

# Comp5514

## Computer Image Generation



## Lecture 01

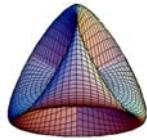
[www.comp.polyu.edu.hk/~csgeorge/comp5514/lec](http://www.comp.polyu.edu.hk/~csgeorge/comp5514/lec)

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PQ825

x7272



2

## Digital Image Construction

1

## Human Vision Basics

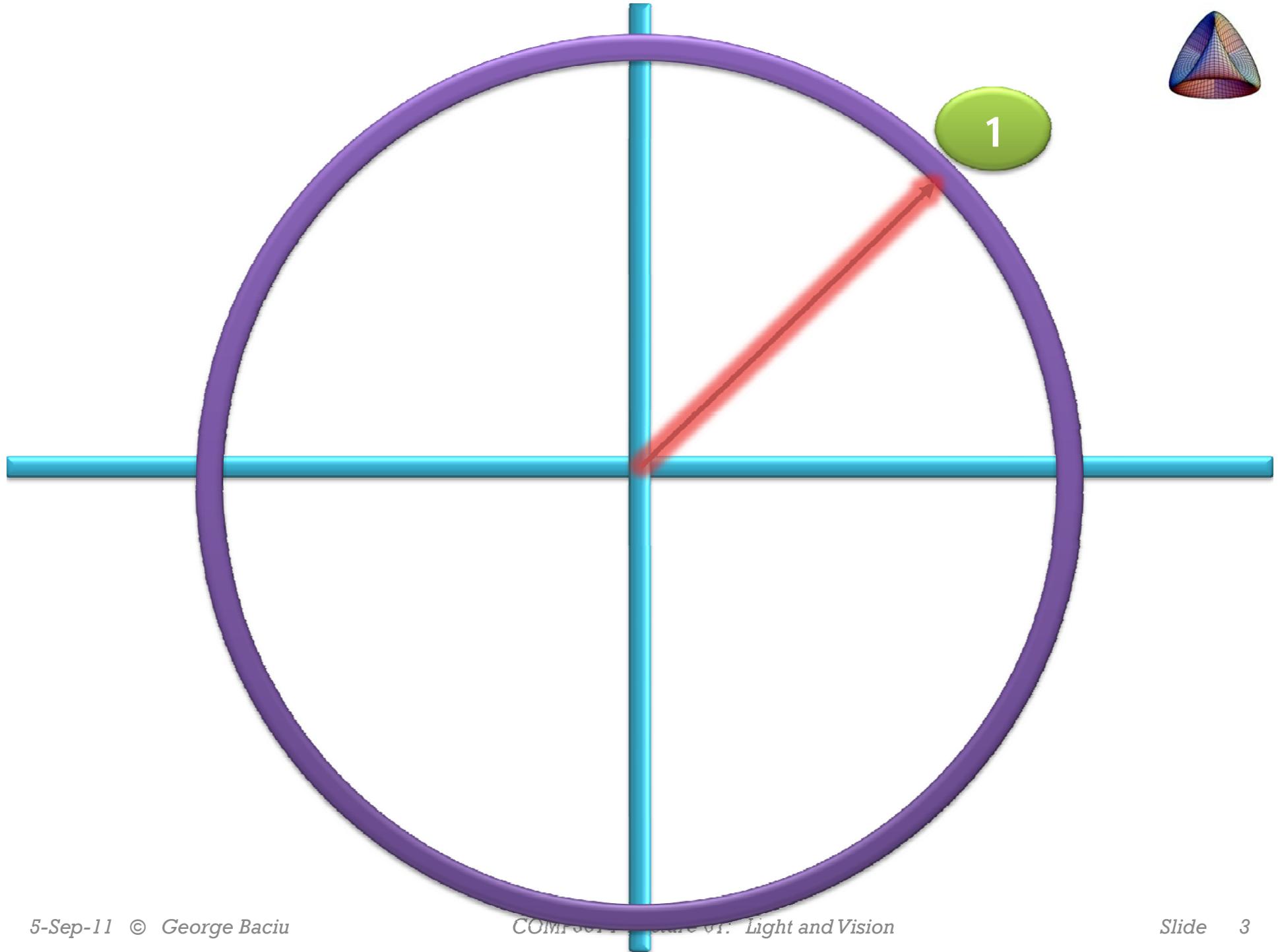
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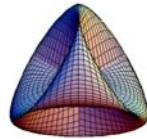
## Display Systems Technology

4

## Pipelined Rendering Phases



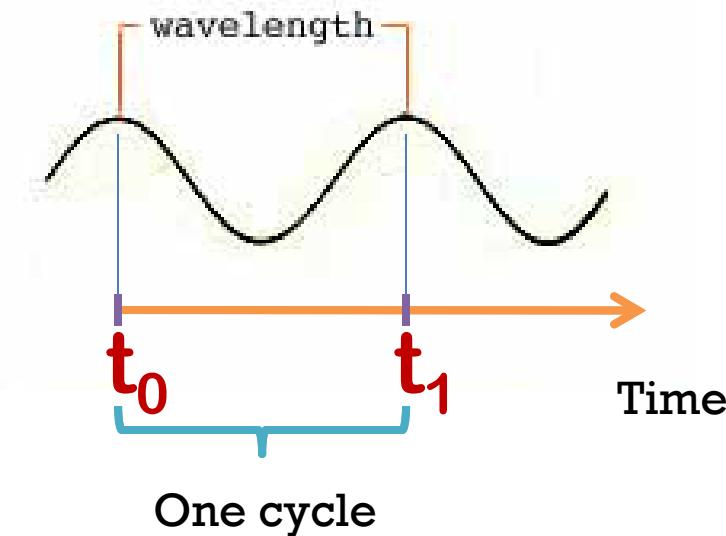




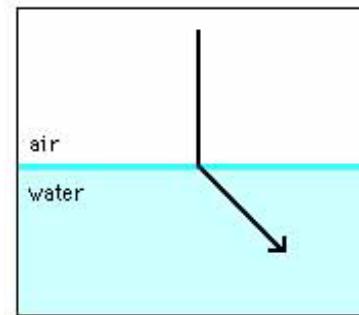
# Simple Light Physics

- Four basic light interactions

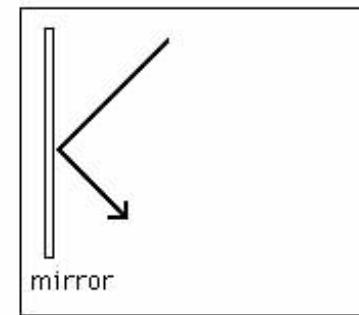
Light Propagation



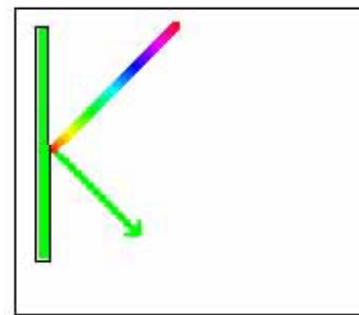
$$\Delta T = t_1 - t_0$$



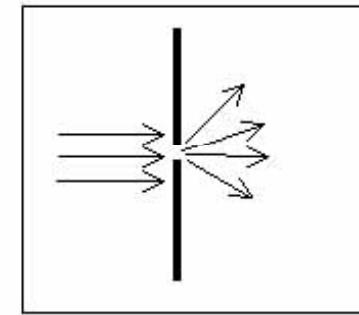
Refraction



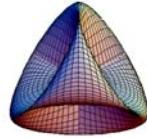
Reflection



Absorption



Diffraction

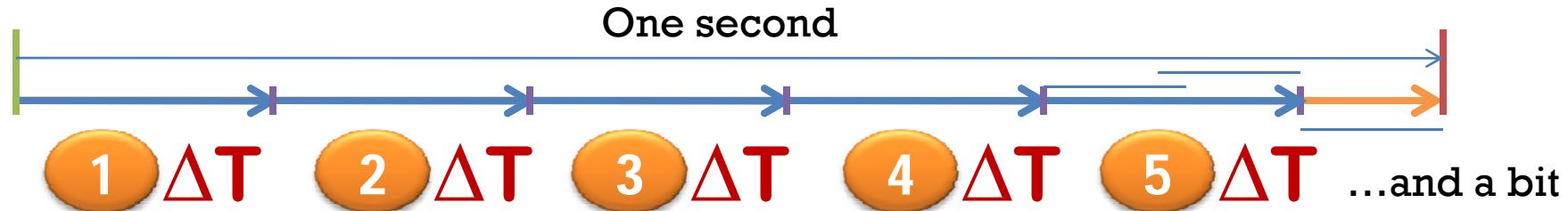


# Time and Frequency

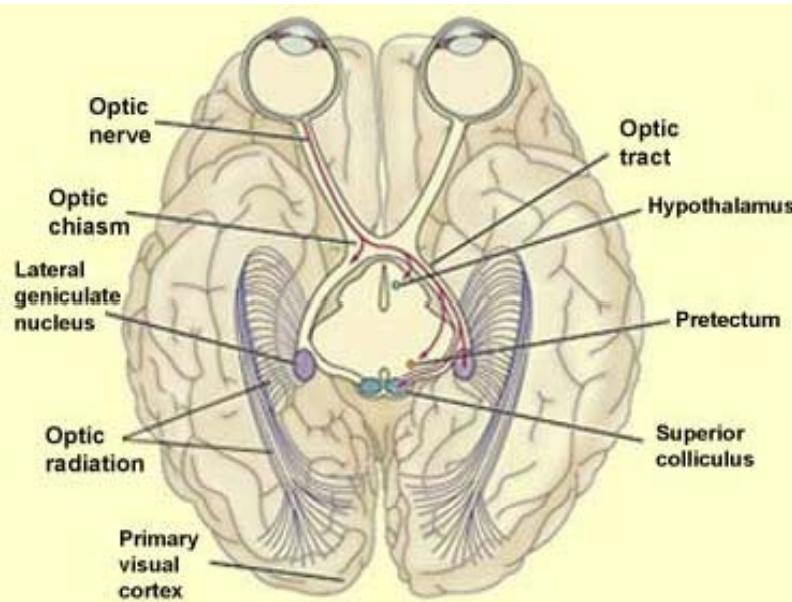
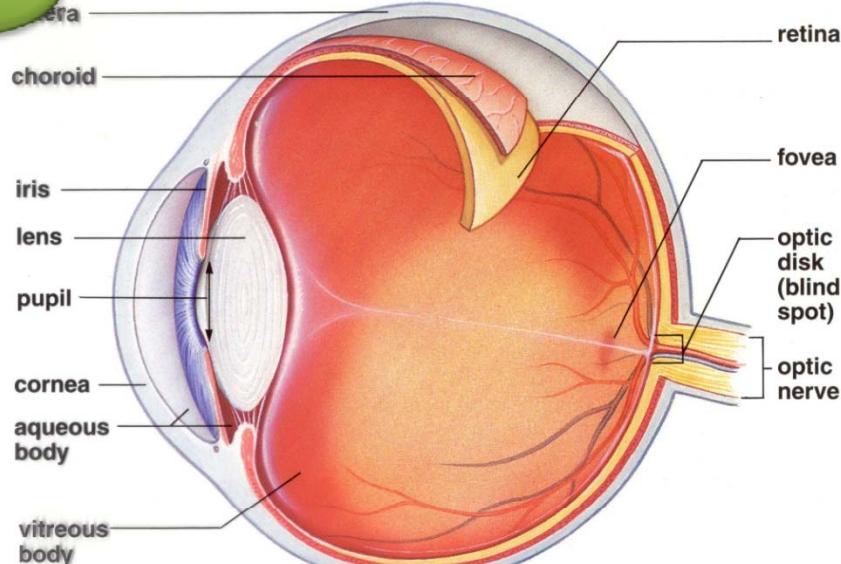
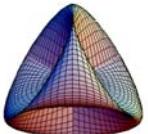
- One cycle takes:

$$\Delta T = t_1 - t_0$$

- How many  $\Delta T$ 's in one second?

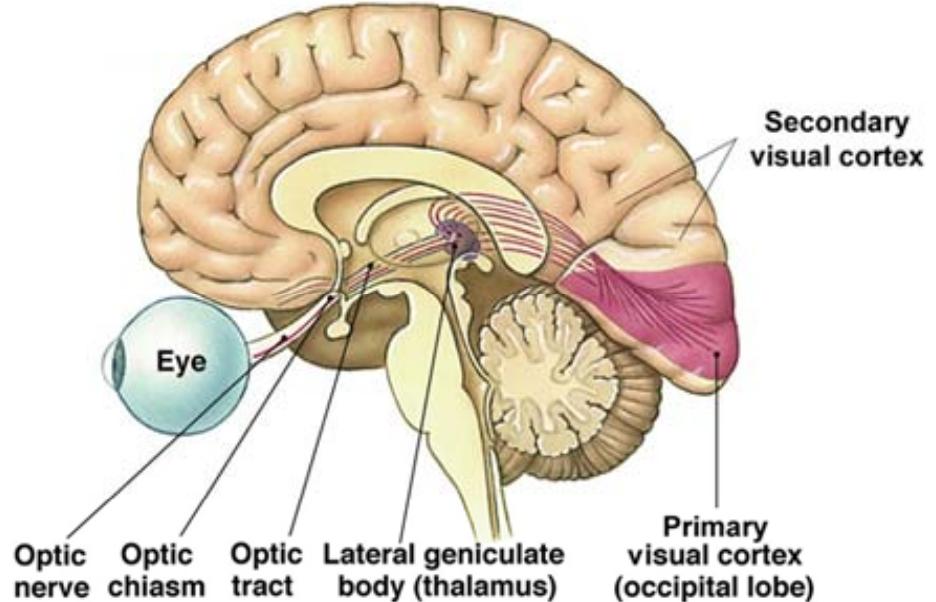


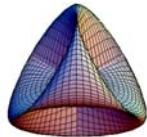
So the frequency is:  $F = 5.54$  cycles per second



Basic Introduction to

# 1. HUMAN VISUAL SYSTEM





# Image Projection

- Image formation in the eye

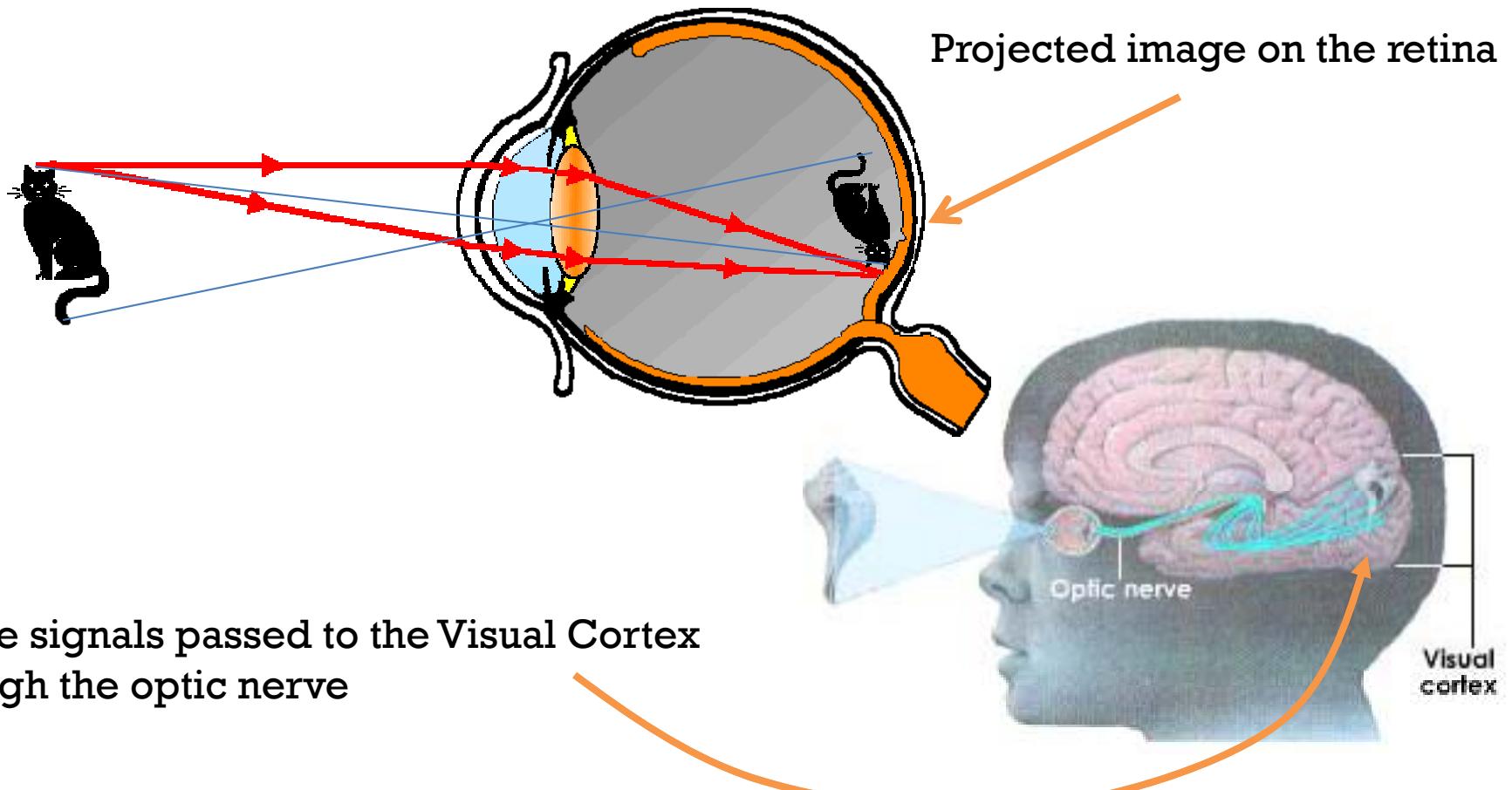
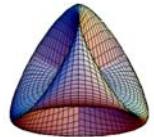
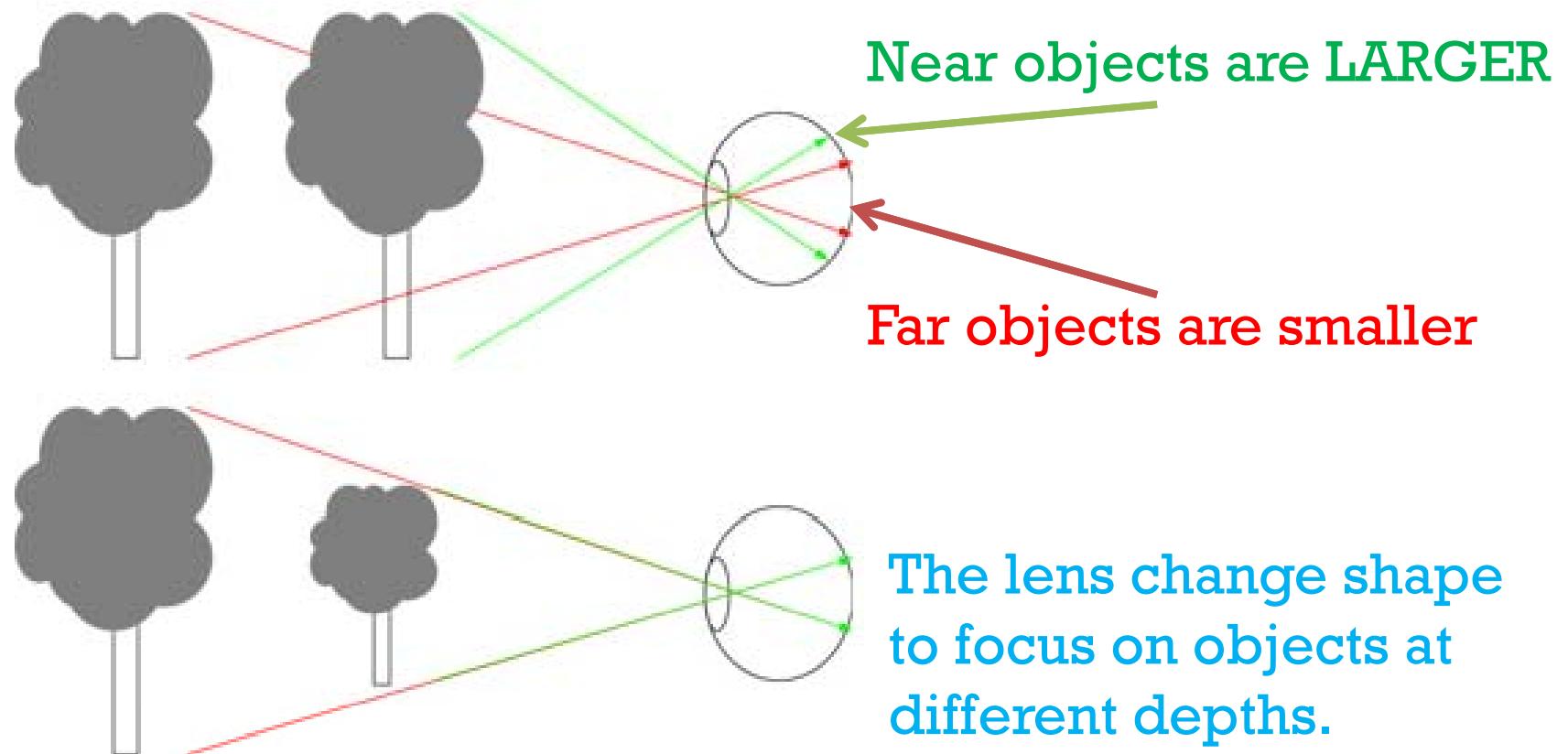


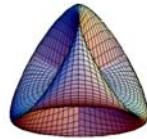
Image signals passed to the Visual Cortex  
through the optic nerve



# Visual Angle

- Object size and visual angle

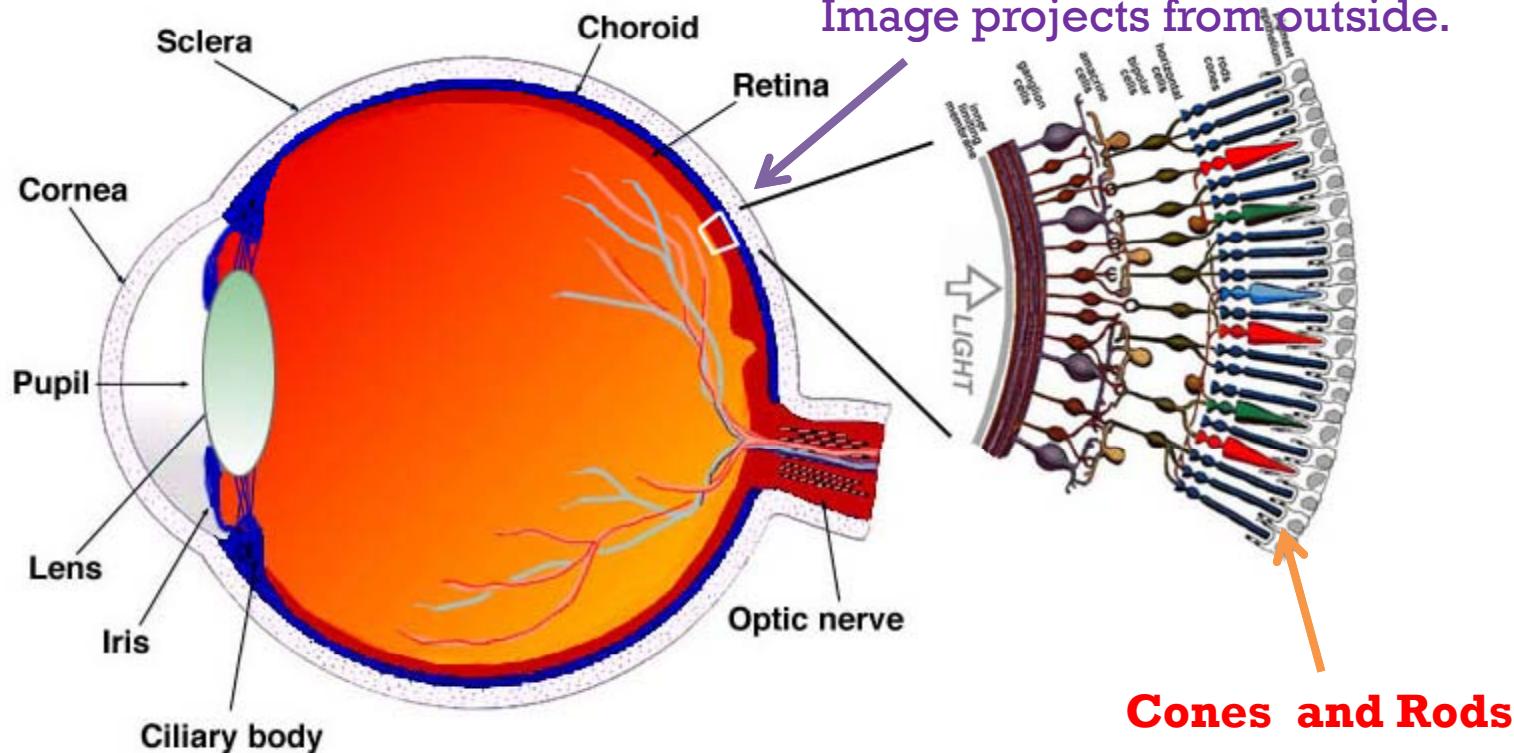


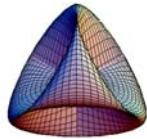


# Retina

- Retina – light-sensitive tissue on the inner surface of the back of the eye.

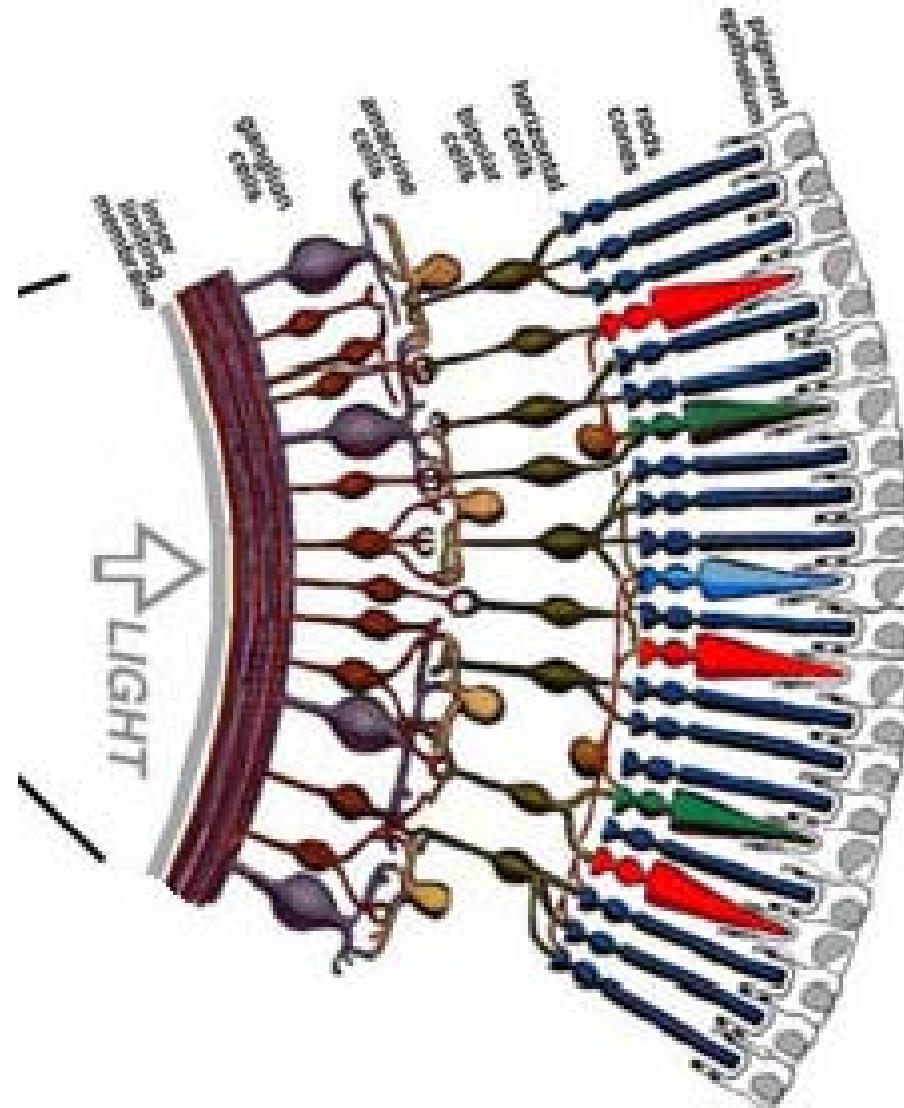
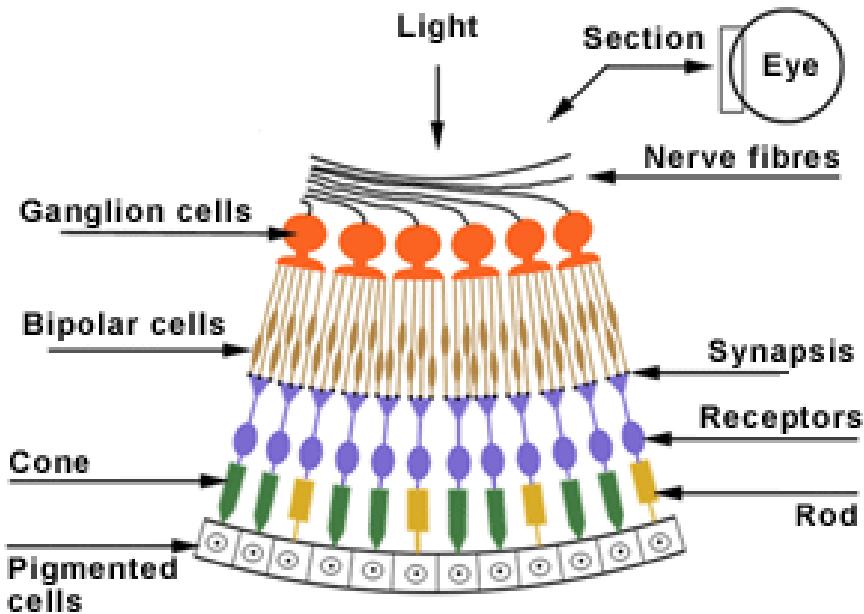
Like a screen where the  
Image projects from outside.

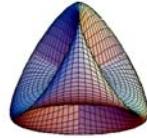




# Cones and Rods

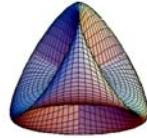
- Cones and Rods





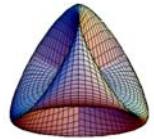
# What do Rods do?

- **Rods:** about 92M cells.
- **Rods:** are photoreceptor cells that are sensitive to low illumination, ie in darkness and at night;
- **Rods:** sensitive to single photon light intensity.
- **Rods:** 100 times more sensitive than cones.
- **Rods:** concentrate at the outer edge of the retina.
- **Rods:** responsible for peripheral vision.
- **Rods:** responsive in the 498nm wavelength, green-blue.
- **Rods:** slower response than cones ie 100ms.



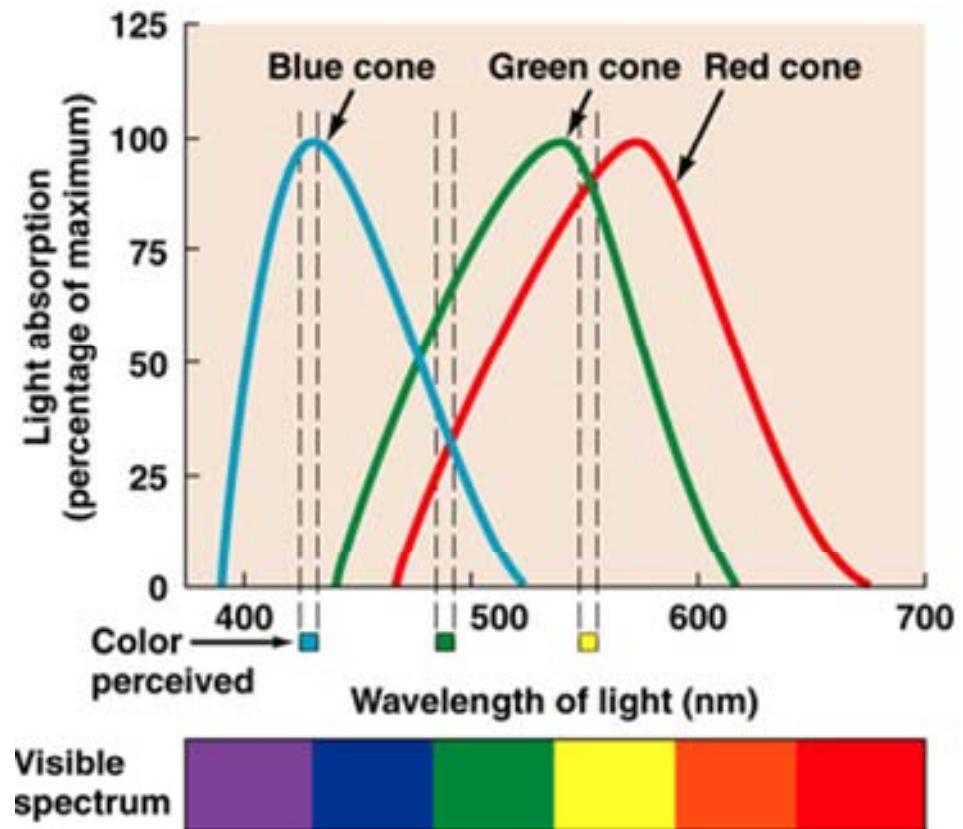
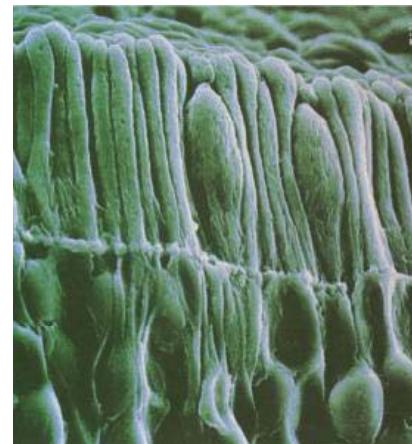
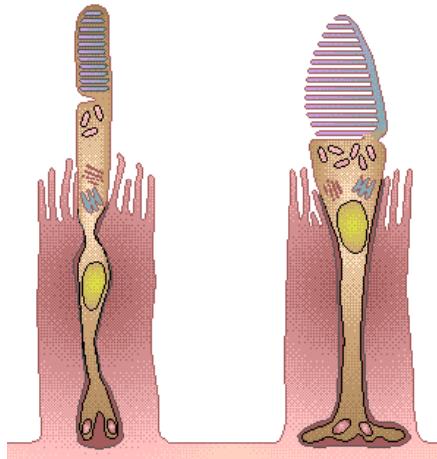
# What do Cones do?

- **Cones**: about 6-7M cone cells.
- **Cones**: responsible for bright light.
- **Cones**: responsible for color vision.
- **Cones**: less sensitive to dim light.
- **Cones**: faster response to changes in light.
- **Cones**: motion detection.



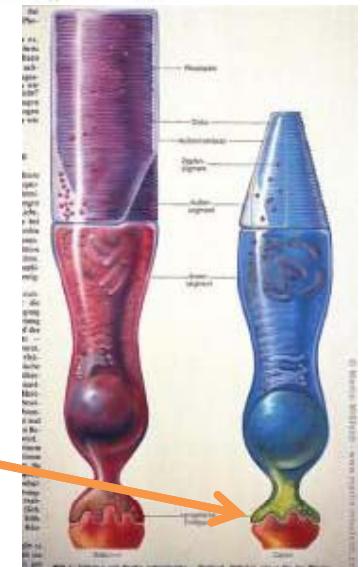
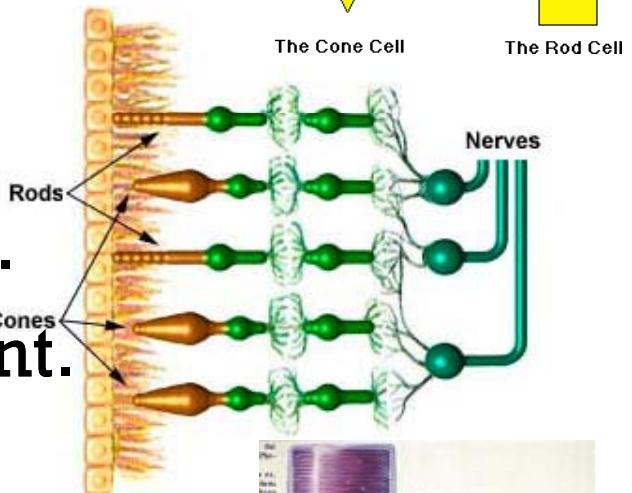
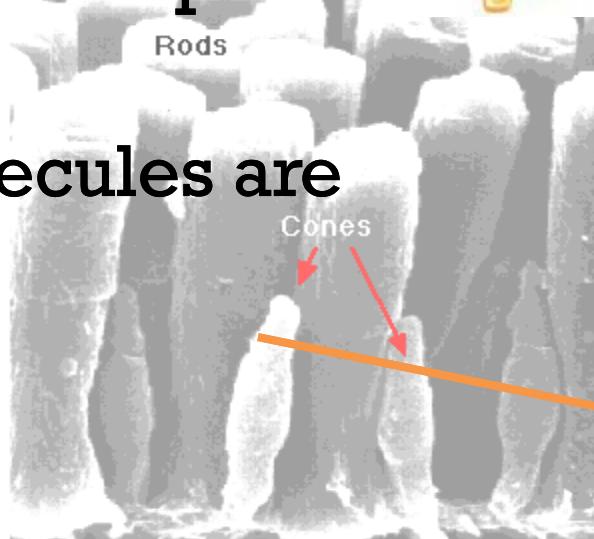
# Cones

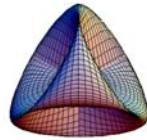
- Sensitivity to EM Spectrum



# Cones

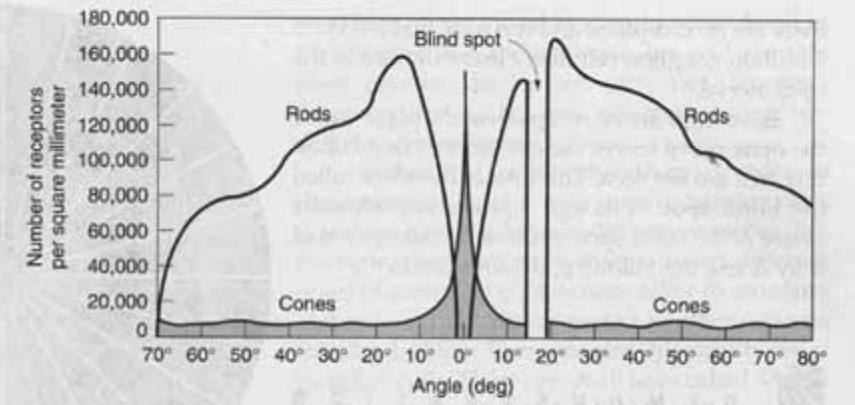
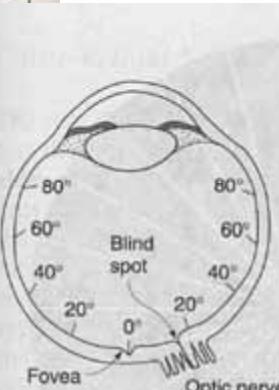
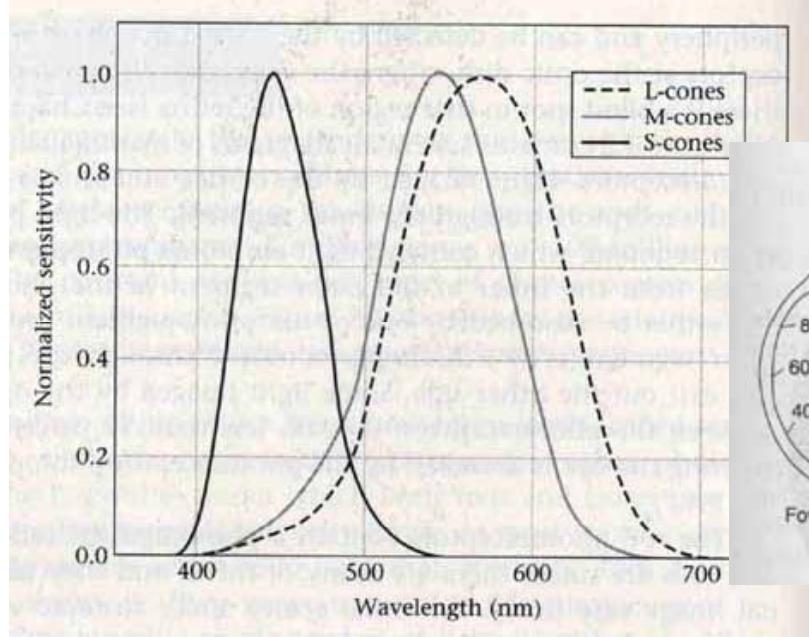
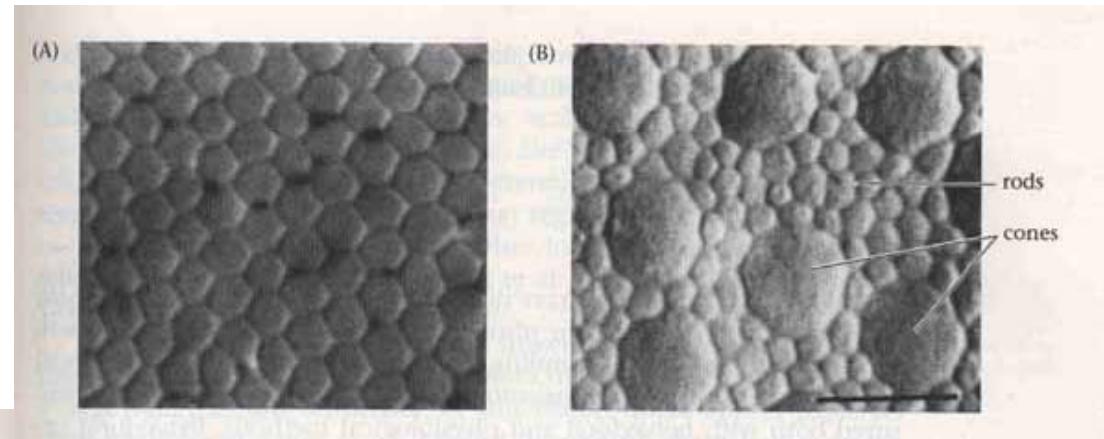
- Approximately 6M cones.
- Cones are a little wider than rods.
- Contain a coiled up visual pigment.
- Synaptic Terminal makes up the base of the cone cell.
- Neurotransmitter molecules are stored and released.

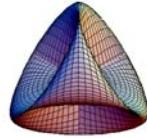




# Three Types of Cones

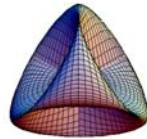
- L-cones
- M-cones
- S-cones





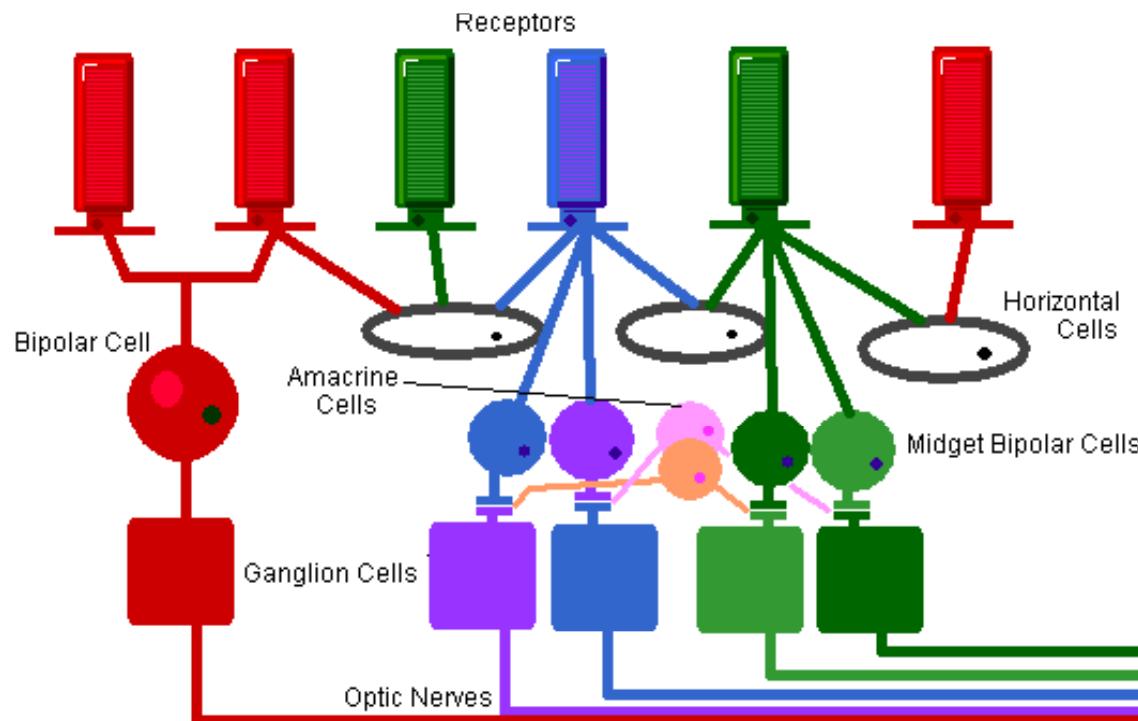
# Cone Types

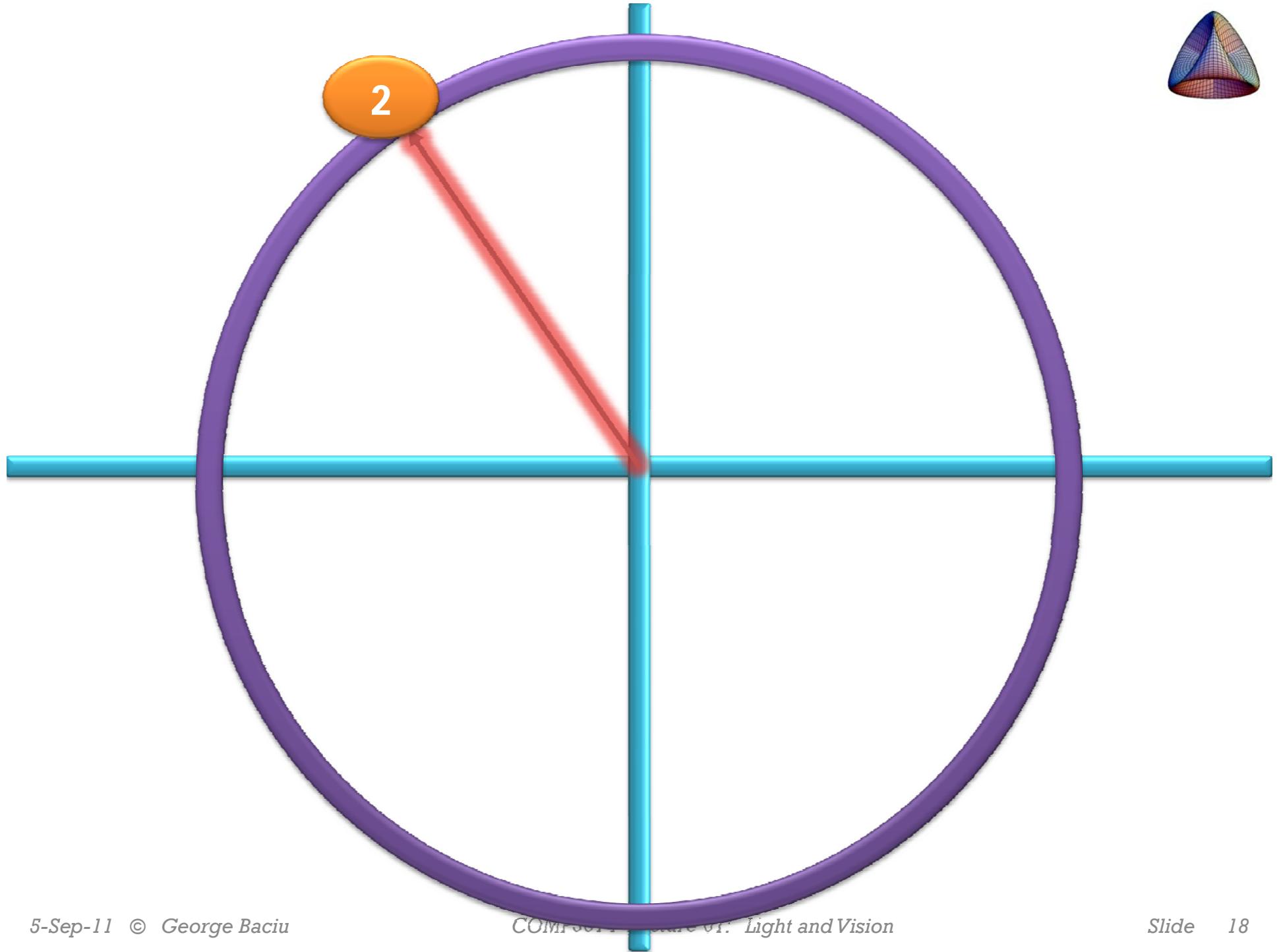
- **L-Cones:** **Long** – respond to light of **long** wavelengths ie 564-580nm. yellow
- **M-Cones:** **Medium** – respond to light of **medium** wavelength, ie 534-545nm. green.
- **S-Cones:** **Short**–respond to light of **short** wavelength, ie. 420-440nm violet.

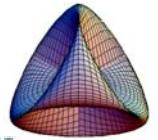


# Image Formation

- The cones perform spectral filtering in three ranges of light wavelengths.

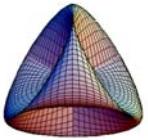






Basic Introduction to

## 2. DIGITAL IMAGES



# Basics: Pixels & Images

- **Pixels and Images**

A digital image is represented as a discrete grid of picture elements = pixels.

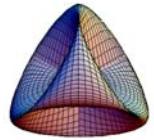
Resolution: from 320 x 200 to 2000 x 1500



Black and White Images: each pixel is given a value usually between 0 and 1.  
Internally, in the computer memory the value is stored as 0 to 255. Why?

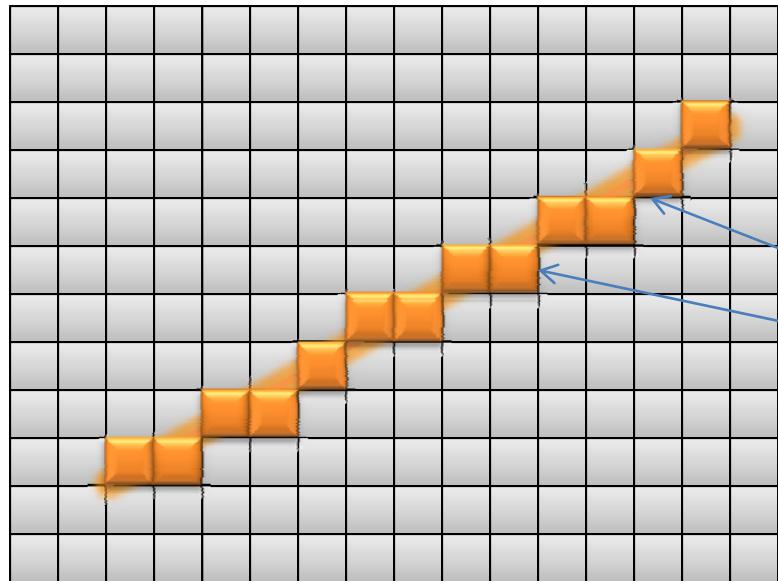
Color Images: each pixel is given by three values: (0, 0, 255) = (R,G,B)

**Red Green Blue**

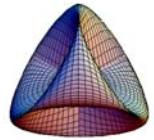


# Images at low res

- A line - What do we see?

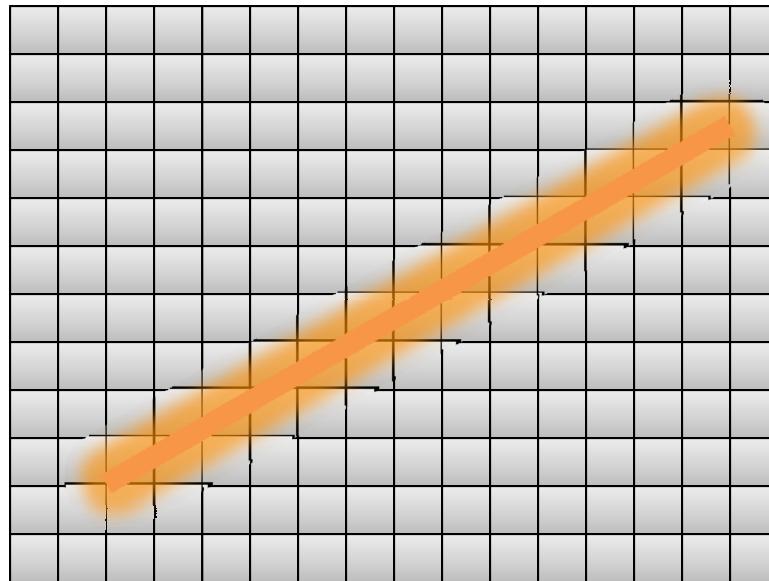


Aliasing effects

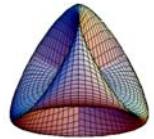


# Images at low res

- How to fix it?

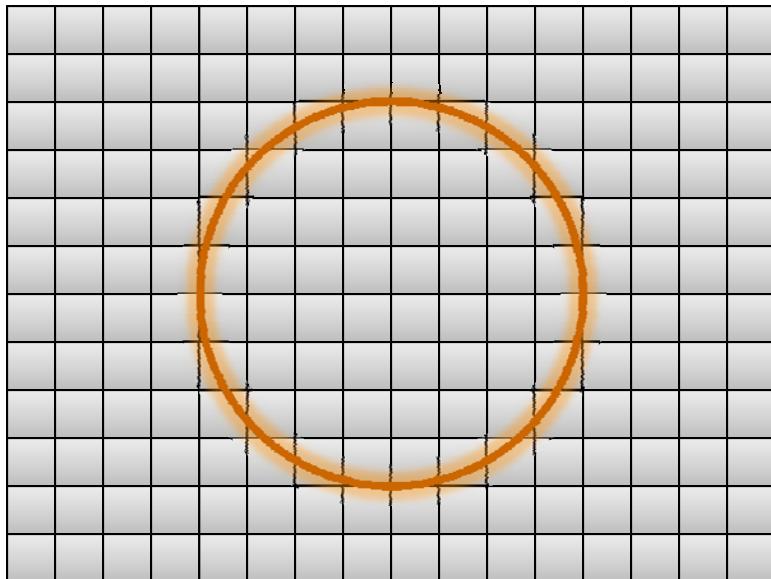


## Anti-aliasing Algorithms

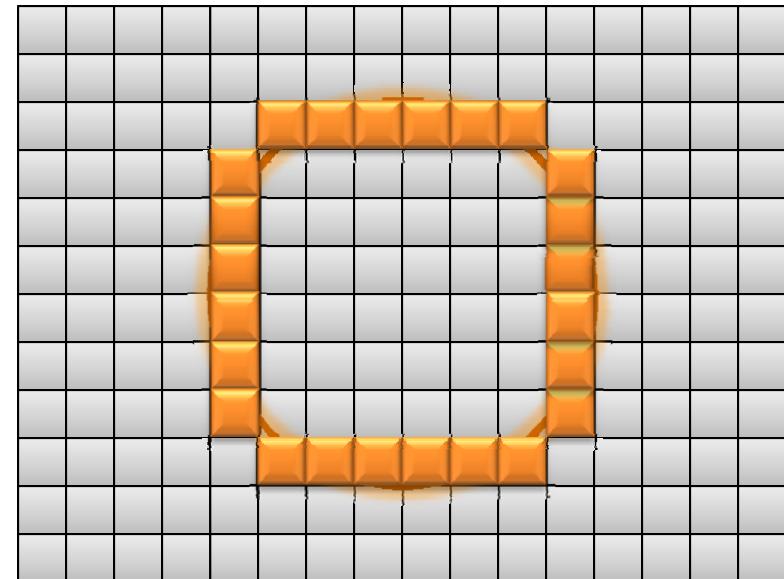


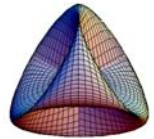
# Images at low res

- A cicle?



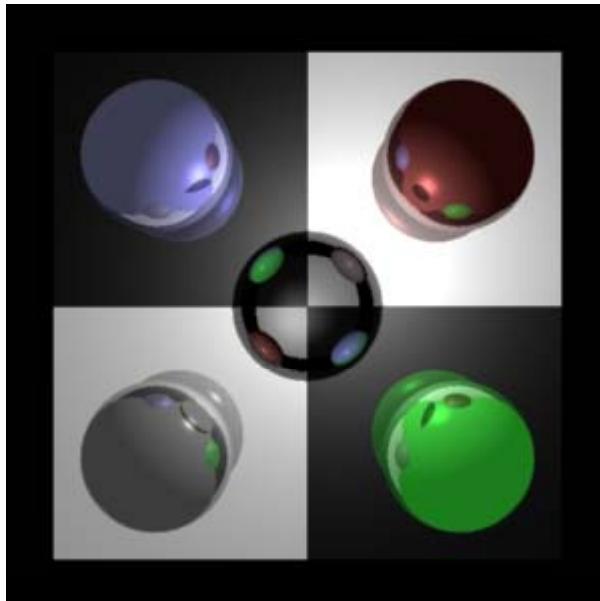
What do we see?



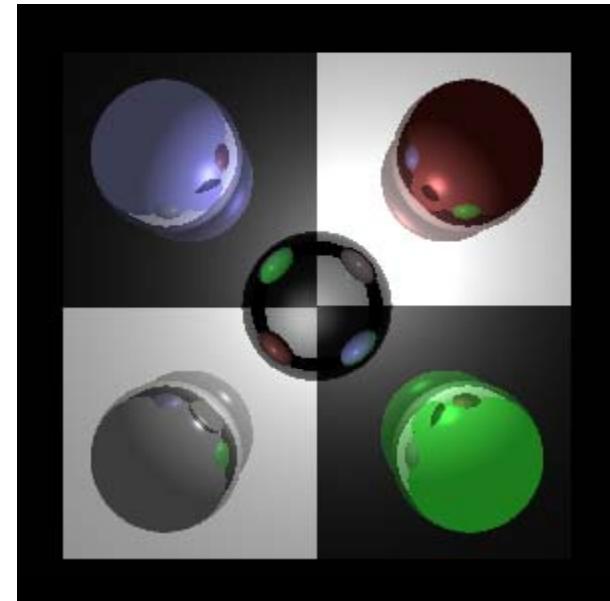


# Ray Tracing

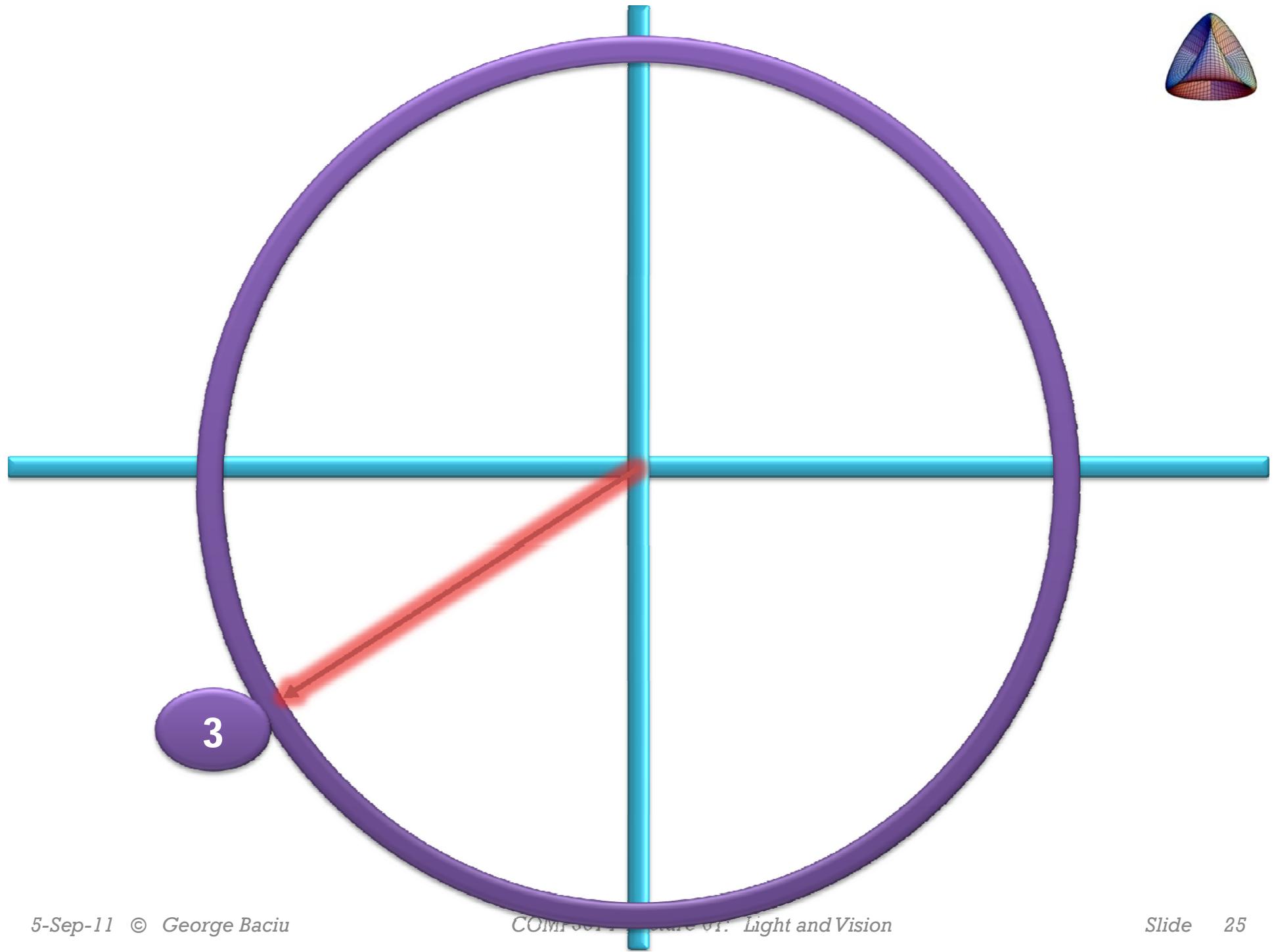
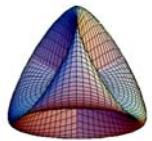
- Aliasing is especially visible in high frequency images, such as ray traced images.

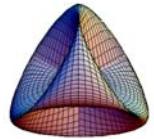


Aliasing



AntiAliased

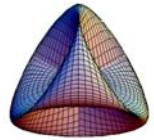




Basic Introduction to

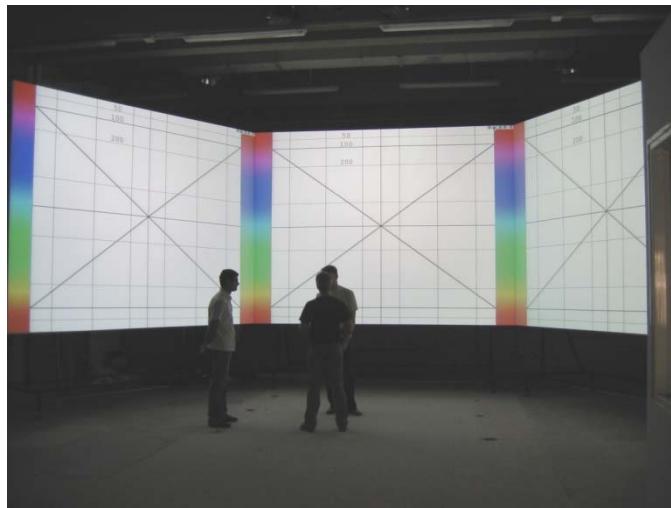
## 3. DISPLAY SYSTEMS

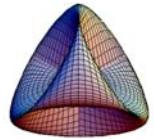




# Current Displays

- Very Large:
- And... LARGER:



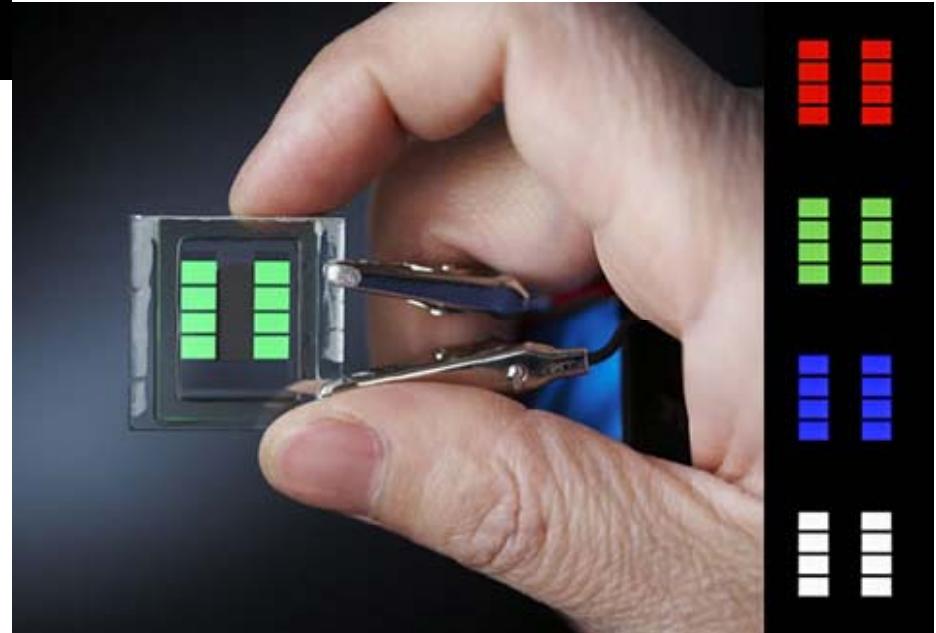


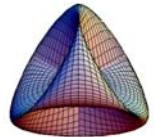
# Current Displays

- Small



- And... smaller



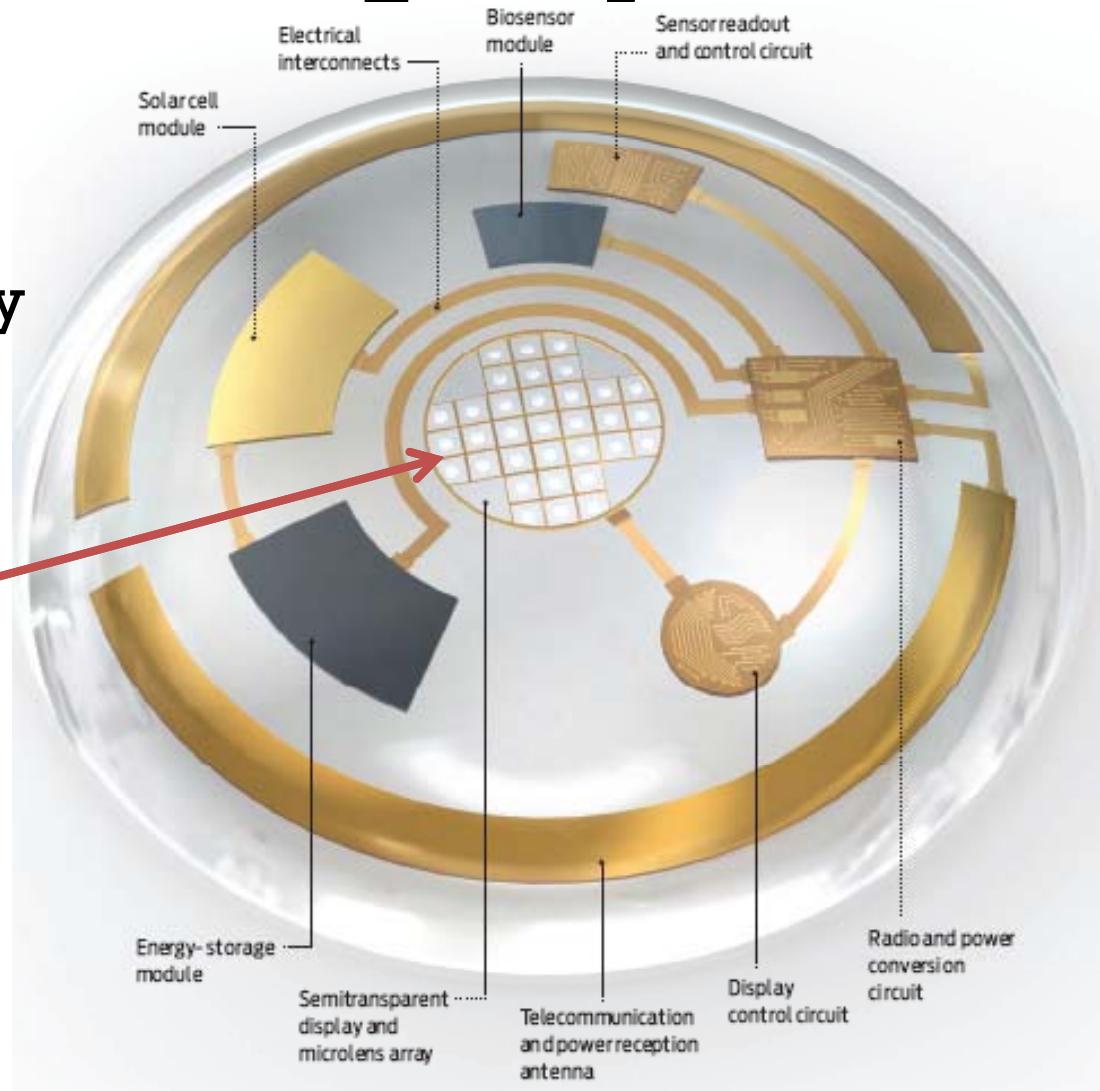


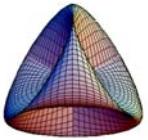
# Future Displays

- Smallest

Contact Lens Display

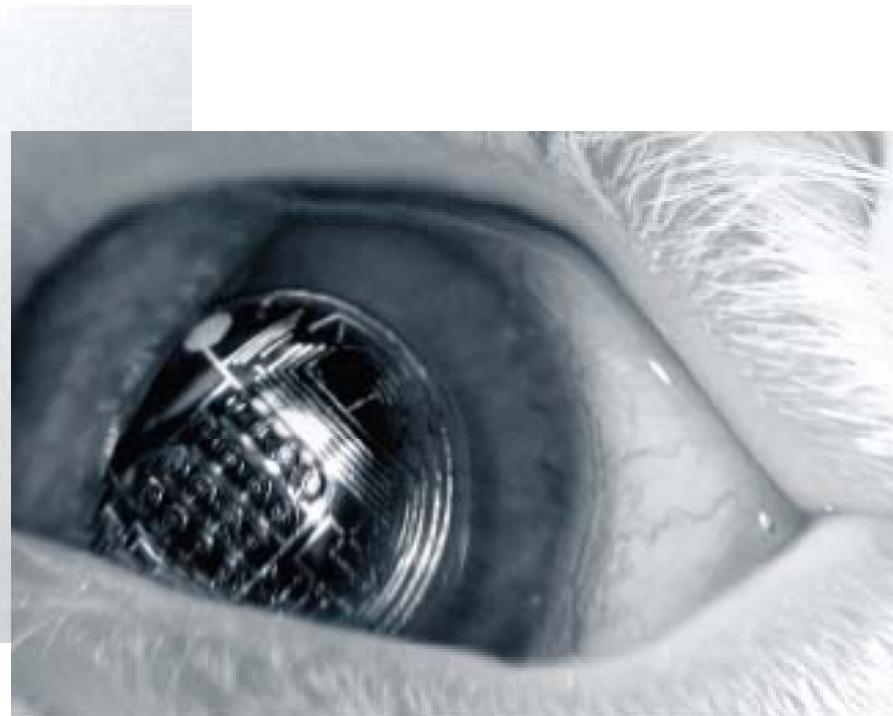
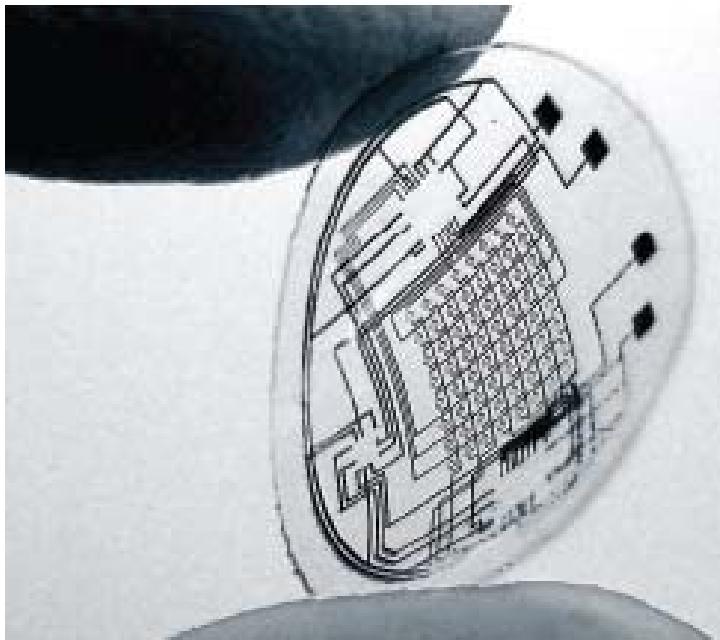
Semitransparent  
Display  
and  
Microlens Array

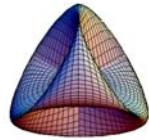




# Contact Lens Displays

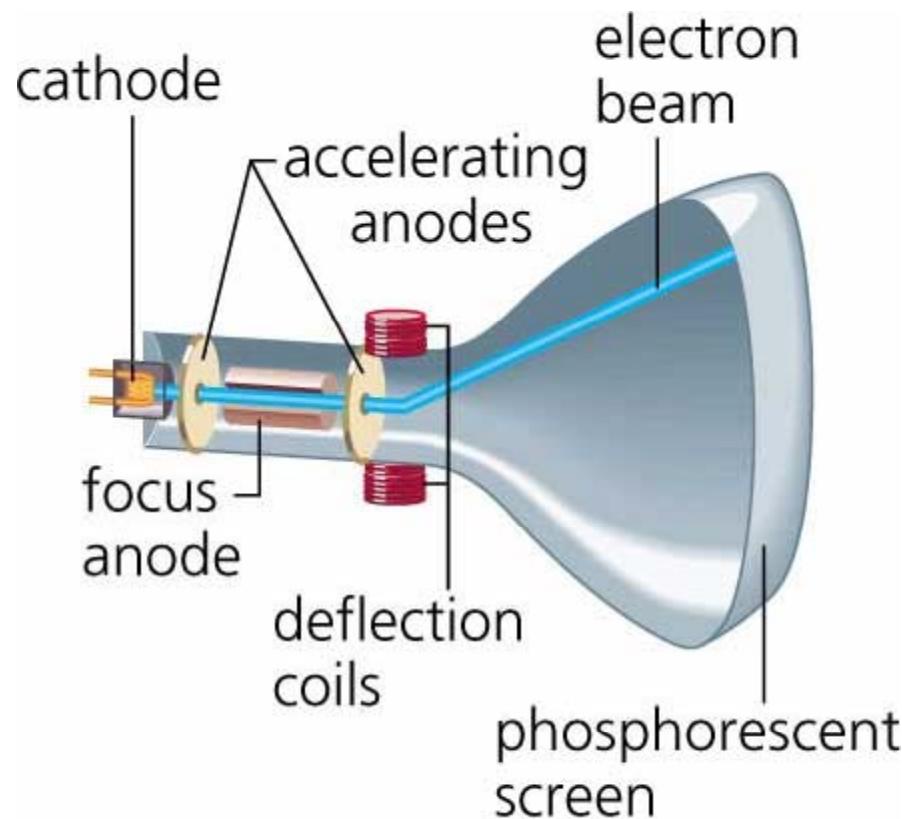
- Display circuit etched into polysilicon lenses – directly placed onto the eye.



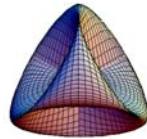


# CRT's... the old ways

- Cathode Ray Tubes (CRT)



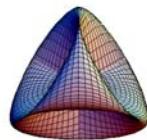
Powered by DIYTrade.com



# LCD Displays

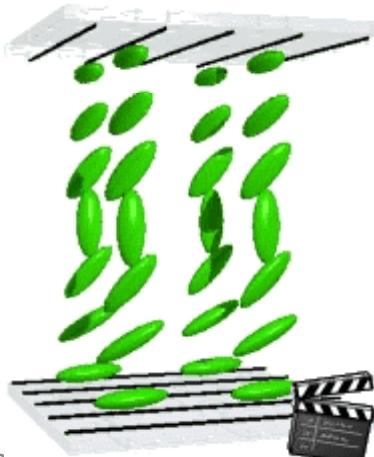
- Most common
- High production volume
- Costs are significantly reduced
- Energy efficient
- Space efficient



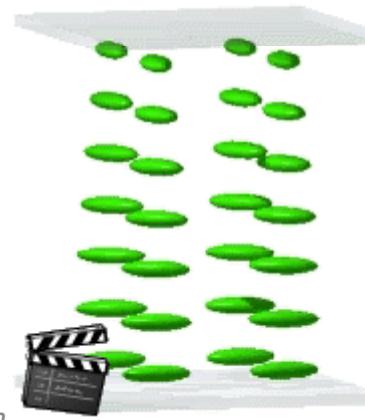


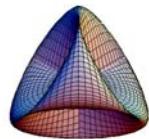
# Liquid Crystals (LC)

- What are LC's?
  - Substance exhibiting states between a liquid and a solid.
  - Crystals re-align when an electric field is created by applying a voltage between two electrode plates.



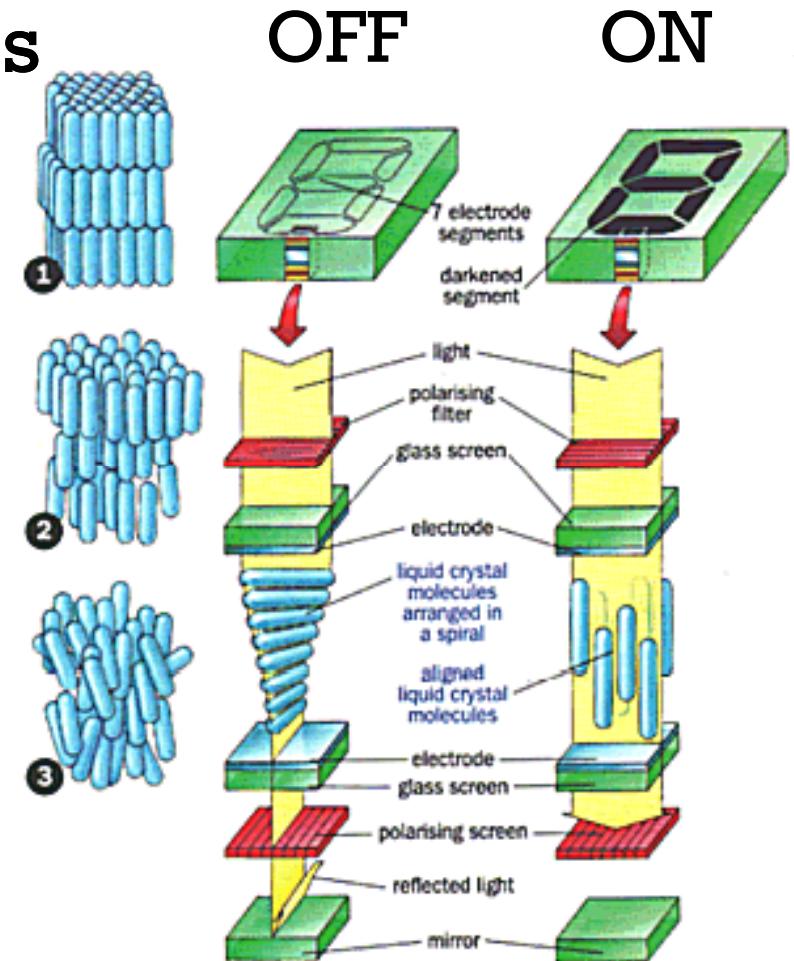
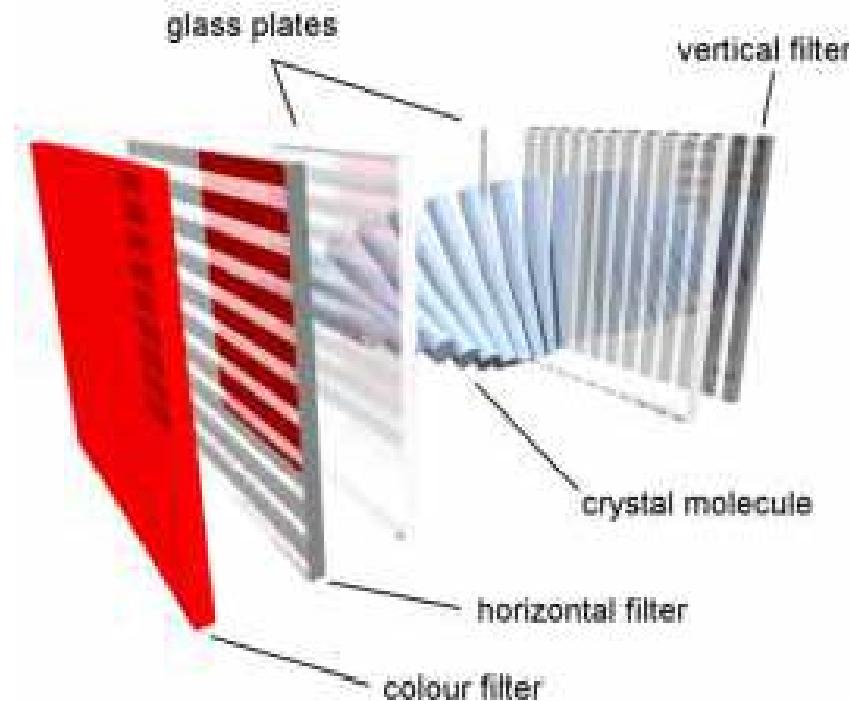
Two different  
States of LC's

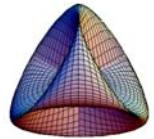




# Basic Principle

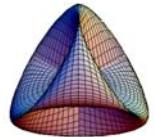
- Nematic Liquid Crystals





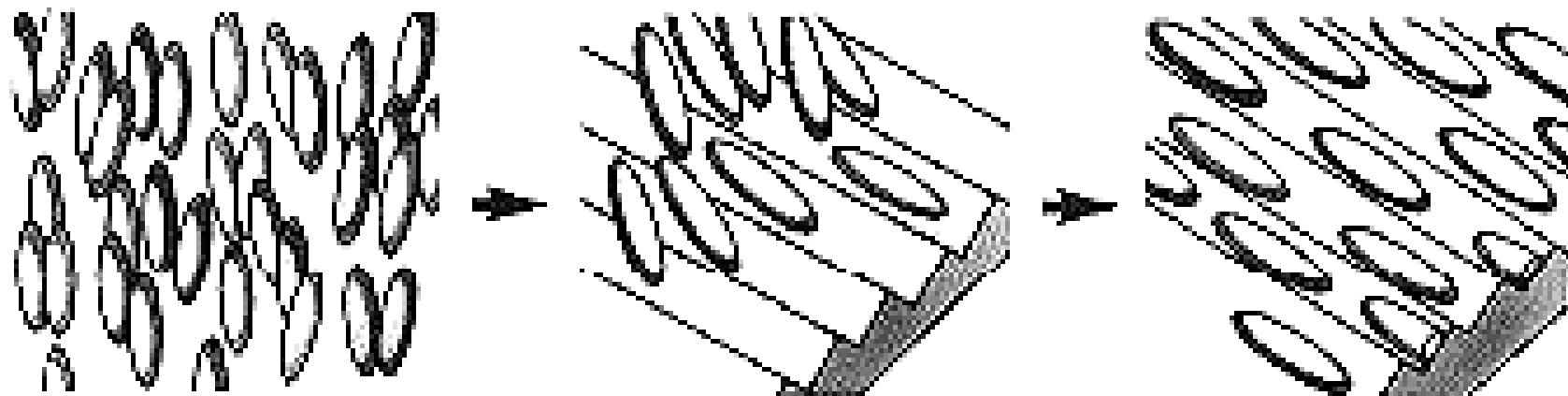
# On-Off States

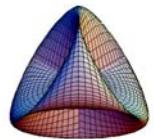
- OFF-State:
  - voltage off – crystals twist-align with grooves.
  - Polarized light passes through the helical aligned crystals and hits the backplane mirror reflecting white light; **screen appears transparent**.
- ON-State:
  - Voltage on – crystals straighten with electric field.
  - Liquid crystals are not aligned with the polarization of the light; the light beam is blocked by the polarized screen; no reflection from the back mirror; **screen appears dark**.



# Passive State

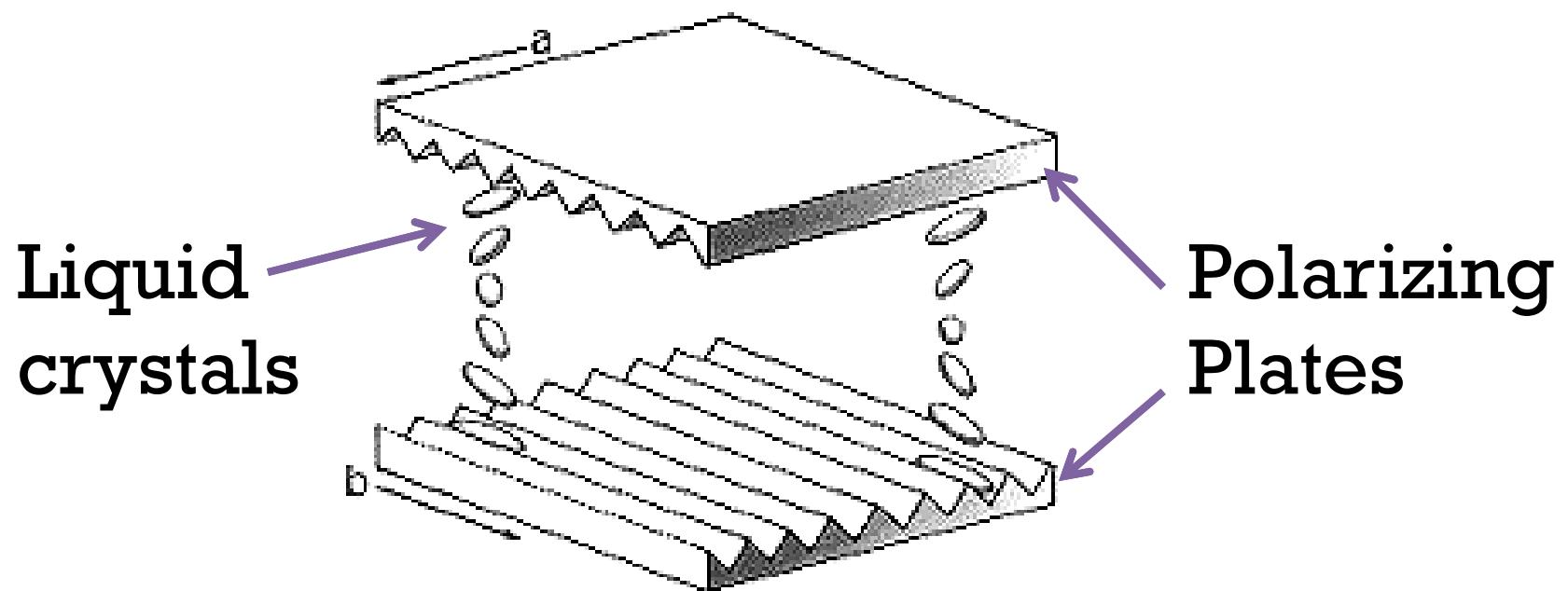
- In passive state, liquid crystals arrange themselves by following the grooves of wall plates.

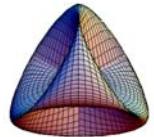




# Passive State

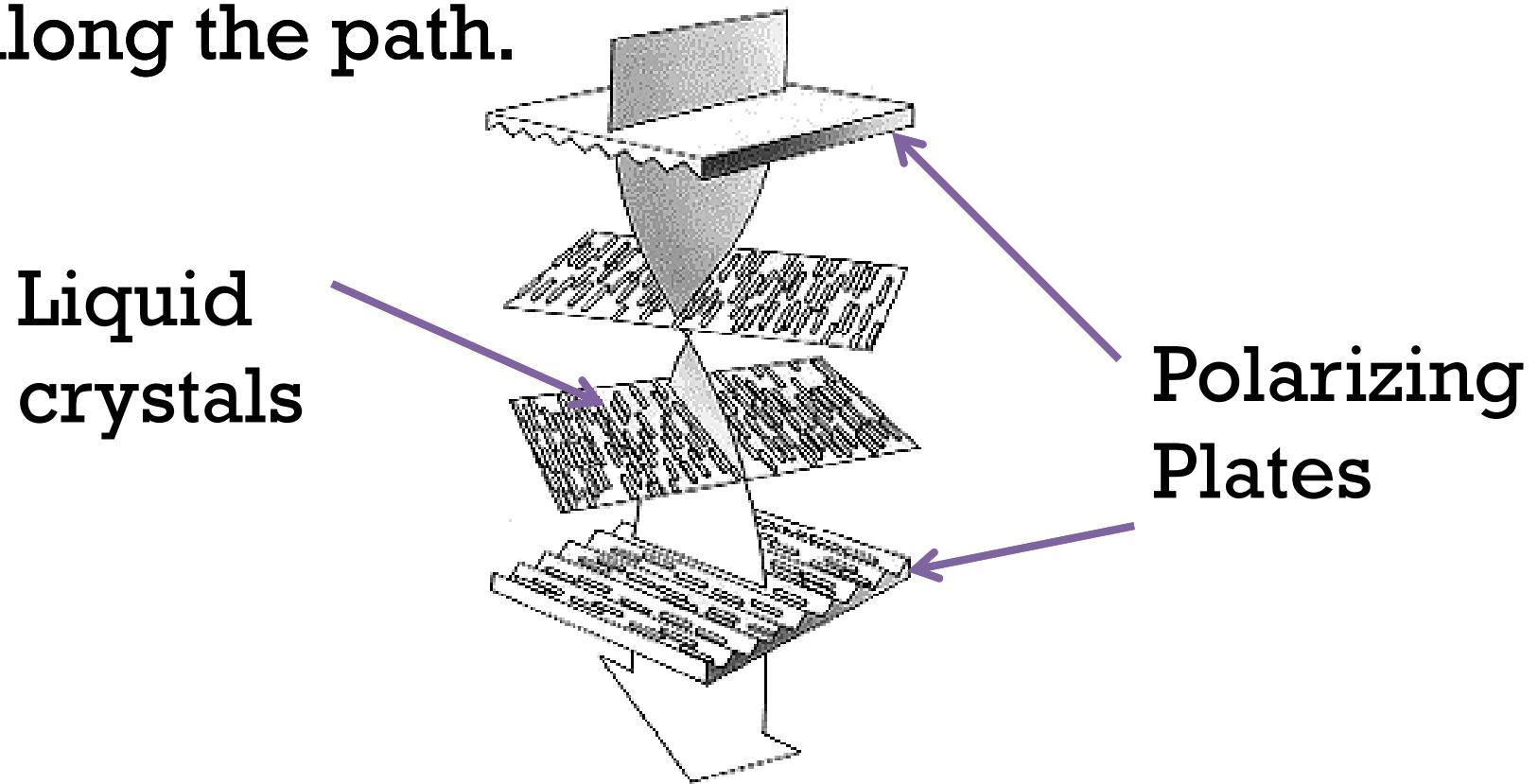
- Crystals can be made to create a helical structure by placing two plates with grooves perpendicular to each other.

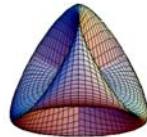




# Passive State

- Light passes through the crystals twisting along the path.



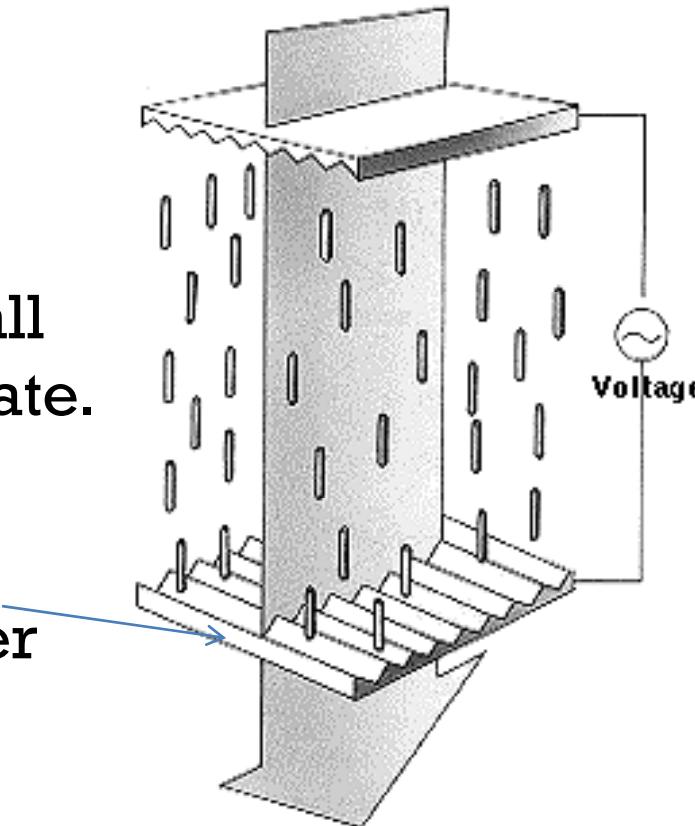


# Active State

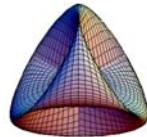
- By applying an electric voltage, the crystals snap in alignment with the electric field.

Light beam does not twist forcing a perpendicular fall on the lower polarizing plate.

Light beam does **not** pass through the lower polarizer



**Screen darkens**

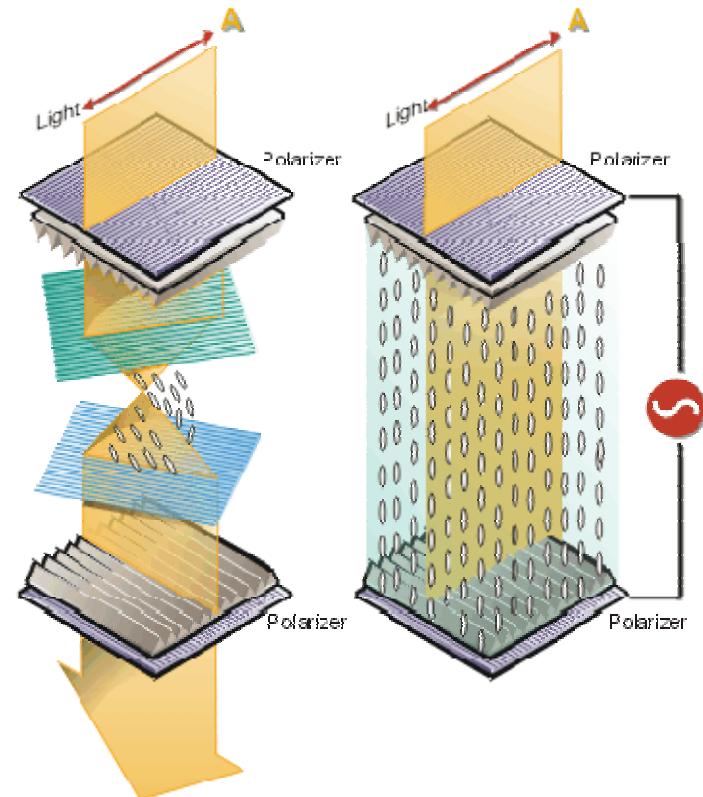


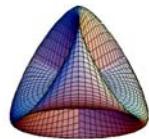
# Again: OFF and ON

- Voltage OFF
  - Light passes through
  - Screen is transparent
- Voltage ON
  - Light stops
  - Screen appears dark

OFF: light

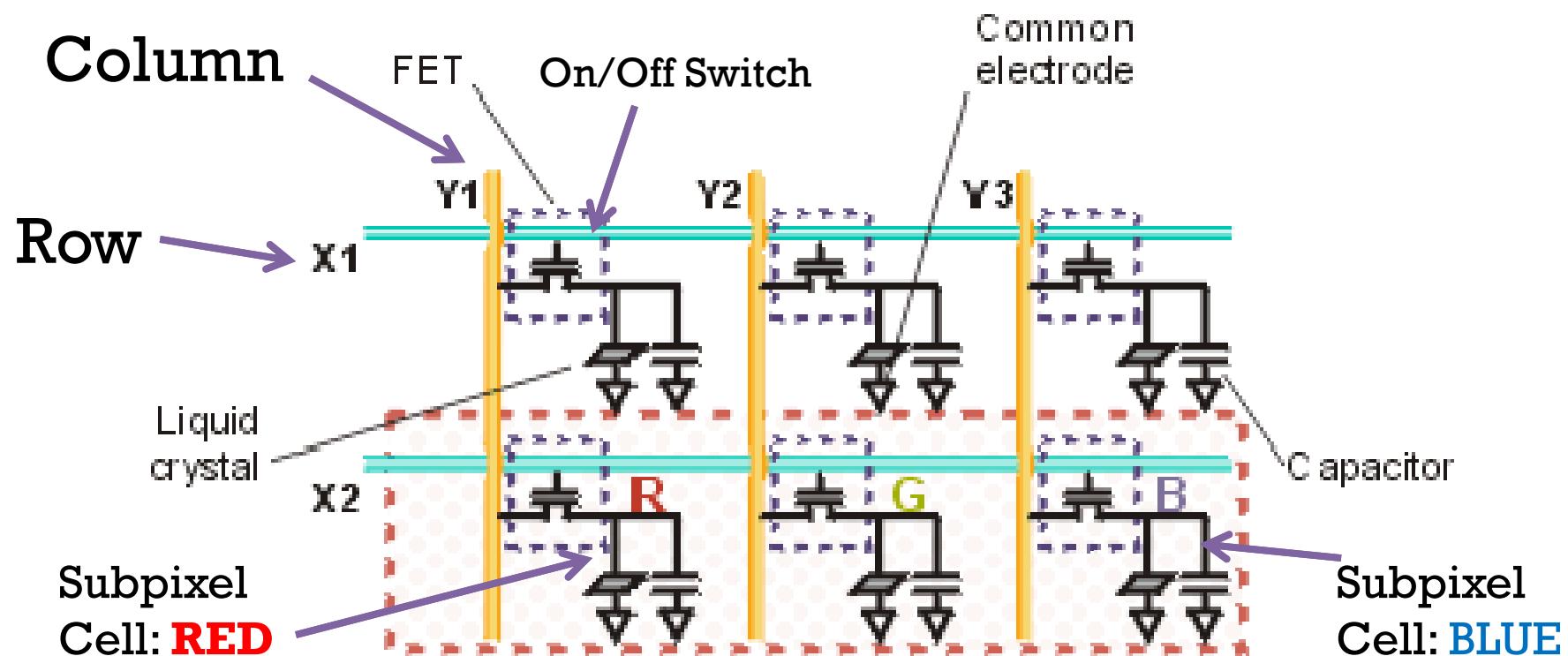
ON: dark

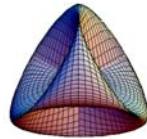




# TFT = Thin Film Transistor

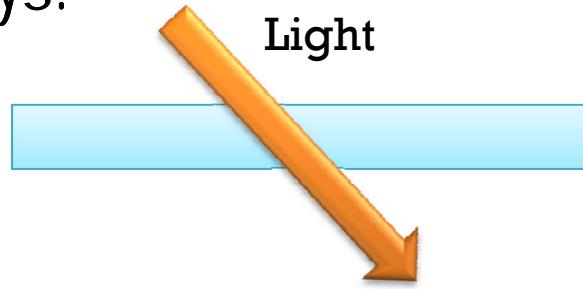
- Constructed on a glass surface using photolithography.





# Enhancements

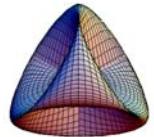
- **Transmissive** = light from the backlight passes once thru the pixels out to your eye. Notebook computers use transmissive displays.



- **Reflective** = light from the environment is reflected at the back of the display and passes back thru the pixels out to your eye.

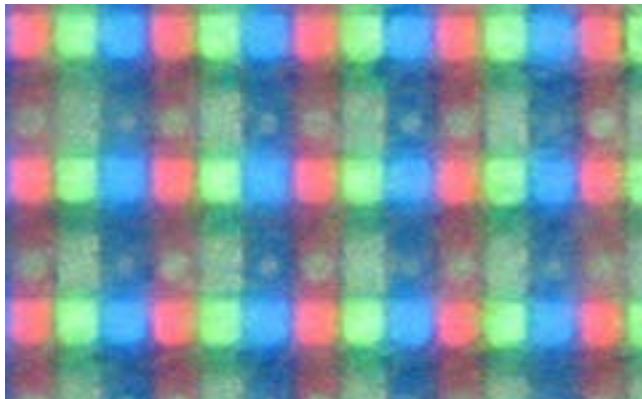


- **Transflective** = transmissive + reflective.



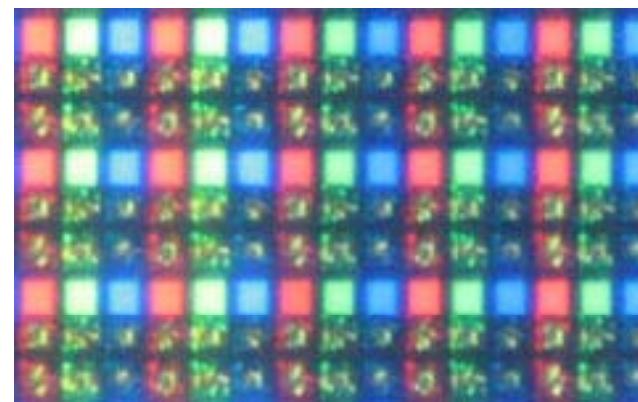
# How it looks...

- Different screens under the microscope.



iPod

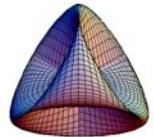
2.5" 320 x 240 transreflective TFT



Nokia 6230i

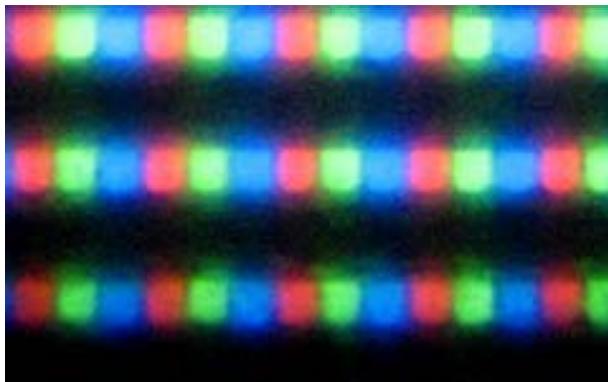
1.7" 208 x 208 transreflective TFT

Both TFT LCD displays captured  
with a Canon PowerShot SD200 thru a 30X microscope.

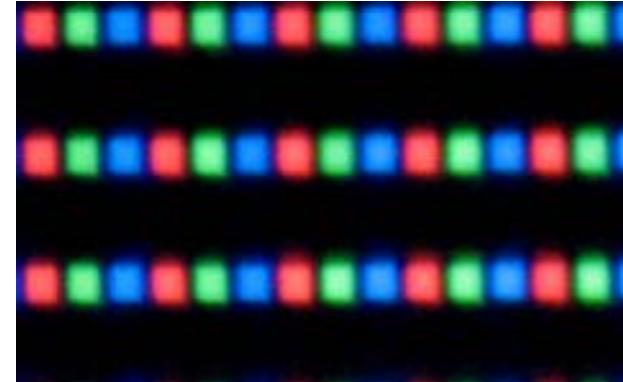


# How it looks...

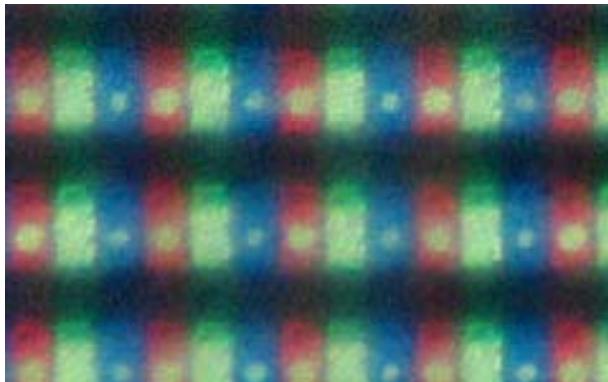
- Different screens under the microscope.



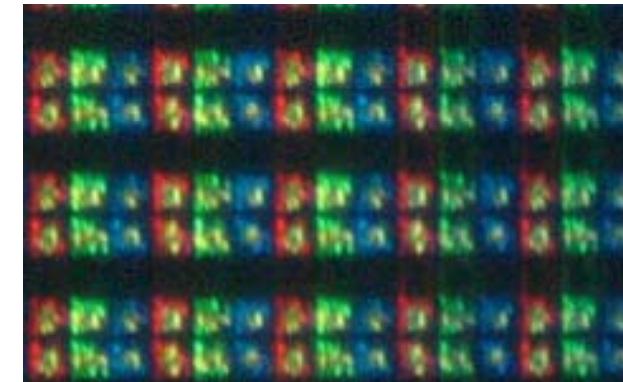
iPod transmissive row only



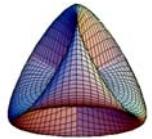
Nokia 6230i transmissive only



iPod reflective row only

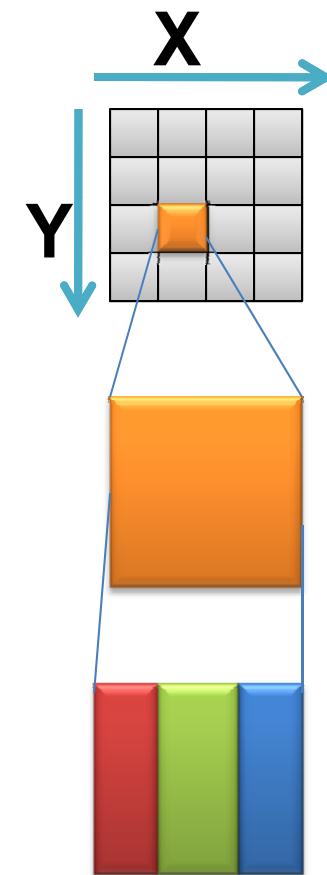


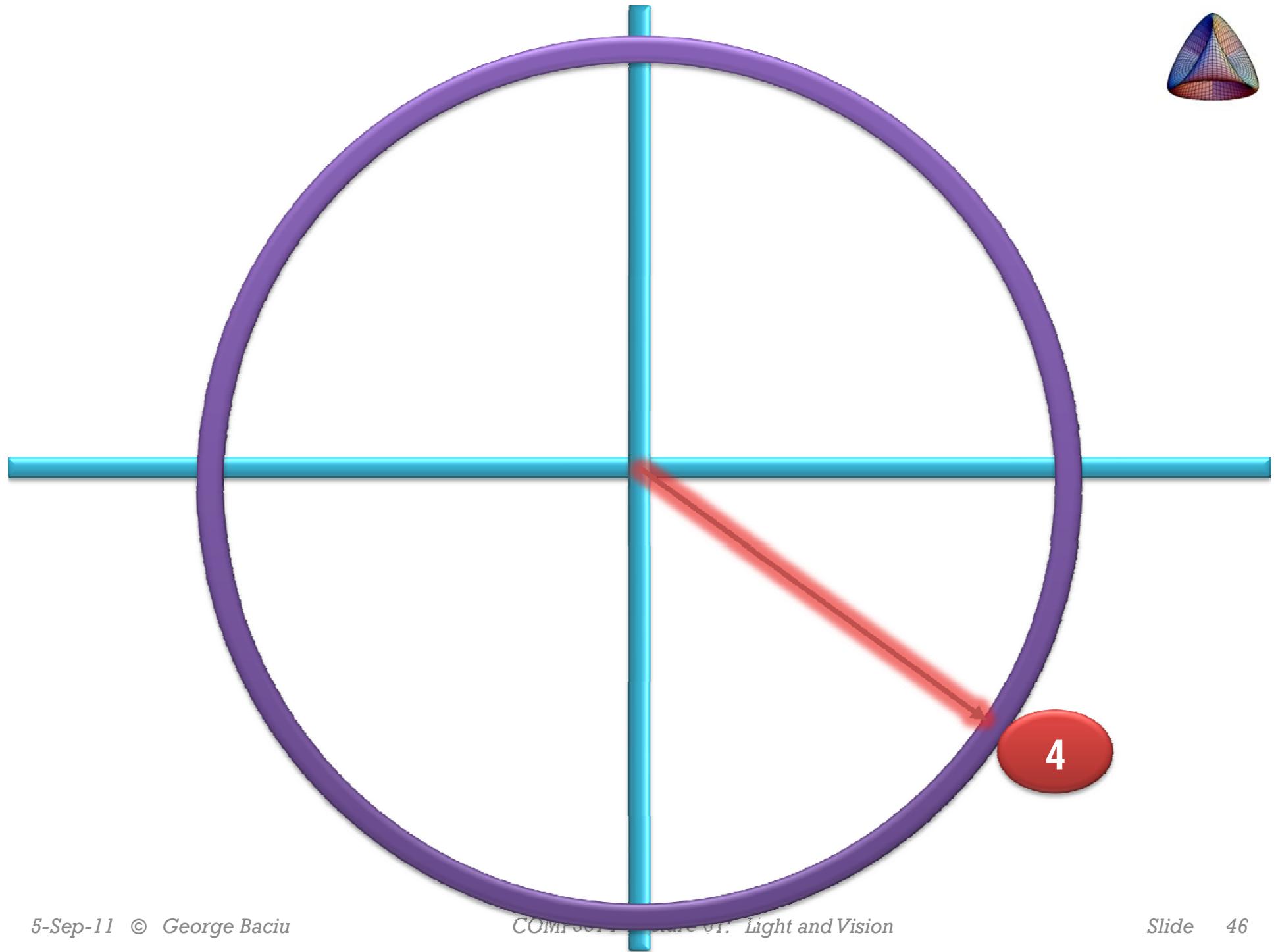
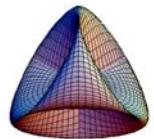
Nokia 6230i reflective only

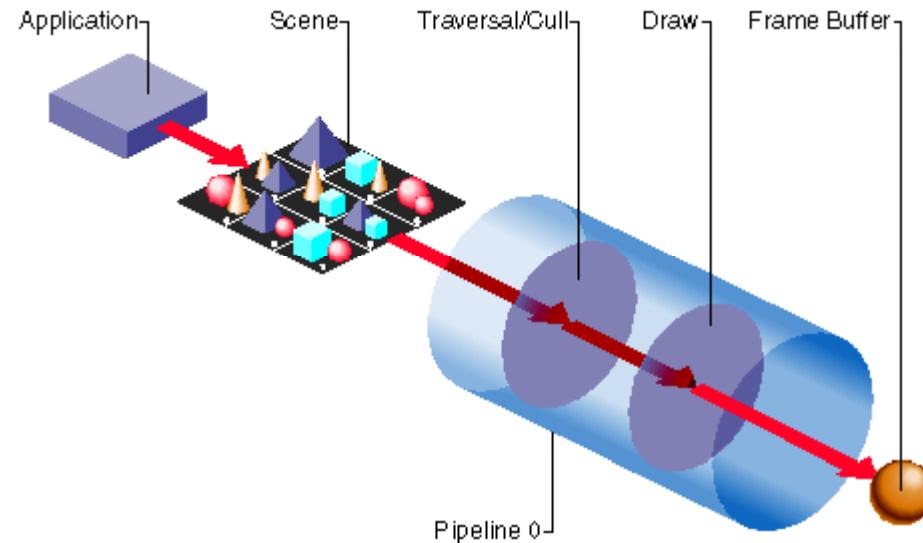
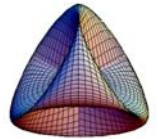


# Summary

- All displays have the same basic characteristics:
  1. Active Matrix = address
  2. Picture Elements = Pixel
  3. Sub-pixel elements: R, G, B

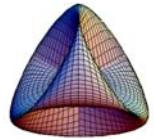






Basic Introduction to

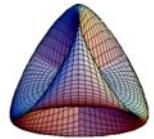
## 4. PIPELINED RENDERING



# Nature Scenes

- Real-time nature

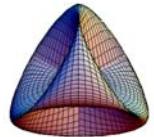




# Facial Animation

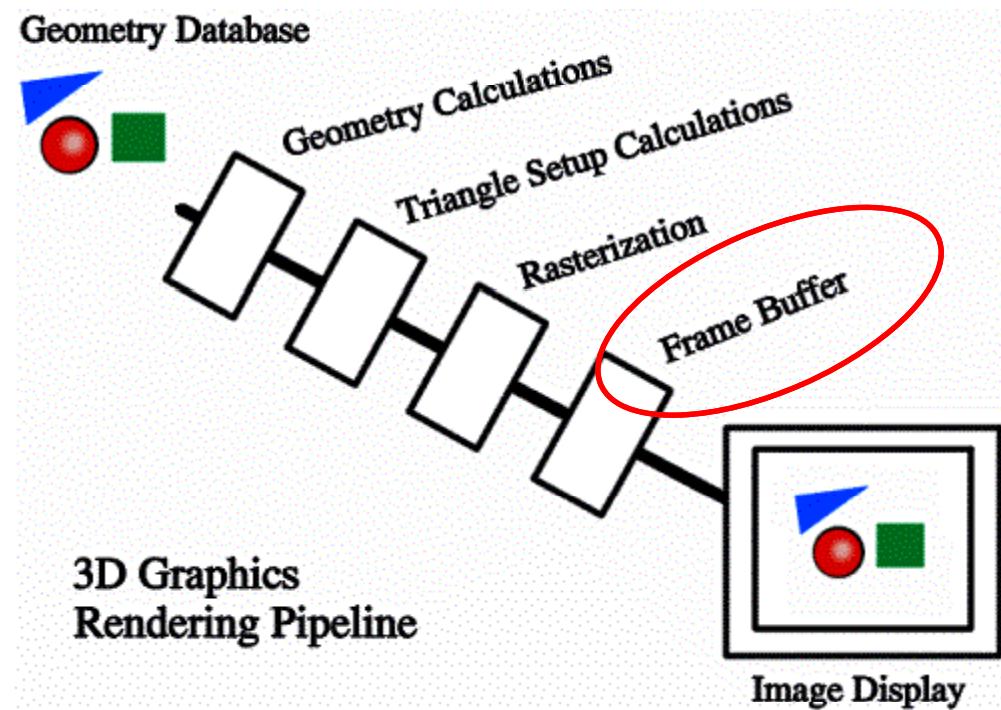
- Real-time face

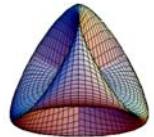




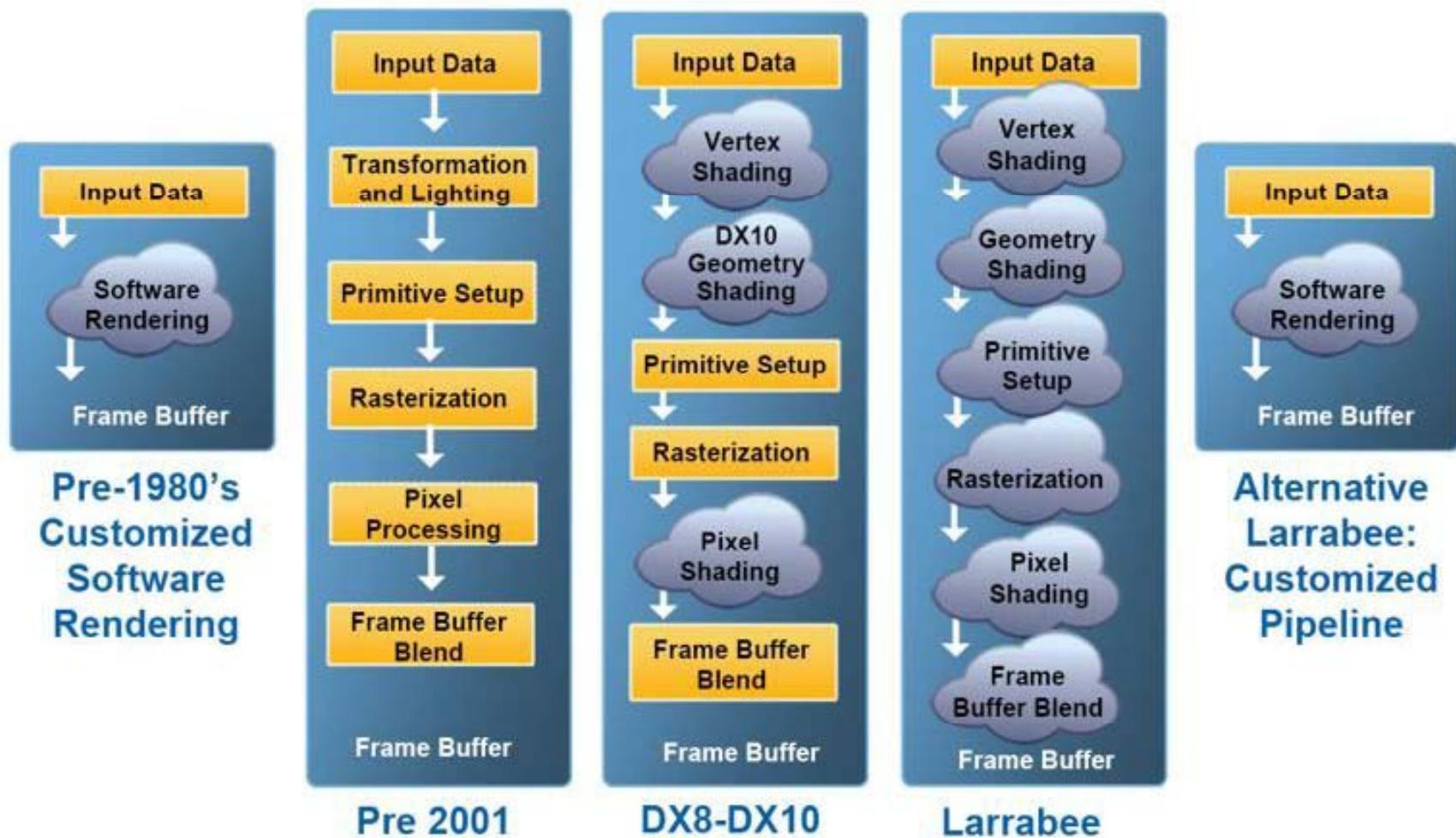
# Rendering

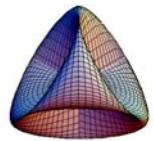
- In a pipeline





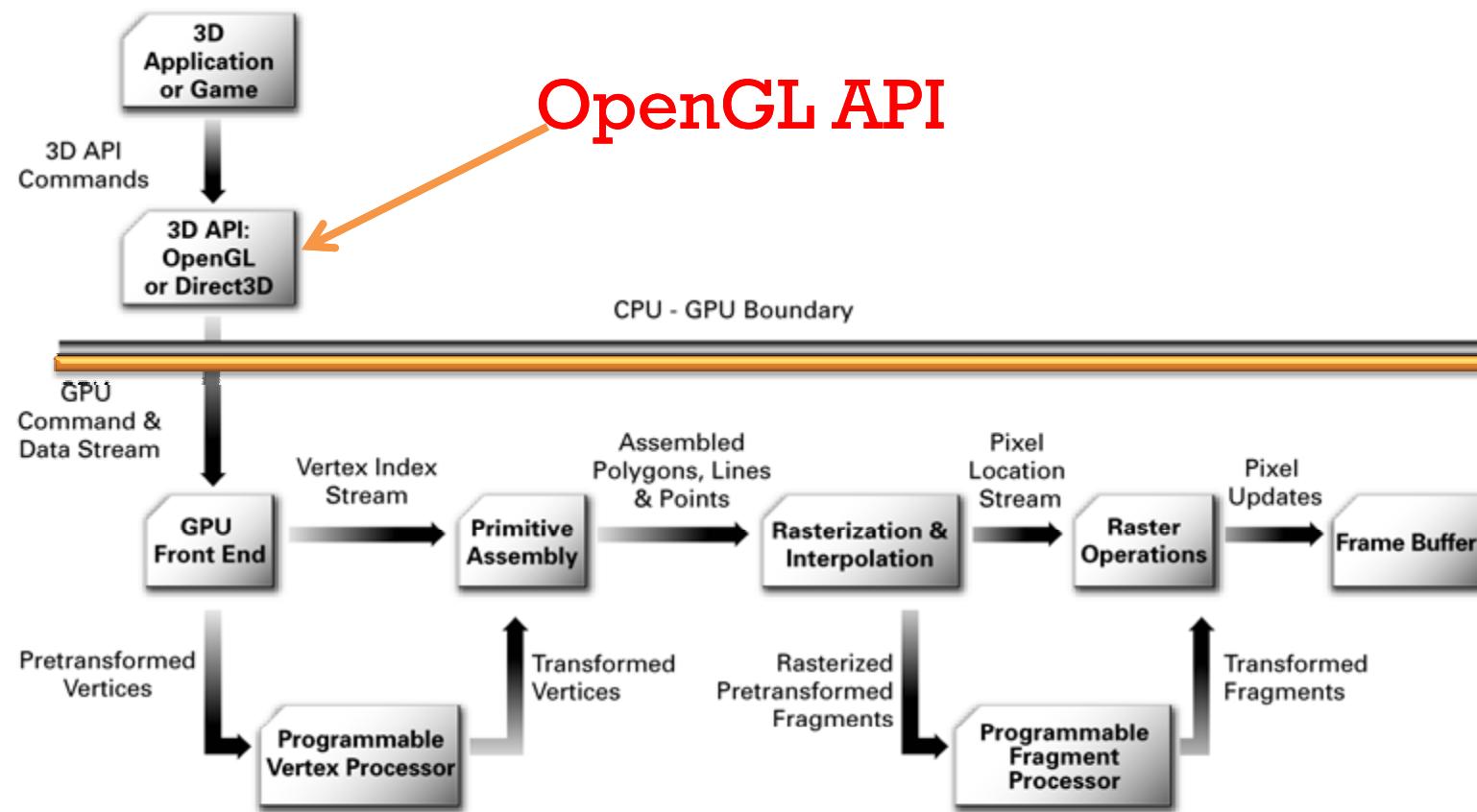
# Short History Graphics Rendering Pipelines





# CPU-GPU Boundary

- Processing division



# GPU Evolution

- OpenCL:
  - Open Computing Language
  - Runs on CUDA
  - Heterogeneous Computing



DX7 HW T&L  
1999 - Test Drive 6



DX8 Pixel Shaders  
2001 - Ballistics



DX9 Prog Shaders  
2004 - Far Cry

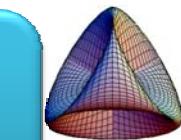


DX10 Geo Shaders  
2007 - Crysis



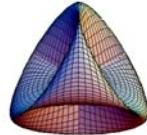
CUDA (PhysX, RT, AFSM...)  
2008 - Backbreaker

Advanced  
Flow  
Simulation  
Modeling



**Future?**

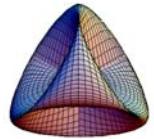
CUDA, DX11 Compute  
OpenCL



# Latest GPU: Fermi

- NVIDIA Fermi GF100:
  - 512 CUDA stream processors
  - 16 Geometry Units
  - 4 Raster Units
  - 64 Texture Units,
  - 40nm fabrication process
  - 3.2 billion transistors
  - 700MHz core clock
  - 1.5GB GDDR5 memory
  - 384-bit memory interface
  - Up to 406W power consumption
  - 98° C

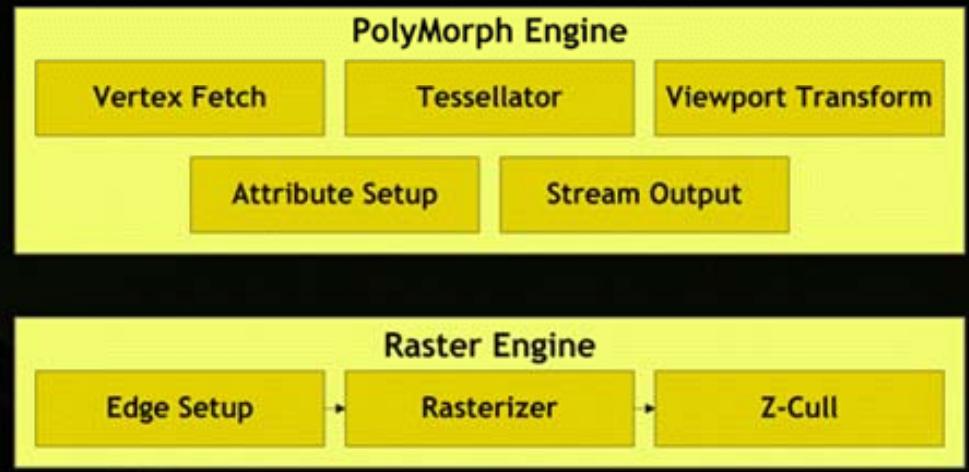


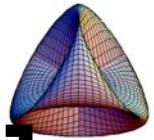


# PolyMorph Engine

## New GF100 PolyMorph and Raster Engines

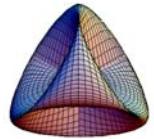
- Dedicated graphics hardware
- **PolyMorph Engine**
  - World space processing
- **Raster Engine**
  - Screen space processing





# FPS = Frames Per Second



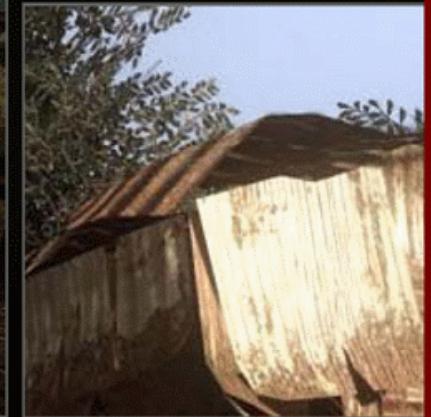


# What does it do?

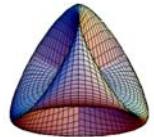
## The Problem of Geometric Realism in Games



- Even premier titles face this problem due to limitations of today's GPUs
- Pixels are meticulously shaded, but geometric detail is modest



NVIDIA embargoed information

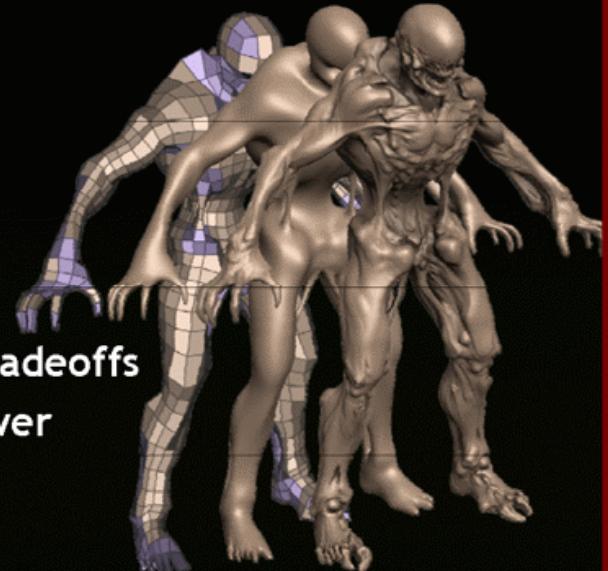


# Dynamic LOD

## Tessellation - What and Why

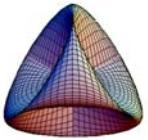


- Memory footprint & BW savings
  - Store coarse geometry, expand on-demand
  - Enables more complex animations
- Scalability
  - Dynamic LOD allows for performance/quality tradeoffs
  - Scale into the future - resolution, compute power
- Computational efficiency
  - Dynamic LOD
  - GPU animate and expand compact representation

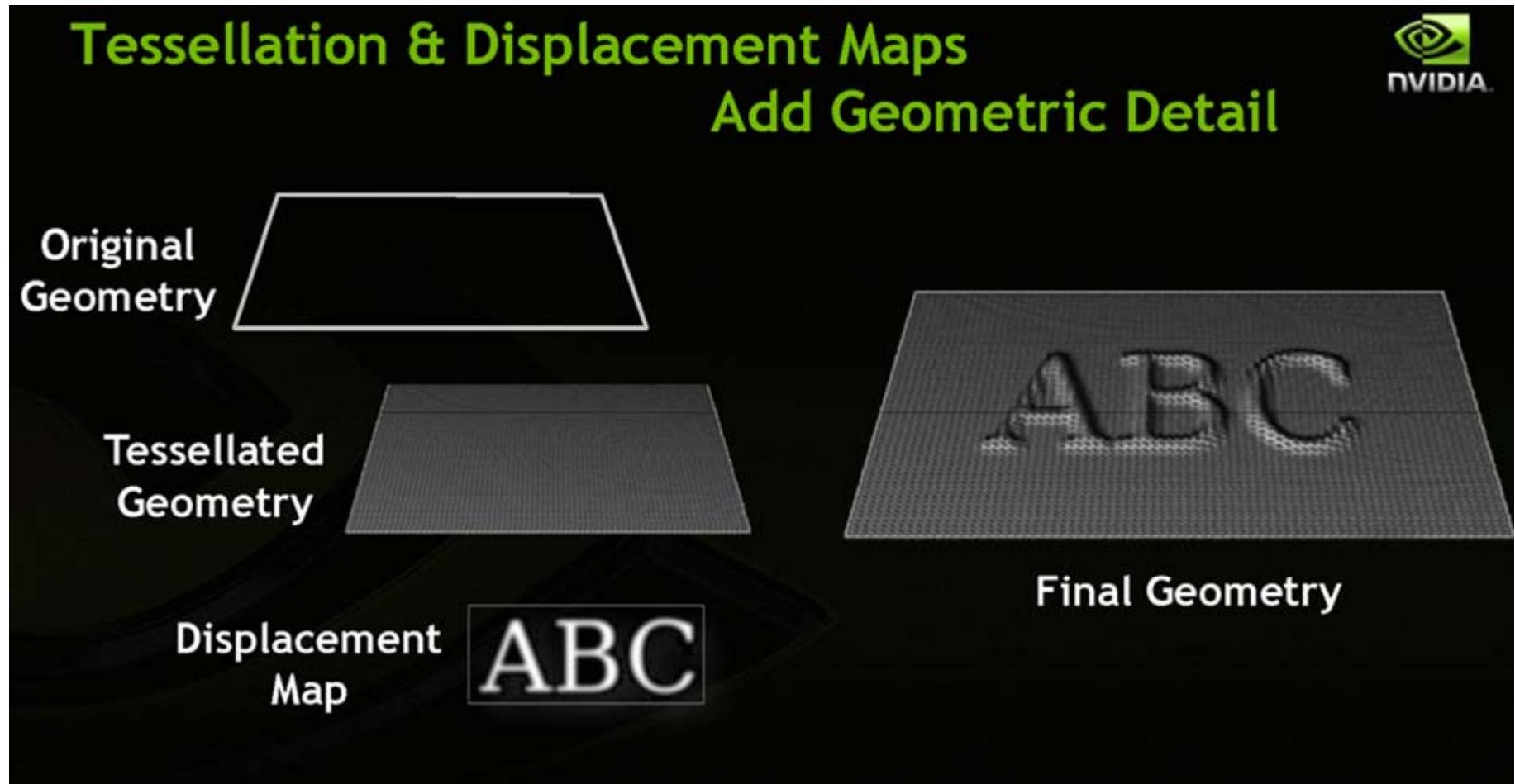


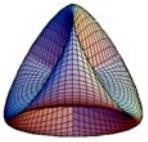
© Kenneth Scott, id Software 2008

NVIDIA embargoed information



# Tesselation + Disp. Maps



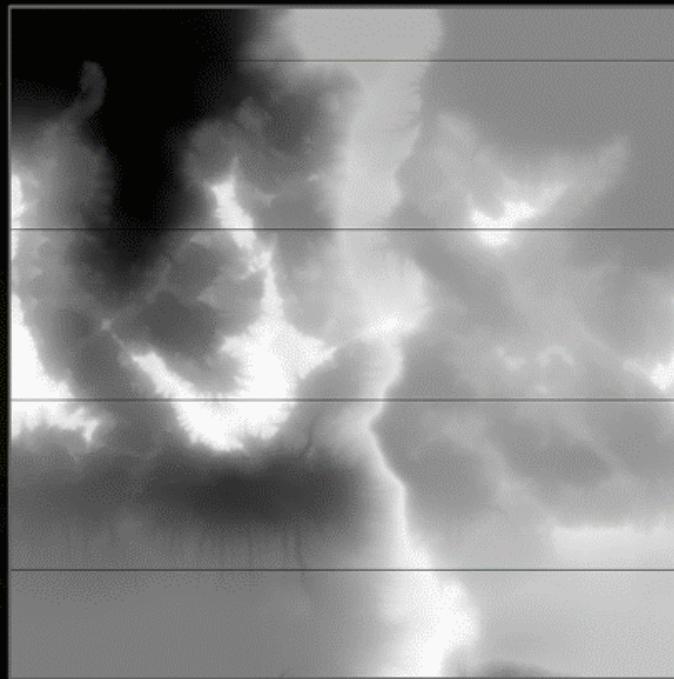


# Disp. Map and Shading

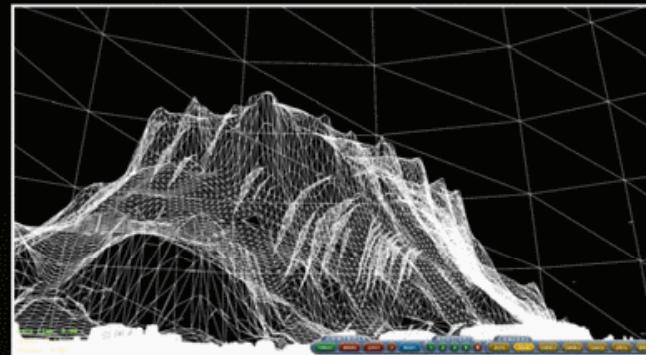
**Displacement Map and Shading**  
**Create Visual Realism**

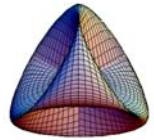


Terrain Displacement Map



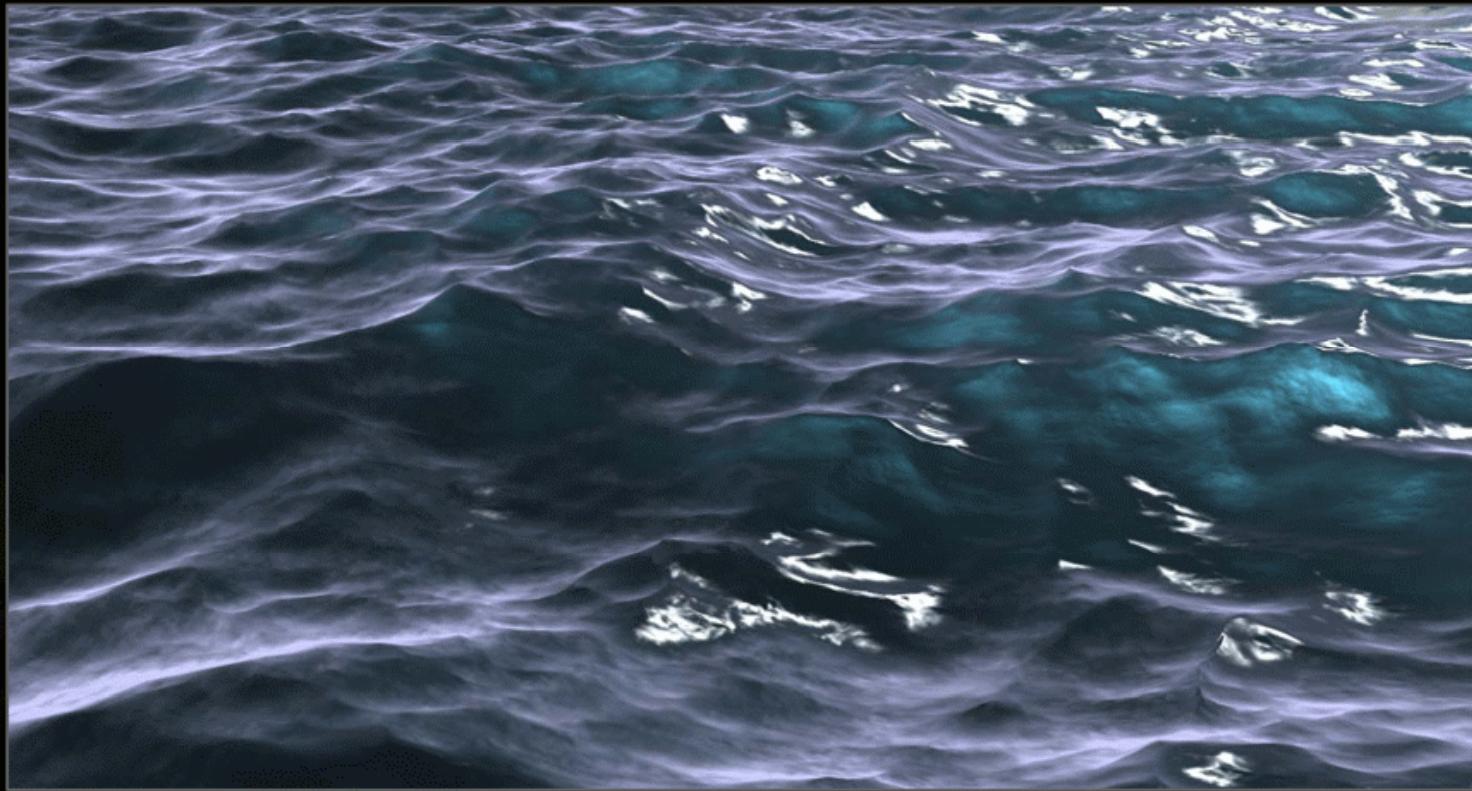
NVIDIA embargoed information



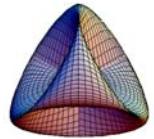


# And...Water

Water (Demo)



NVIDIA embargoed information



# And...Hair

## Hair (Demo)

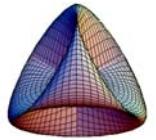


- Combine tessellation, geometry shading and compute to generate hair



(demos)

NVIDIA embargoed information



*Try things out...*

