

## Interactive System インタラクティブシステム特論(2)

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Hash tag #itsys

## Schedule

- 4/5 講義 Lecture
- 4/12 講義 Lecture
- 4/19 講義 Lecture
- 4/26 (Conference)
- 5/3 休日
- 5/10 講義 Lecture
- 5/17 講義 Lecture
- 5/24 (Conference)
- 5/31 講義 Lecture
- 6/7 講義 Lecture／発表論文選択
- 6/14 講義 Lecture
- 6/21 (Conference)
- 6/28 発表 Presentation
- 7/5 発表 Presentation
- 7/12 発表 Presentation
- 7/19 発表 Presentation
- 7/26 (Conference)
- 8/2 (Conference)

## Handouts on the web

<http://kaji-lab.jp/ja/index.php?people/kaji/interactive>

–現在は2012年版がおかれています。徐々に変えていきます。  
–Temporary, 2012 Japanese version. Will be replaced progressively.

**–こちらのpdfには動画のリンク先(Youtube等)が埋め込まれているので、紙資料よりも便利。次回から紙資料は配布せず、講義の1時間前までにアップロードします。必要なら事前にダウンロードしてください**

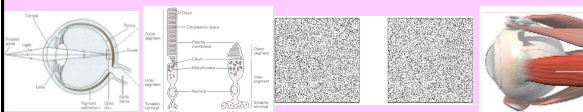
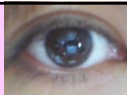
**–From next time, lecture handouts will be online 1 hour before the lecture. Print it if necessary.**

## Outline of the lecture

1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 聴覚、聴覚インタフェース／Auditory Interface
6. 触覚、触覚インタフェース／Tactile Interface
7. 力覚、力覚インタフェース／Haptic Interface
8. 移動感覚インタフェース／Locomotion Interface

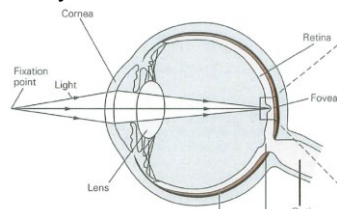


## TODAY's TOPIC

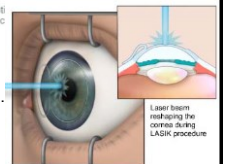


- 目の構造／Eye structure
- 目のセンサ／Eye sensors
- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

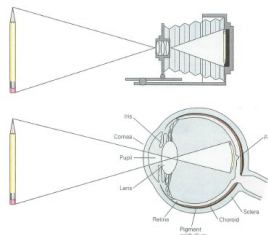
## 眼の構造／Eye Structure



- 角膜／Cornea: surface lens
  - LASIK: Laser in Situ Keratomileusis
- 水晶体／Lens: Internal lens.
  - Focal length is adjustable by deformation.
- 虹彩／Iris: Adjust amount of light.
- 網膜／Retina: Light sensor



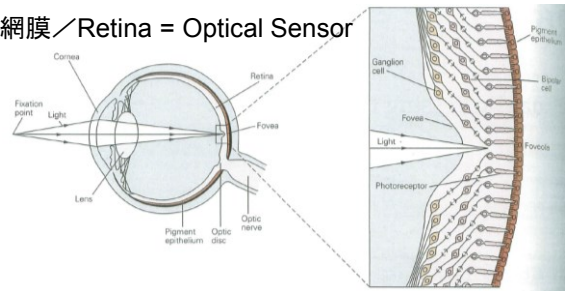
## カメラとの比較 / Comparison with Camera



- レンズ / Lens  
Camera: 1  
Eye: 2
- 虹彩 / Iris: same
- センサ / Sensor  
Camera: Film or CCD  
Eye: Retina

- Difference = Focal length adjustment (焦点調節)
  - Camera: Shift lens
  - Eye: Deform lens

## 網膜 / Retina = Optical Sensor



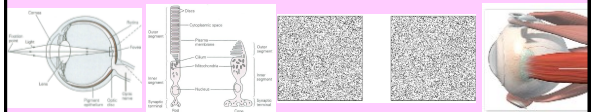
- 中心窩 / Fovea: Center of vision. Very high spatial resolution.
- Optic nerve: Nerve from retina to brain.  
Optic nerve is **in front of** the retina. (transparent)
- 盲点 / Optic disc (blind spot): Hole that optic nerve axons exit.

## 盲点 / Blind Spot



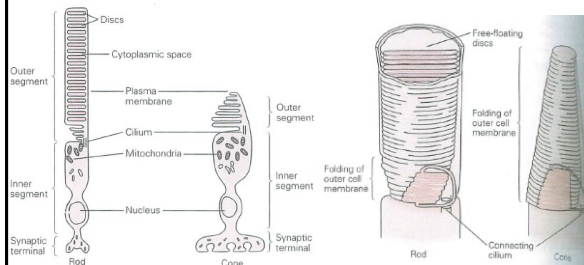
- Close your right eye, and gaze '+' with your left eye.
- Move the paper back and force, and find '●' disappears.
- You also find the line connected.

## TODAY's TOPIC



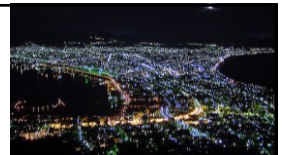
- 目の構造 / Eye structure
- 目のセンサ / Eye sensors
- 奥行き知覚 / Depth perception
- 眼球運動 / Eye movement

## 網膜の視細胞 / Optic cells in the retina

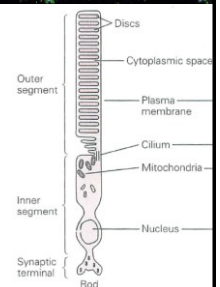


- Rod Cell (桿体細胞) and Cone Cell (錐体細胞)
  - Light to electric conversion is done at outer segment.
  - Channels composed of protein is opened by the light.
  - Rod cell has longer outer segment.

## 桿体細胞 / Rod cell

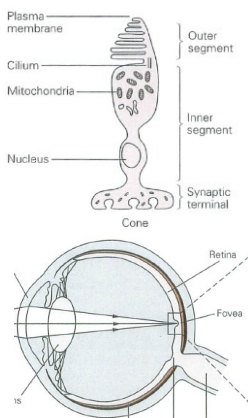


- **Black and White sensor.**
- Plays major role when dark
- High sensitivity (x100 cone cell)
  - Can capture single photon
- One eye has 130,000,000 cells.
- Slow response.

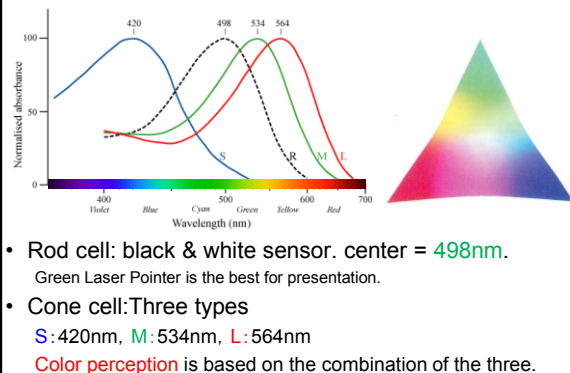


### 錐体細胞 / Cone cell

- **Color sensing**
  - Three types (L,M,S)
  - Caused by different proteins in the channel.
- Play major role when bright.
- Has lower sensitivity.
- One eye has 7,000,000.
- **Clustered at fovea (中心窩).**
- Fast Response.



### 桿体細胞・錐体細胞 / Rod cell & Cone cell



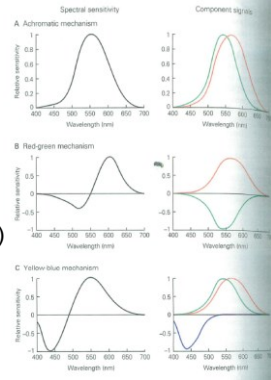
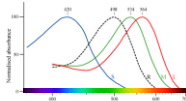
### 色知覚メカニズム / Brain color perception ≠ R,G,B

Take **differentials** and compose another 3 axis.

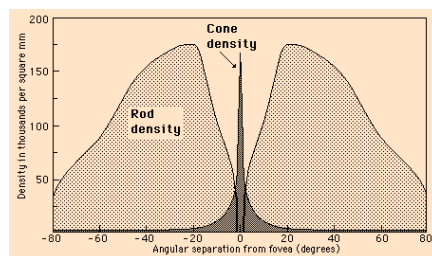
- L+M(+S) (Blighness)
- M-L (Red-Green axis)
- S -(L+M) (Blue-Yellow axis)

• They are the basis of "complementary color" (補色)

- there is no such thing as "reddish green"



### 桿体・錐体の分布 / Distribution of the cells.



- Cone cell = central vision (中心視)
  - ✓ Peripheral vision is almost color blind
- Rod cell = peripheral vision (周辺視)
  - ✓ You can see stars better by peripheral vision



### 色知覚は空間解像度が低い Color process has very low resolution

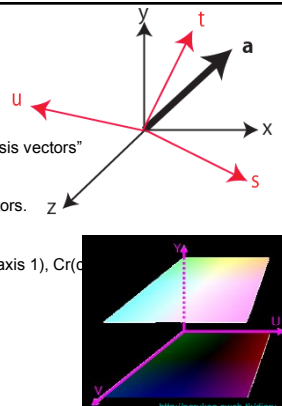


### RGB and YCbCr(YUV)

RGB: corresponds to 3 cone cells.

Mathematics tells us... ANY 3 independent vectors can be "basis vectors" (orthogonality not required)

RGB = One type of 3 independent vectors. There are infinite ways.



YCbCr (YUV): Y(brightness), Cb(color axis 1), Cr(color axis 2). Similar to brain's color perception.

$$Y = 0.257R + 0.504G + 0.098B + 16$$

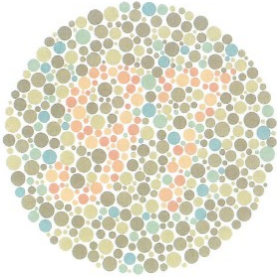
$$Cb = -0.148R - 0.291G + 0.439B + 128$$

$$Cr = 0.439R - 0.368G - 0.071B + 128$$

Used in JPEG image compression

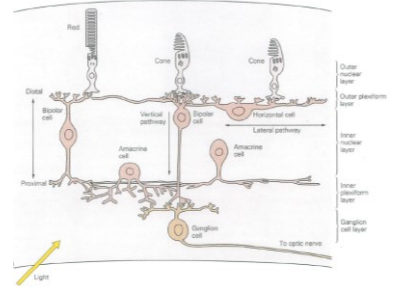
<http://mike.ken.coxs.fordian.dian.com/kyuwp2007/>

色盲 / Color blindness



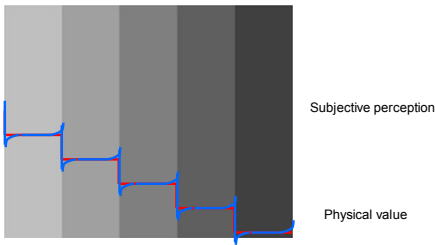
- One to three types of cone cells lacks.

網膜での情報処理 / Retinal image processing

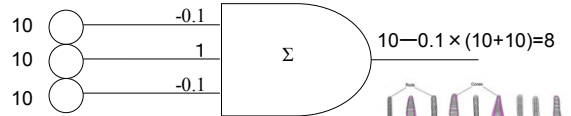


- Sensors: About 200,000,000 / eye
- Nerve axons to the brain: about 1,000,000 / eye
- Retinal image process: 200 cells ⇒ 1 output

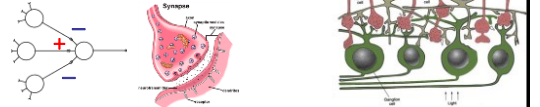
Key to the retinal process: "Mach belt" illusion



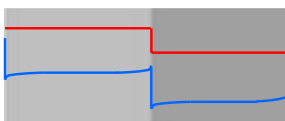
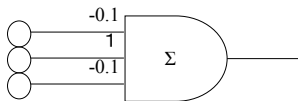
側抑制 / Lateral inhibition (1/3)



- Synaptic calculation
- Central input: +(plus)
- Surrounding input: -(minus)

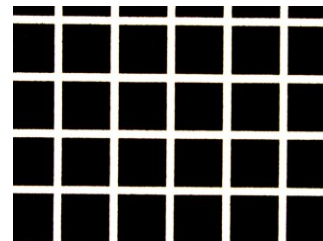


側抑制 / Lateral inhibition (2/3)



10 10 10 10 10 10 5 5 5 5 5  
8.0 8.0 8.0 8.0 8.0 8.5 3.5 4.0 4.0 4.0 4.0

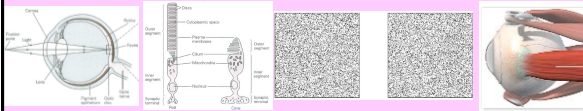
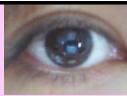
側抑制 / Lateral inhibition (3/3):  
Harman grid illusion



- (1) 周辺視 / peripheral vision: the cross point becomes dark, due to lateral inhibition
- (2) 中心視 / central vision: No such effect ⇒ The peripheral vision "compress" larger field.



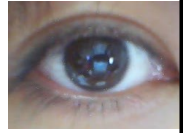
TODAY's TOPIC



- 目の構造 / Eye structure
- 目のセンサ / Eye sensors
- 奥行き知覚 / Depth perception
- 眼球運動 / Eye movement

奥行き知覚の鍵 / Depth perception cues

- 単眼性 / With single eye
  - 経験 / Experience
  - 焦点調節 / Accommodation
  - 運動視差 / Motion Parallax



- 両眼性 / With two eyes
  - 輻輳角 / Vergence eye movement
  - 両眼視差 / Binocular disparity

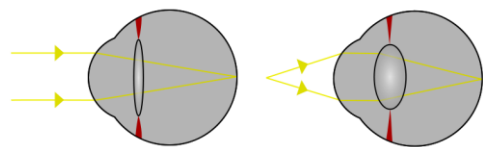


Depth cue(1) 経験 / Experience



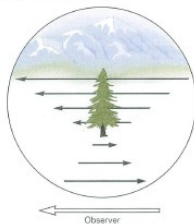
- 重なり(遮蔽) / Occlusion
  - Occluded (shielded) objects are more distant than occluding (shielding) objects.
- 遠近法 / Perspective
  - Near = Large, Bottom, Clear
  - Far = Small, Top, Blur
- 記憶 / Memory
  - Knows the physical size

Depth cue(2) 焦点調節 / Accommodation:  
Changing the power of the lens



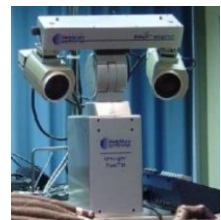
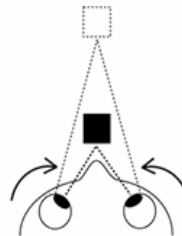
- Automatic focus adjustment by lens deformation
- The adjustment itself works as depth cue.
  - works at close range.

Depth cue(3) 運動視差 / Motion Parallax



- When the head moves...
  - Near: Moves in the opposite direction.
  - Far: Does not move, or moves in the same direction.

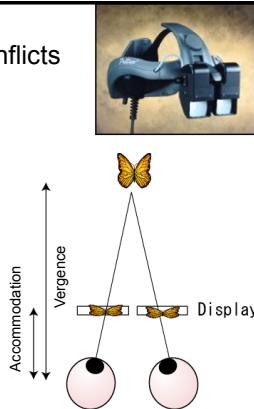
Depth cue(4) 輻輳 / Vergence eye movement



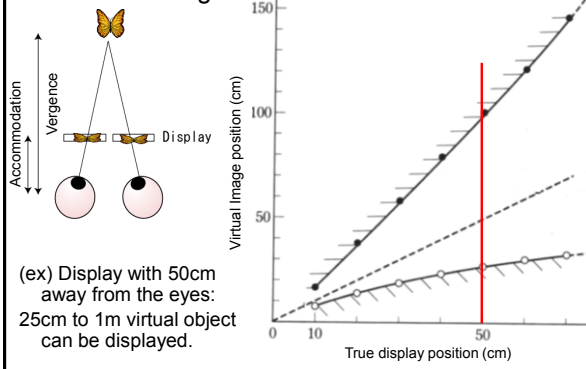
- The eyes converge (move inward) and diverge (move outward) by distance.

### 輻輳 - 調節矛盾の問題 Vergence-accomodation conflicts

- Accommodation & vergence are slightly coupled.
- Stereo display problem:
  - Accommodation=constant
  - Vergence = variable
  - ⇒ **Severe Fatigue**



### 輻輳 - 調節矛盾の許容範囲 Tolerance of vergence-accomodation conflicts



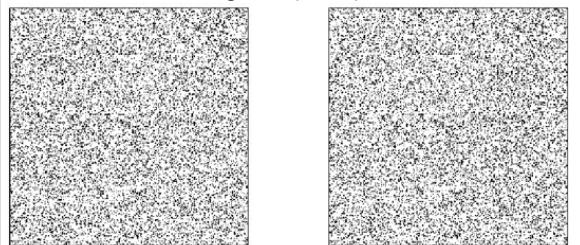
### Depth cue(5) 両眼視差/Binocular disparity

- Disparity = image shift
  - Vergence: single point.
  - Binocular disparity: whole field of view.
- Most important for VR system

### Stereogram



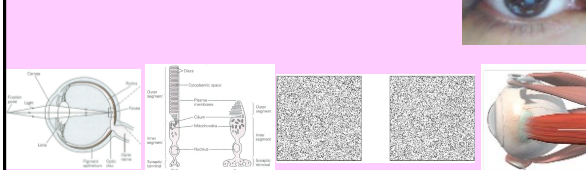
### ランダムドット・ステレオグラム Random dot stereogram (RDS)



- Proof of "pure disparity can be distance cue". Before the RDS, "experience" was thought to play major role.
- Found and used during Vietnam War.

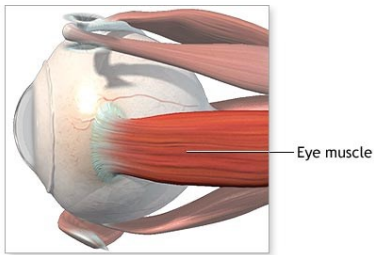


### TODAY's TOPIC



- 目の構造/Eye structure
- 目のセンサ/Eye sensors
- 奥行き知覚/Depth perception
- **眼球運動/Eye movement**

## Eye movement

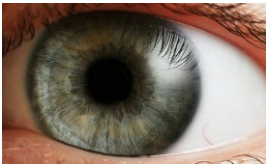


- 6 muscles (3 pairs) rotate eyes.

## Eye movement: 入力手段として / As an Interface



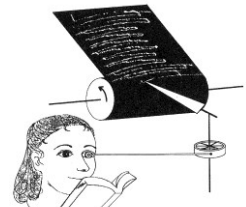
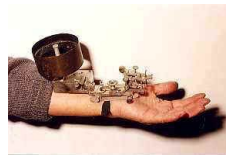
## How to measure Eye movement



- アナログ測定 / Analog measurement
  - コンタクトレンズ / Contact Lens
  - 眼底電位 / Electrooculography
  - 強膜反射 / Limbus Tracking Method
- 画像処理 / Computer Vision
  - パッシブ・アクティブな方法 / Passive・Active Methods

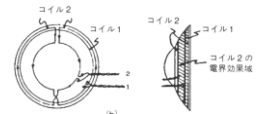
## コンタクトレンズ / Contact Lens

- カイモグラフ (Kymograph)



- バリエーション

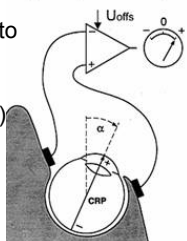
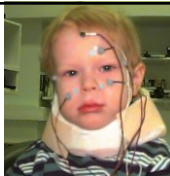
- オプティカル・レバー法  
コンタクトレンズに微小ミラー装着
- サーチコイル法  
コンタクトレンズにコイルを埋込



## 眼底電位

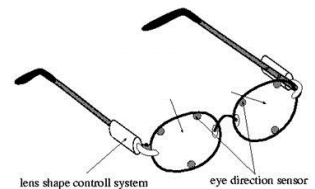
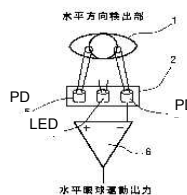
### Electrooculography, EOG

- Horny coat (角膜) has ~1mV positive voltage to Retina (網膜)
- Electrodes (電極) around eyes.  
⇒ Measured voltage is proportional to eye rotation.
- Has wide range (velocity, frequency)
- Accuracy not so good (1 deg~)



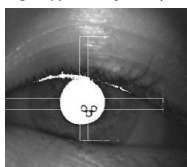
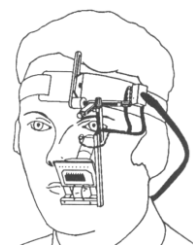
## 強膜反射 / Limbus Tracking Method

- Emit IR light to the eye, measure reflected light.  
黒目と白目の境界に赤外線照射。反射光計測
- Received light: White part > Black part.
- Good for horizontal eye motion.



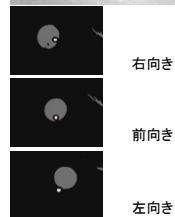
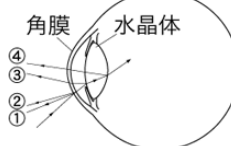
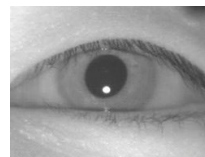
## Computer Vision

- Capture eye image.
- By image processing (pattern matching), eye center is calculated.
- Refresh rate = video rate.



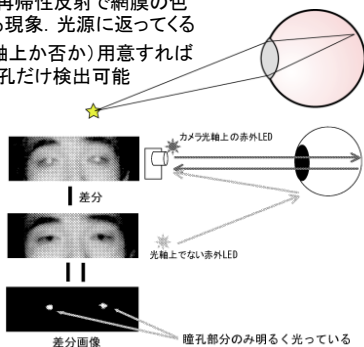
## 角膜反射 / Reflection at Horny Coat

- 点光源の角膜照射時に現れる角膜反射像(ブルキニエ像)から眼球運動を計測
- ビデオカメラで撮影⇒画像処理
- 瞳孔中心との相対位置を使う



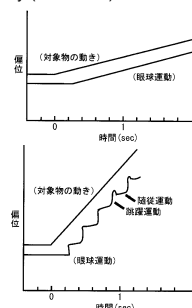
## 赤目現象の利用 / Red-eye Effect

- 目のレンズによる再帰性反射で網膜の色(血管)が反射する現象。光源に返ってくる
- 光源を2種類(同軸上か否か)用意すれば差分画像として瞳孔だけ検出可能



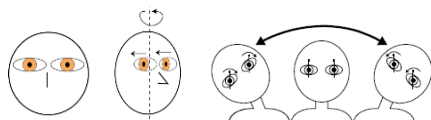
## 眼球運動の種類 / Eye movements

- スムーズパースト(滑動性眼球運動) / Smooth Pursuit
  - Follow slow movement of small dots. Voluntary (conscious)
- サッケード(跳躍性眼球運動) / Saccade
  - Stepwise movement
  - Motion start is voluntary and involuntary.
  - During motion,
    - You cannot stop (involuntary)
    - Visual acuity drops.
- 固視微動 / Miniature eye movement
  - Very small vibration. 30~100Hz.
  - Refresh the image on the retina.
    - Anesthetisation of muscles ⇒ No visual image.



## 安定化のための反射としての眼球運動 Eye movement for stabilization

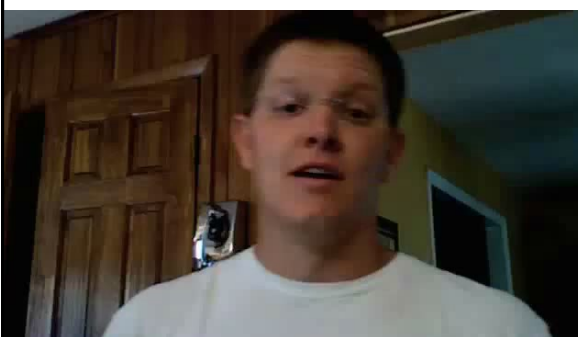
- 前庭動眼反射 / Vestibulo-ocular reflex (VOR)
  - Cancel head rotation.



- 視運動性眼球運動 / Optokinetic Response (OKR)
  - When the whole visual field moves, the eye follows.



## 参考: Chicken Head Tracking - Smarter Every Day

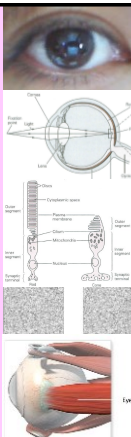


<http://www.youtube.com/watch?v=dPlkFPowCc>



## TODAY'S SUMMARY

- 眼の構造／Eye structure
  - cornea, retina, fovea, blind spot
- 眼のセンサ／Eye sensors
  - rod cell, cone cell, color vision
  - peripheral & central vision
  - image processing
- 奥行き知覚／Depth perception
  - accommodation, vergence
  - binocular disparity
- 眼球運動／Eye movement
  - smooth pursuit, saccade,
  - VOR, OKR



## 小テスト／Mini Test 次回開始まで

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. 錐体細胞と桿体細胞の分布の違いについて述べよ Describe difference of distribution of cone cell and rod cell.
2. 錐体細胞と桿体細胞の明暗および色感受性の違いについて述べよ Describe difference of color and brightness perception of cone cell and rod cell.
3. 焦点調節について説明せよ Explain Accommodation
4. 運動視差について説明せよ Explain Motion Parallax
5. 輻輳について説明せよ Explain Vergence Eye Movement
6. 輻輳調節矛盾について説明せよ Explain Vergence-Accommodation Conflict
7. 両眼視差について説明せよ Explain Binocular Disparity
8. 前庭動眼反射について説明せよ Explain Vestibulo-ocular reflex(VOR)
9. 視運動性眼球運動について説明せよ Explain Optokinetic Response(OKR)  
眼底電位計測について説明せよ Explain Electroculography (EOG)
10. 強膜反射法について説明せよ Explain Limbus Tracking Method
11. 角膜反射法について説明せよ Explain Eye Capture System Using Reflection at Horny Coat