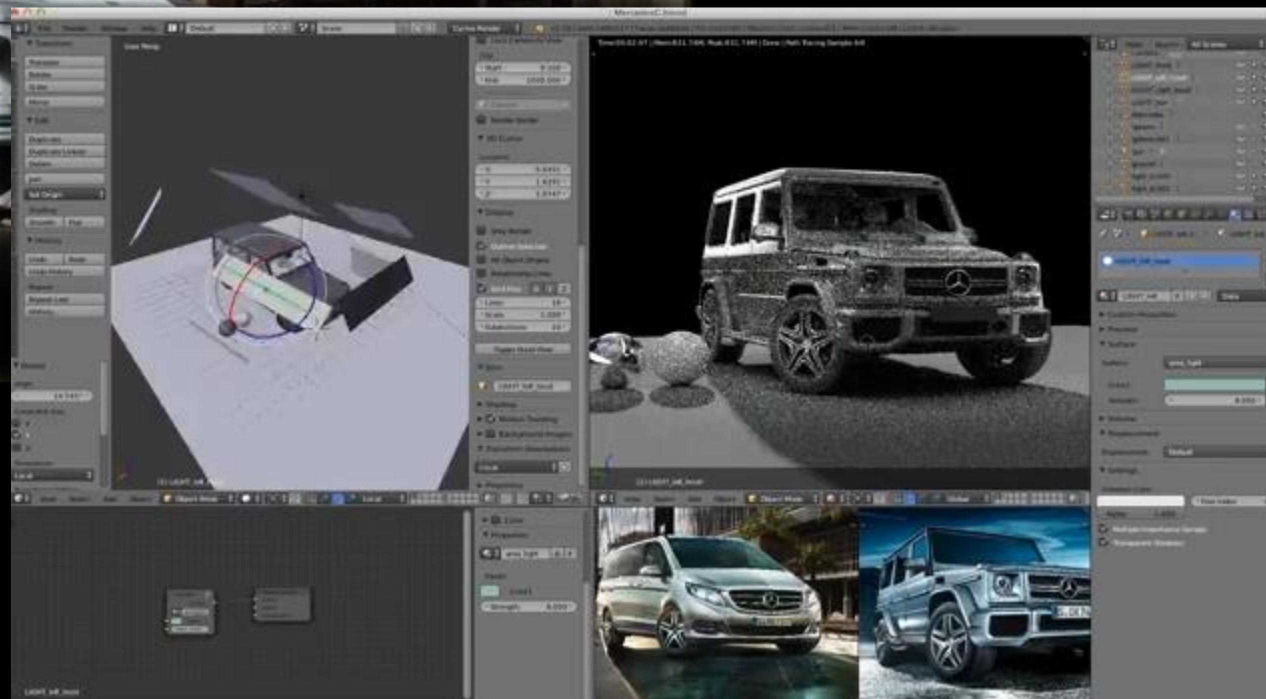
05

Show products (3)

# Fake or real?


Images courtesy
Dudek Digital Imaging

# Fake or real?



Images courtesy
Maciek Ptaszynski

Image created by *Weta Digital*


**vimeo >> “The Great Gatsby VFX”**


vimeo >> “The Great Gatsby VFX”

# Path tracing (Arnold renderer)

Alice in the Wonderland, 2010


Images courtesy of Walt Disney Pictures

# Point-based global illumination: "Up"

# Point-based global illumination: “Toy Story 3”

© Pixar Animation Studios
Image credit: Per Christensen

Computer
Graphics
Charles
University

# Computer Graphics Group

# Graphics@CUNI – Faculty


Alex Wilkie


Pepča Pelikán

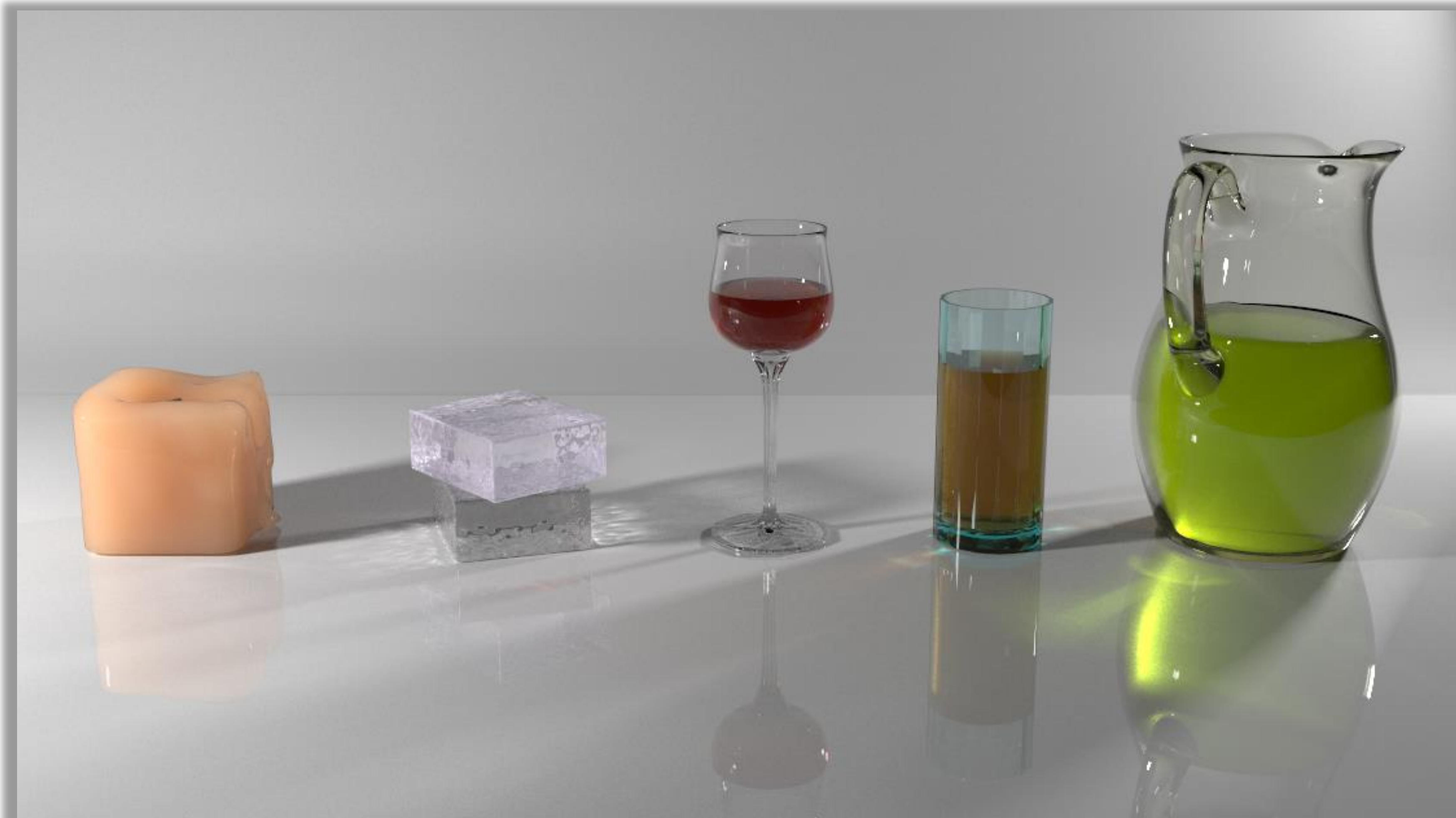

Jarda Křivánek

# Vertex Connection & Merging (VCM)

**SIGGRAPH Asia 2012**

# Robust rendering of volumetric media

**SIGGRAPH 2014**



# Our work in production

corona



# Image synthesis – A gentle intro

# Image synthesis (rendering)

Given a scene description

Create an image
(that looks like reality)

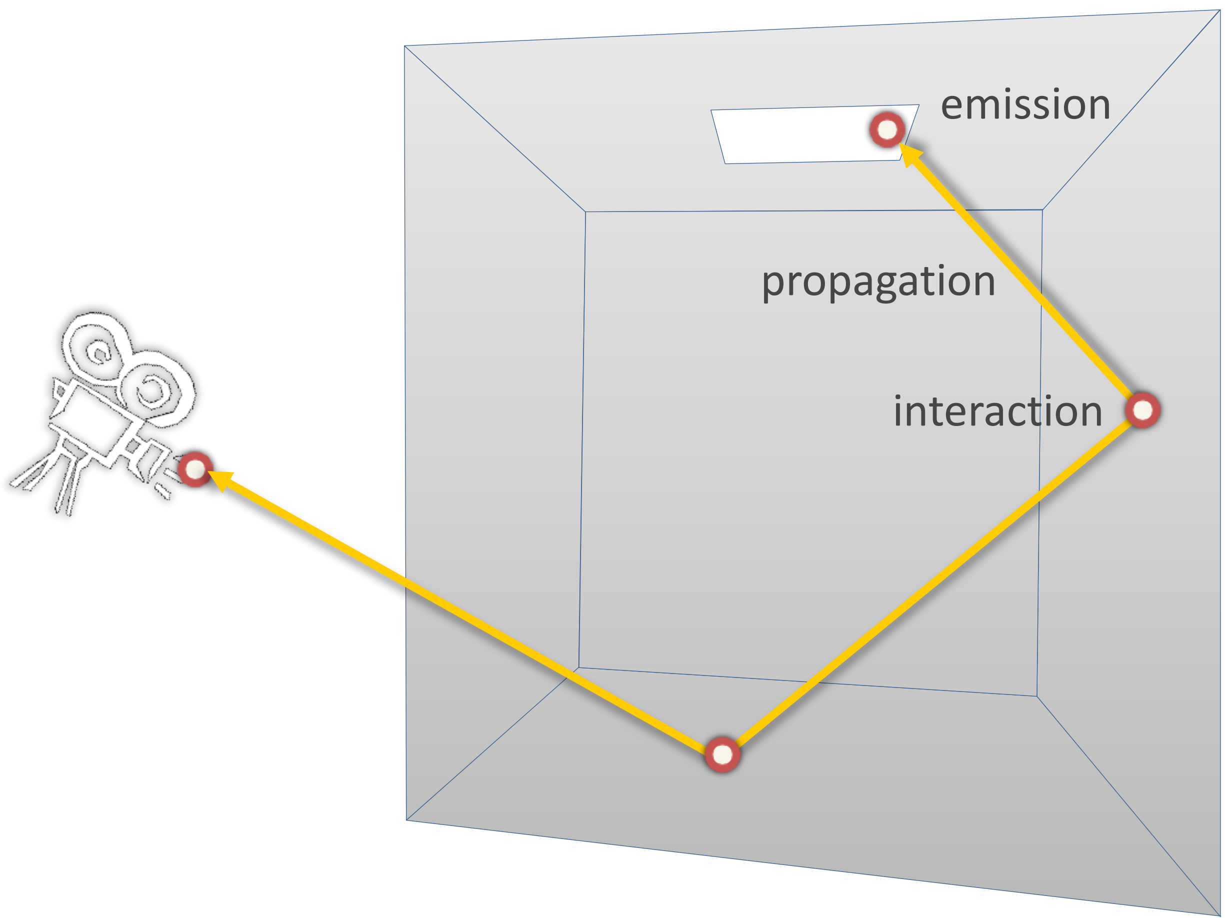
# Scene description

- **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

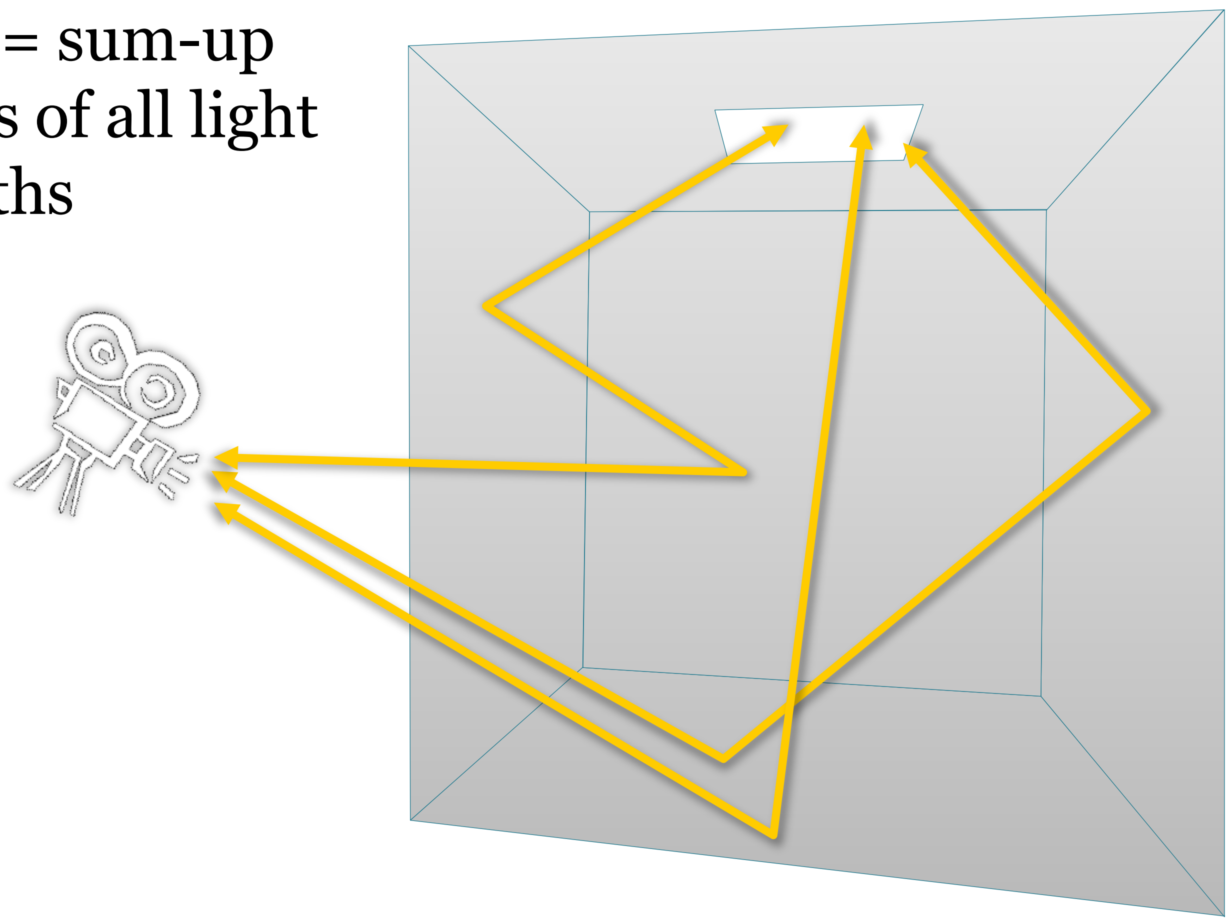
- Movie production
- Entertainment, games
- Industrial design
- Architecture
- Virtual showrooms
- On-line commerce
- Cultural heritage
- Virtual and augmented reality

# Light transport simulation



# Light transport simulation

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



# What's in the image?

# What’s in the image?

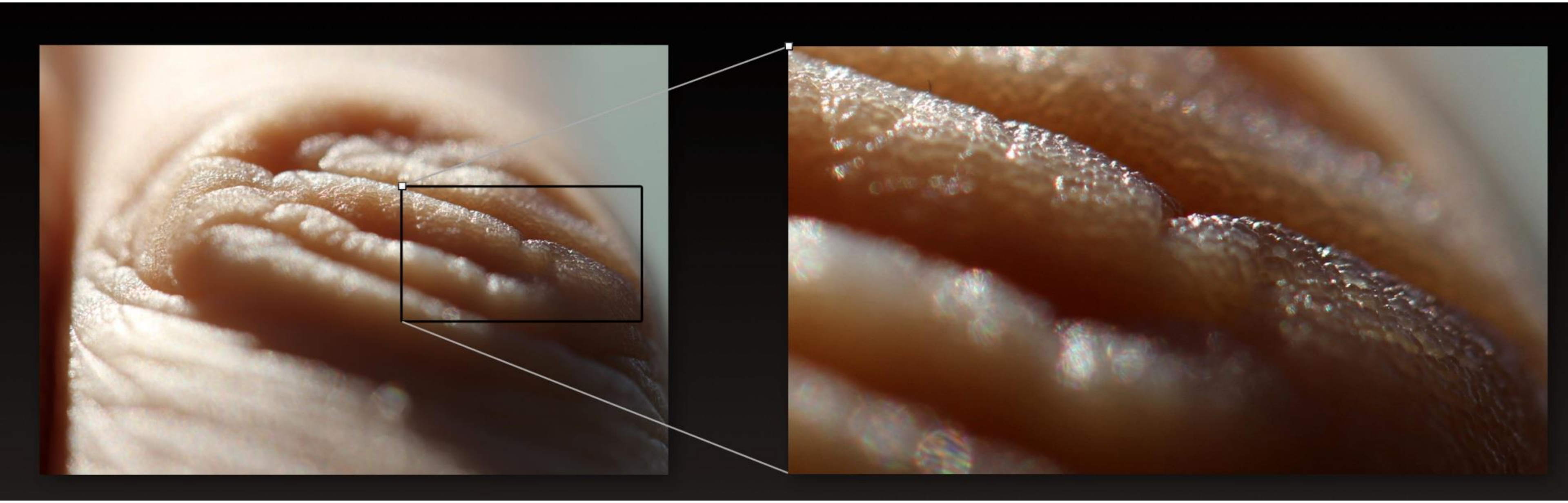
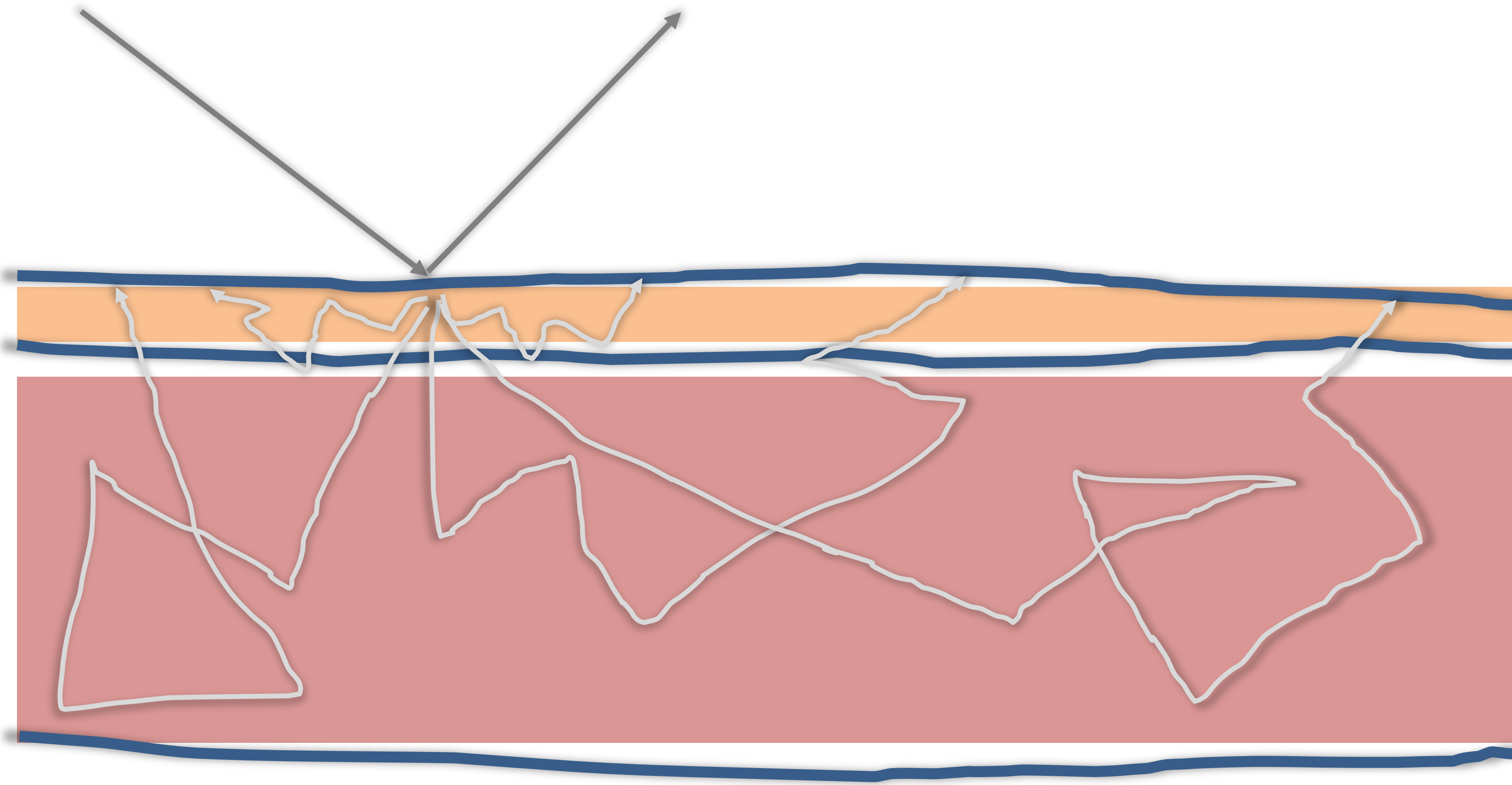
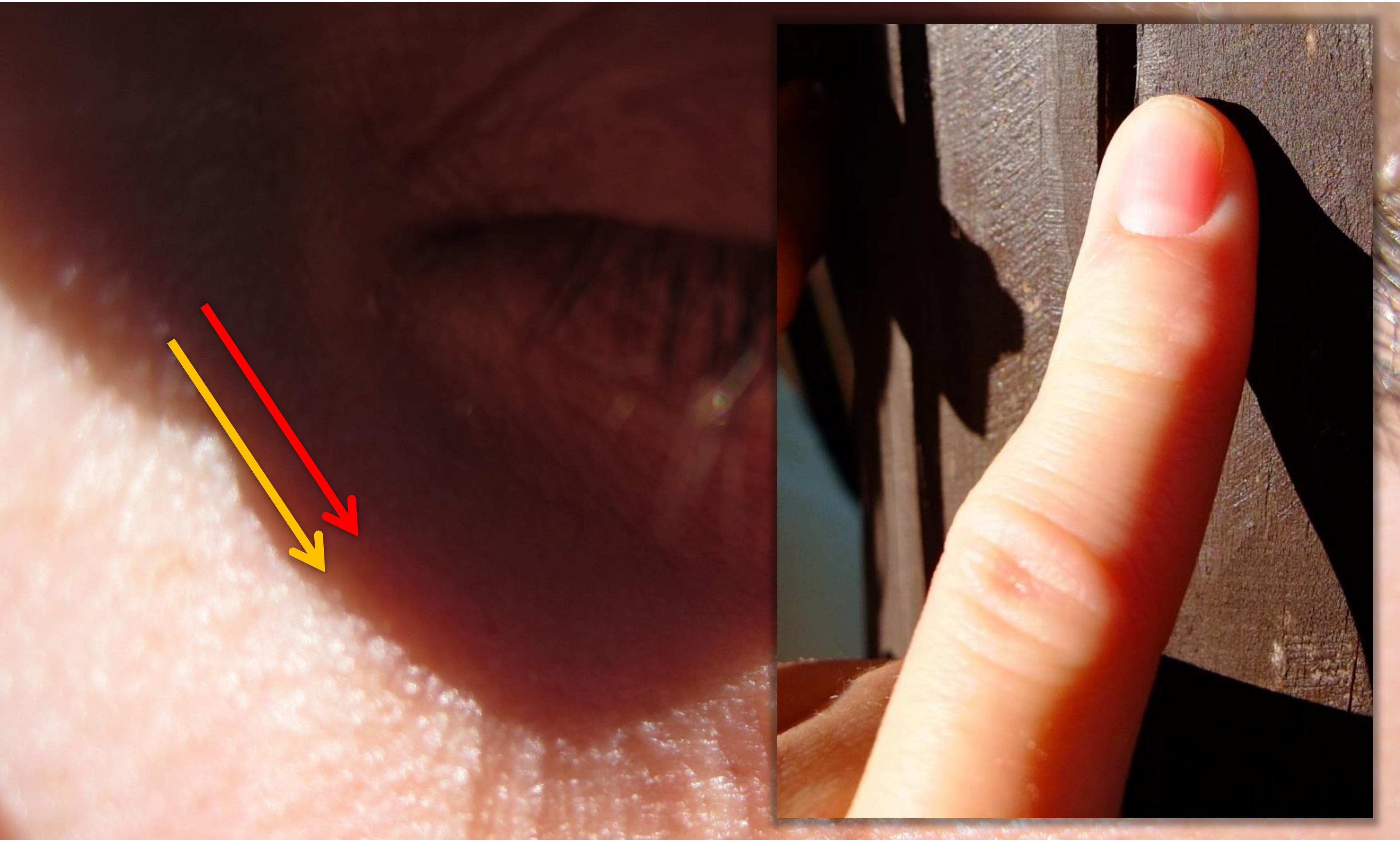


Image courtesy Eugene d’Eon

# Why does skin look the way it does?

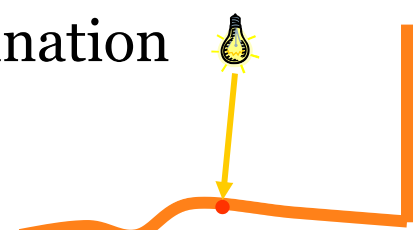


# Subsurface scattering effects on skin

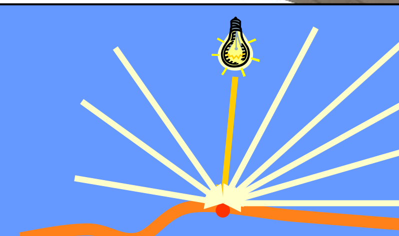


# Global illumination – GI

Direct illumination

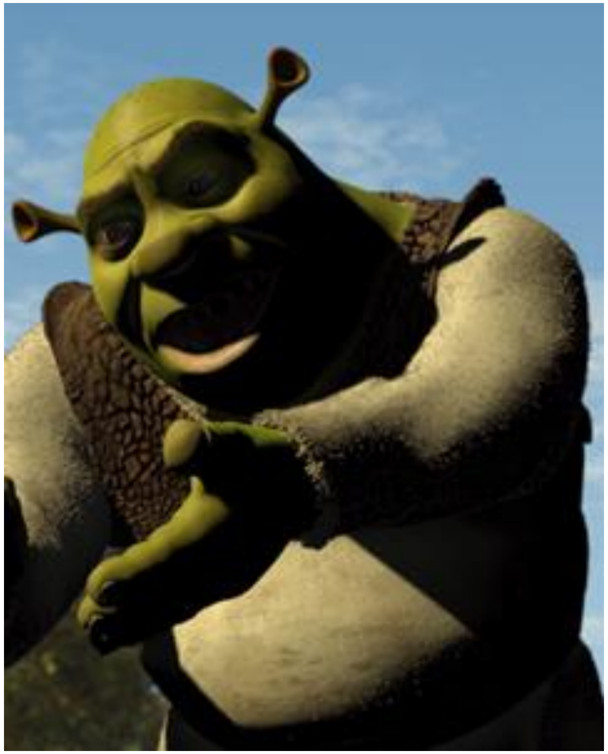


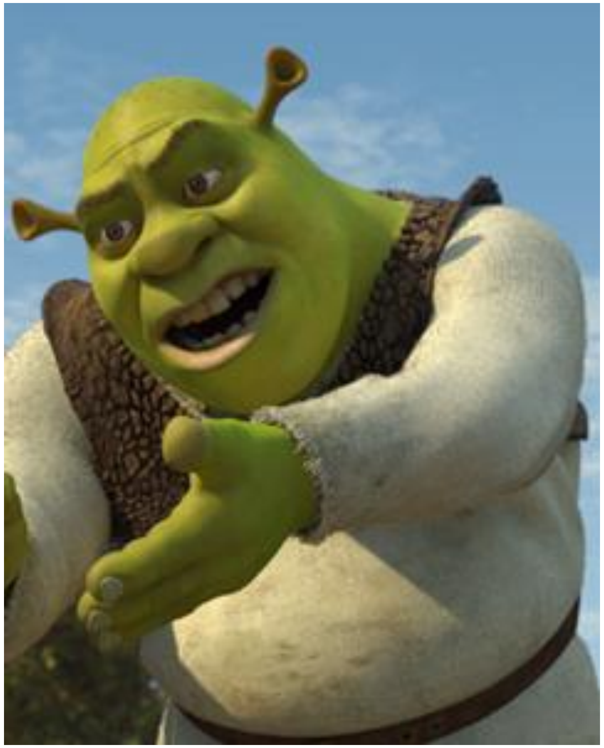
Global =
direct +
indirect



# Globální osvětlení

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

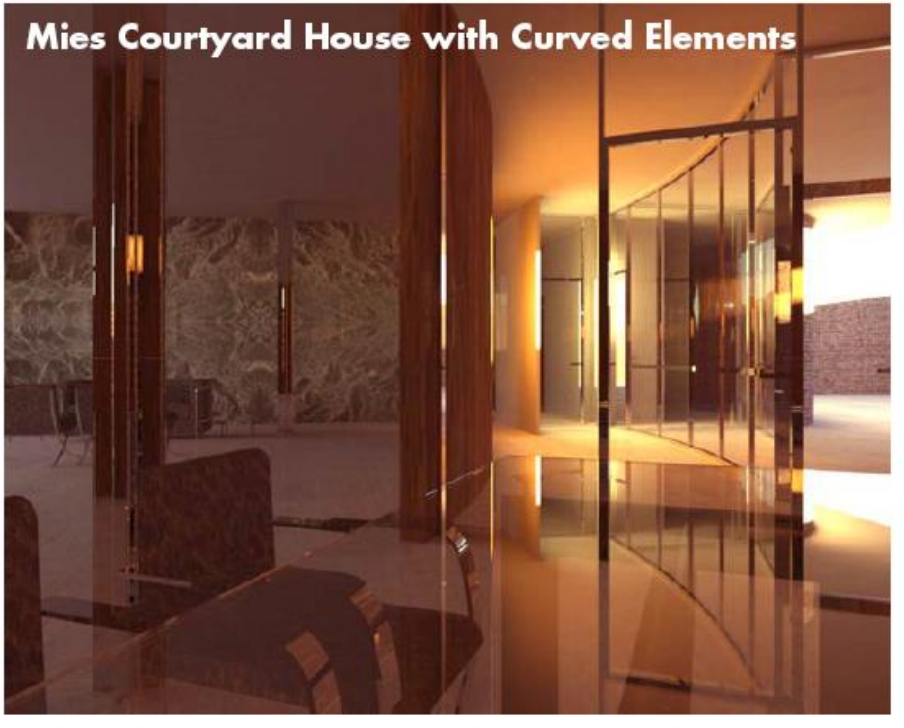




- **Global illumination**
  - Global = Direct + Indirect
  - Light transport between surfaces in the scene
  - Multiple reflections/refractions

# Global illumination effects

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

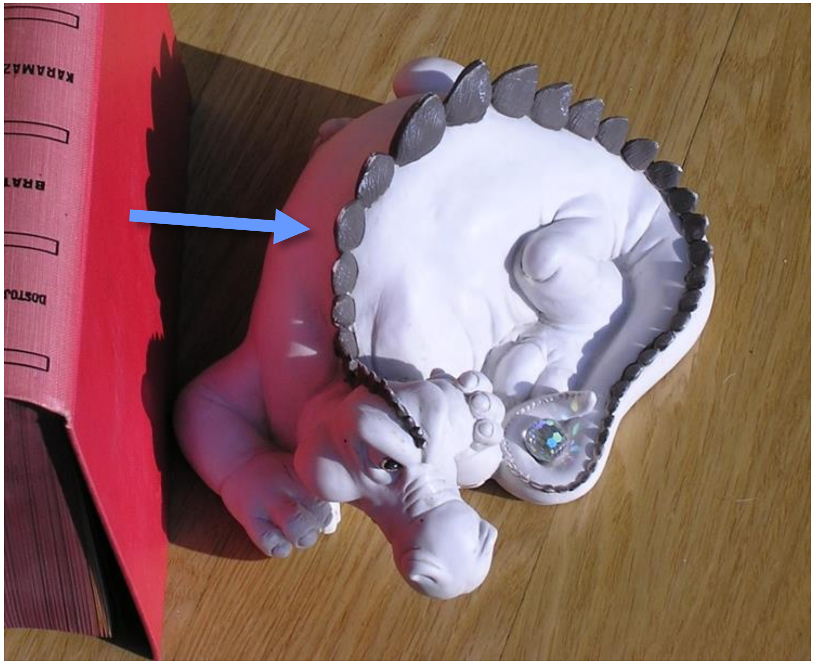


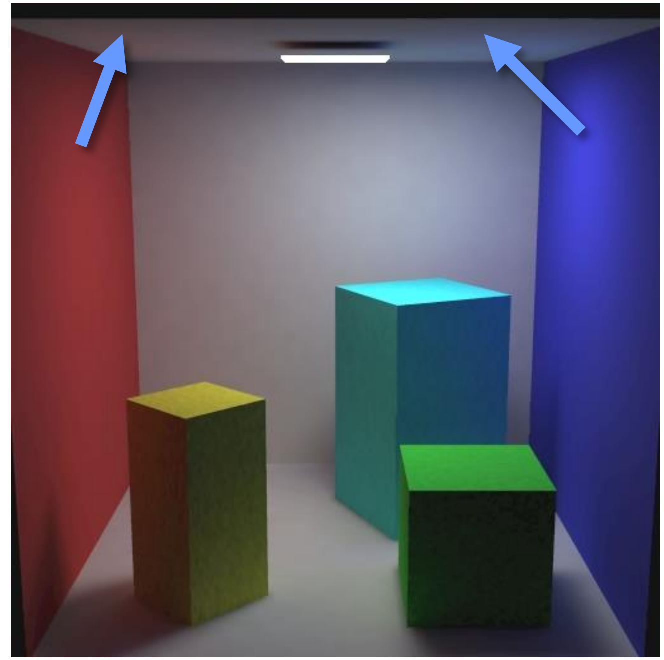

Modeling: Stephen Duck; Rendering: Henrik Wann Jensen

# 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



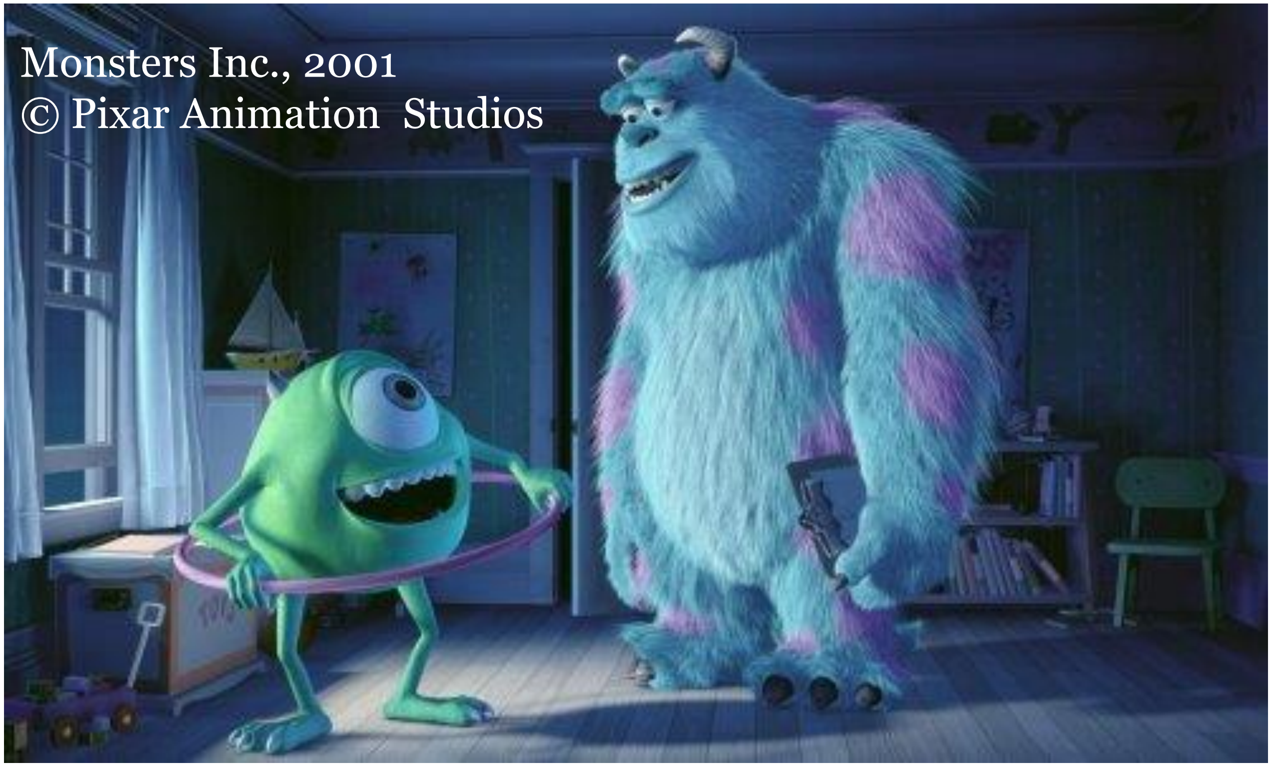


- Light reflected from one diffuse surface onto another
- Important for understanding of the spatial relationships of objects in a given scene (this happens subconsciously)

# 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

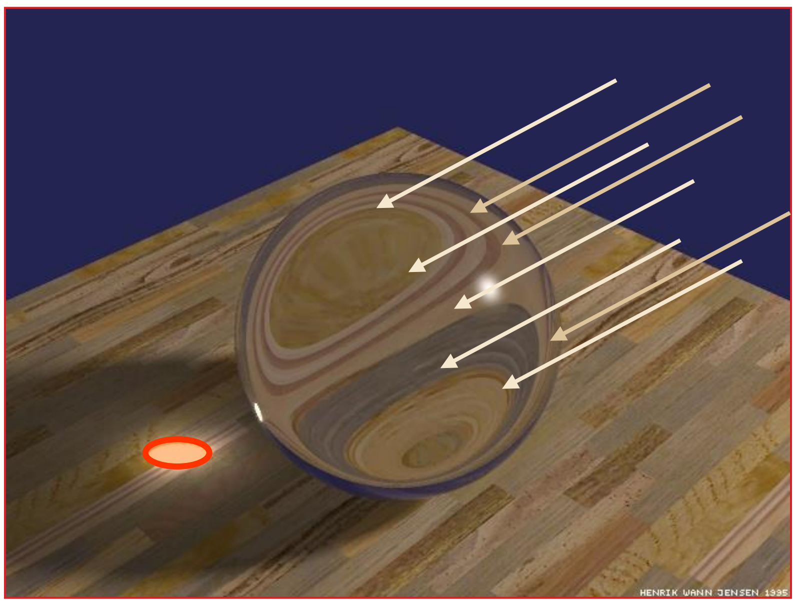
- Focusing of light as it's reflected or refracted, leading to local increase of intensity

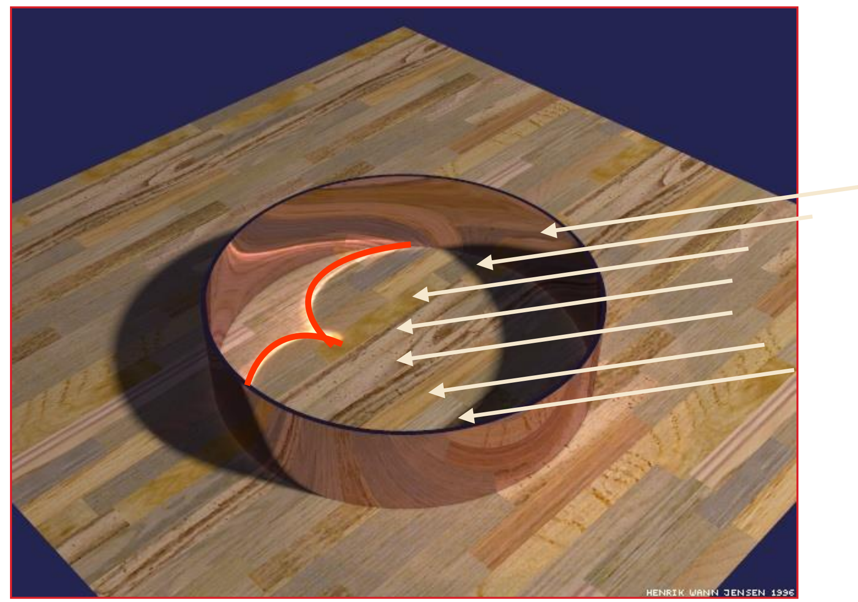
Photograph


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)

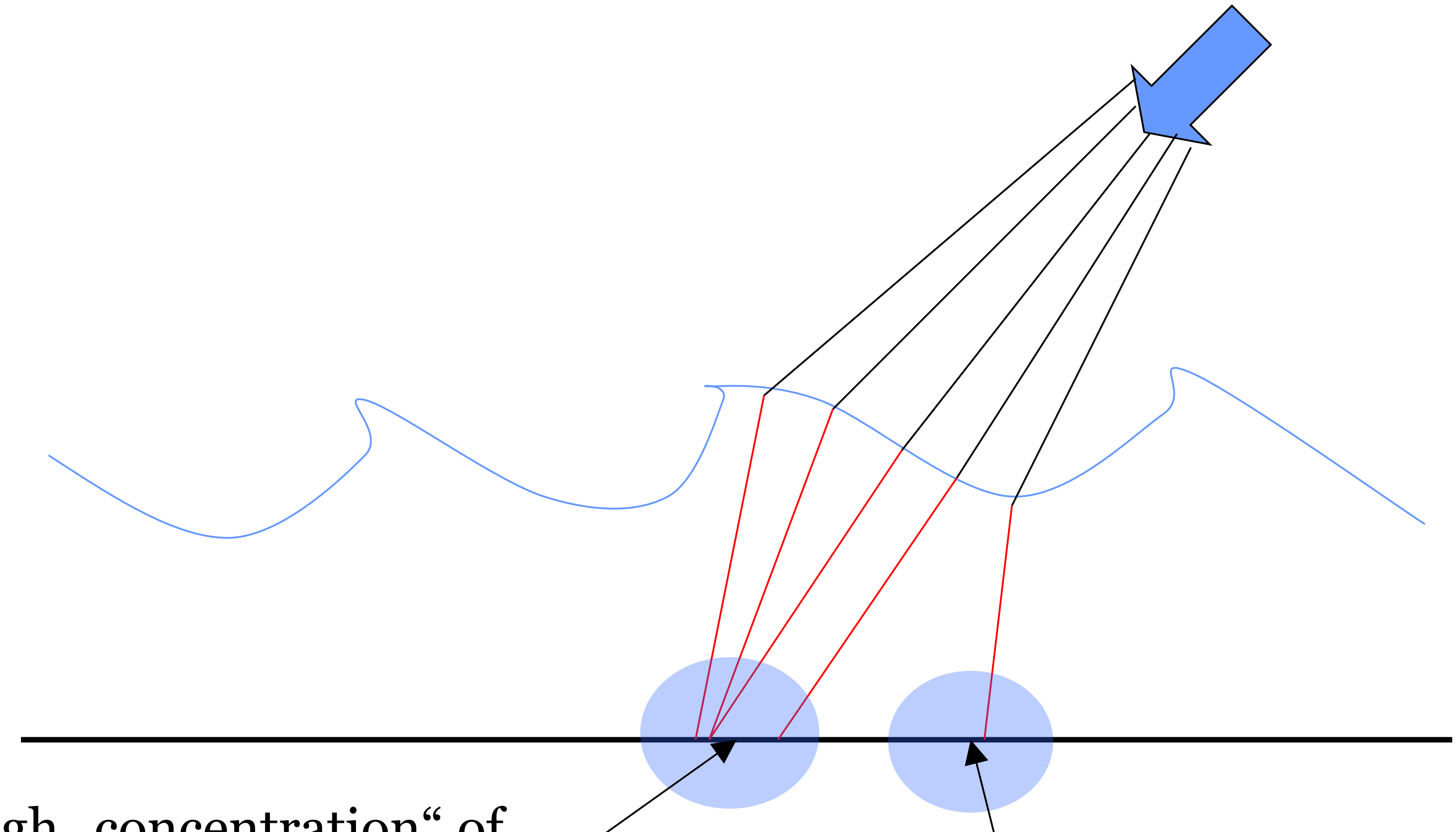


# What do we see when we look at a surface of a swimming pool?

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

# Caustics under water surface



High „concentration“ of photons – high light intensity

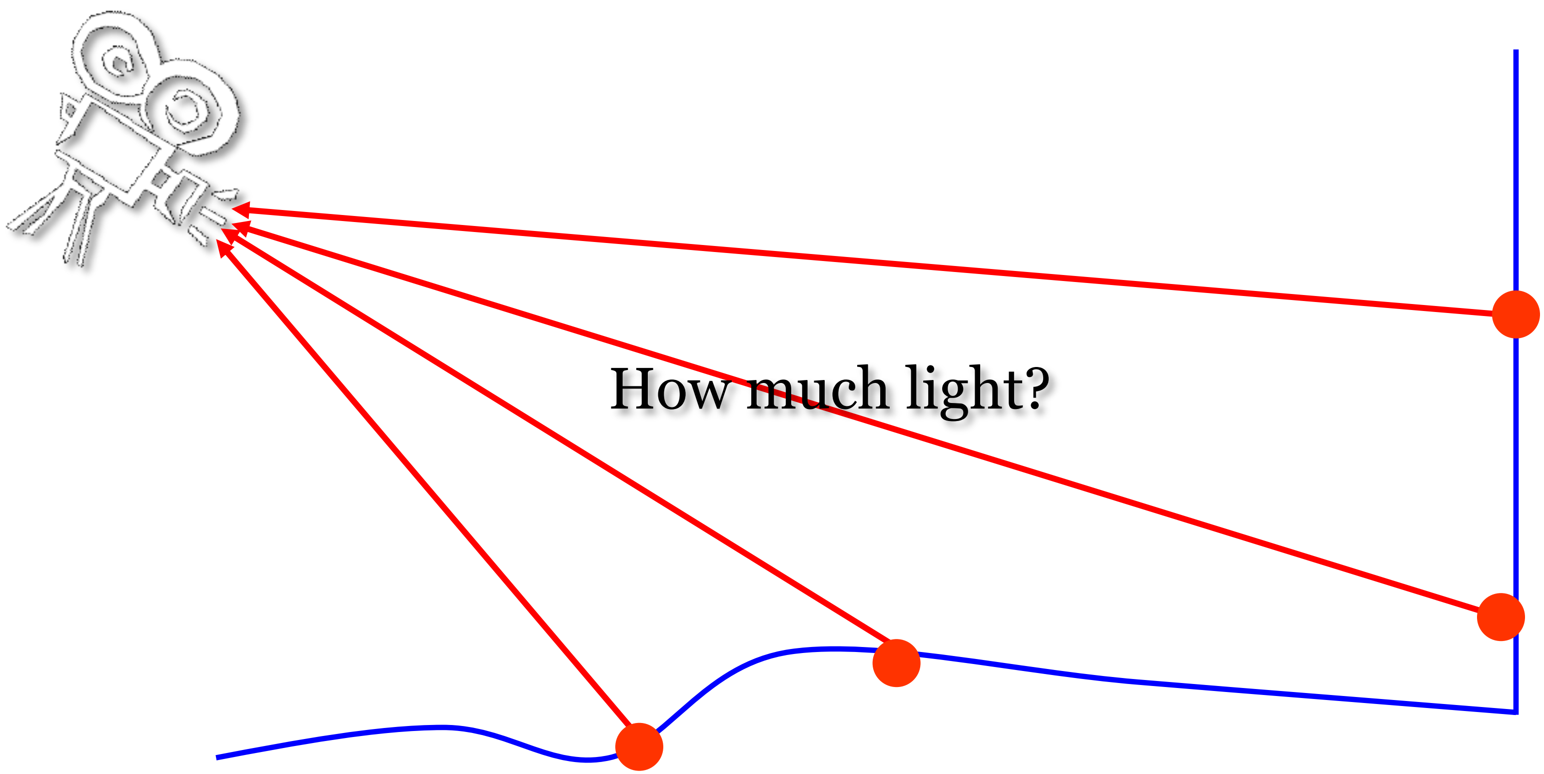
Low intensity

# 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)

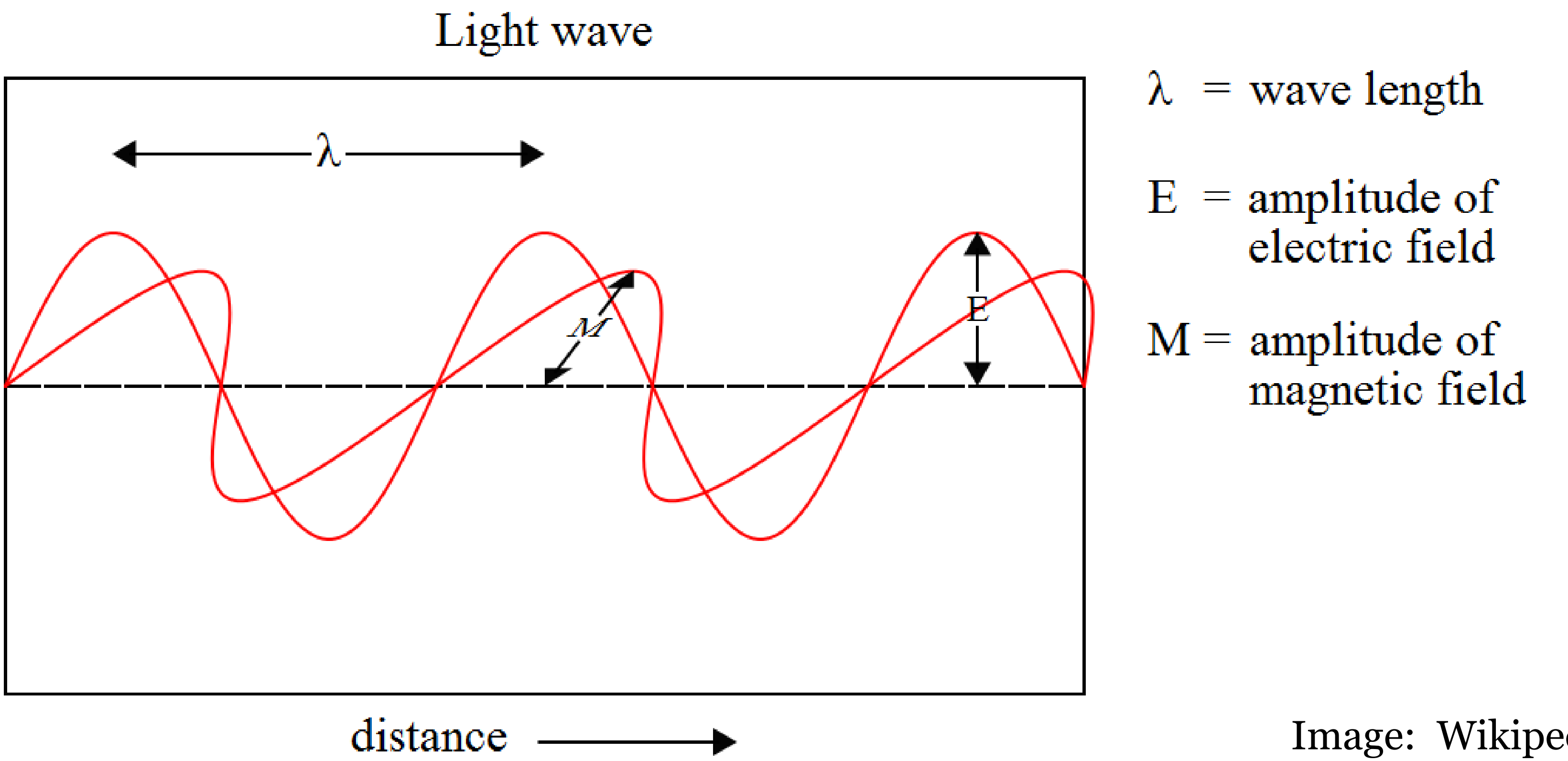



Image: Wikipedia

# Light

- Frequency of oscillations => wavelength => perceived color

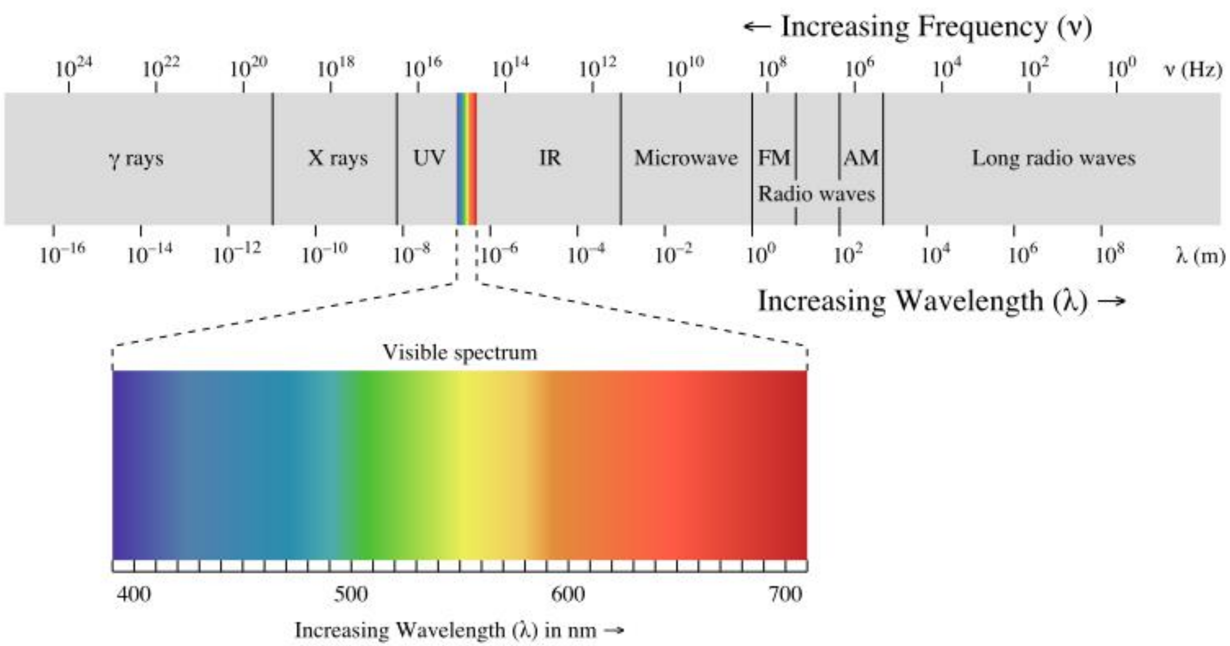


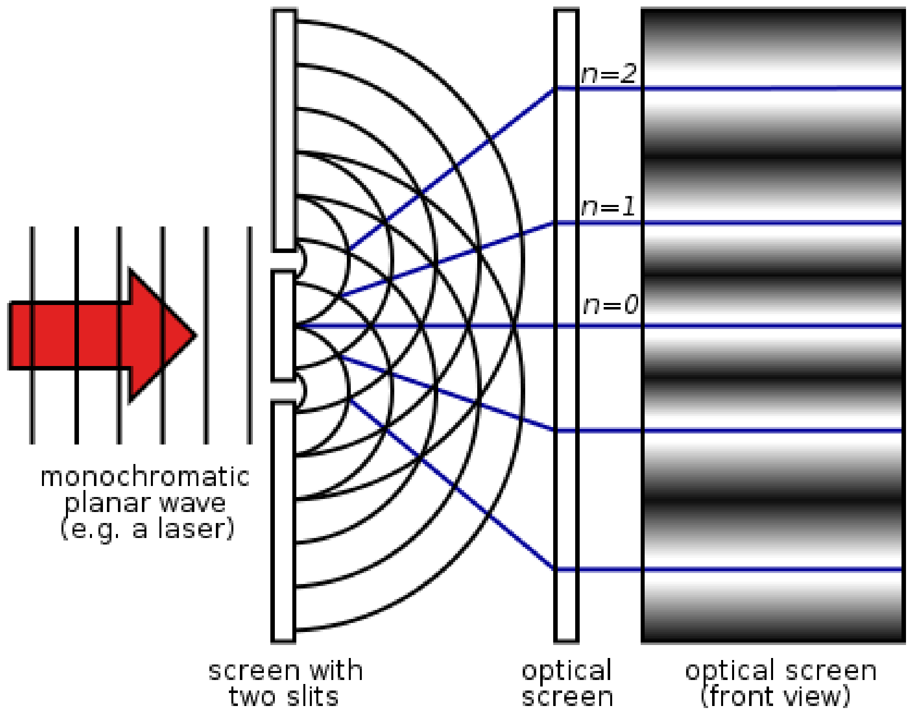

Image: Wikipedia

# 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

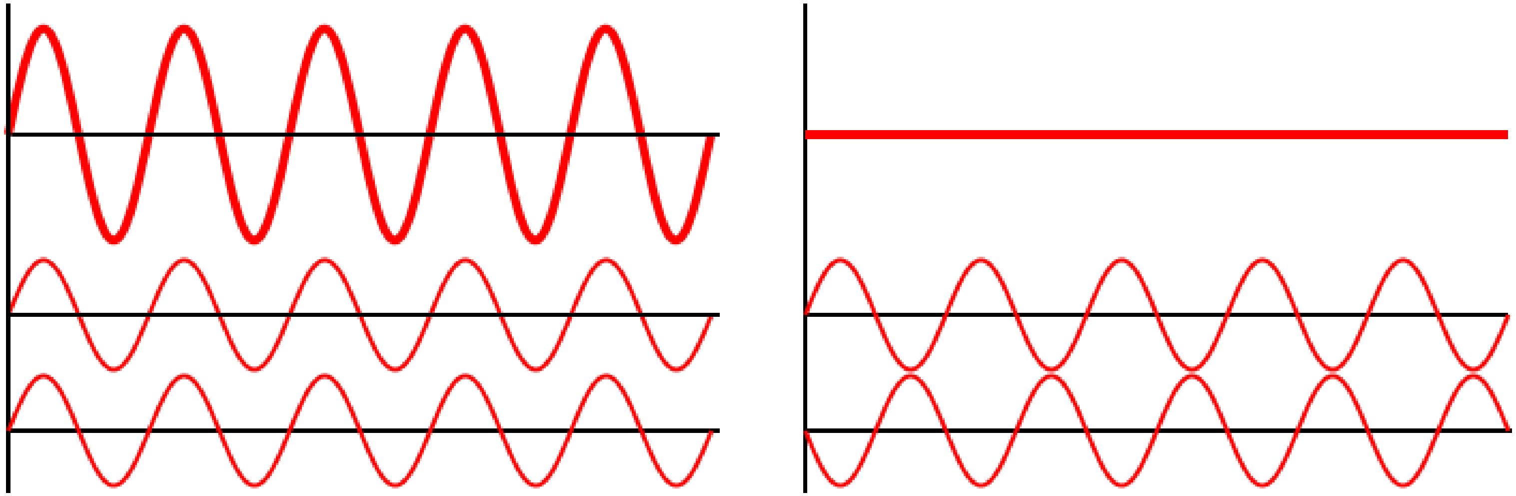
# Effects of the wave nature of light

- **Interference**
  - Young experiment, a.k.a. double-slit experiment



# Effects of the wave nature of light

- **Interference**





  - 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

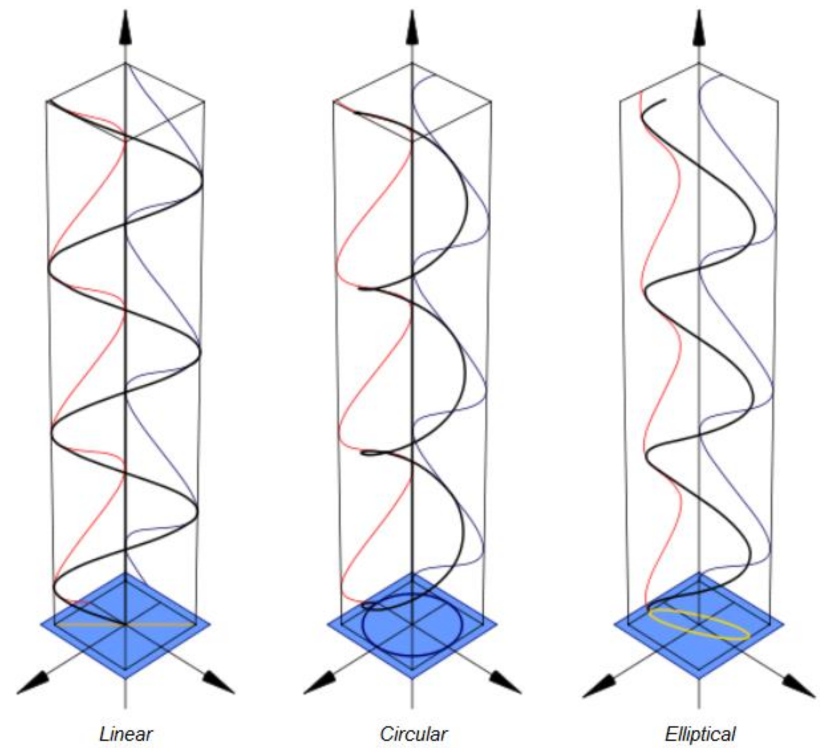

Img: http://en.wikipedia.org/wiki/Iridescence

# 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