ANATOMY OF MACULA & MACULAR FUNCTION TESTS

PRESENTER: DR. SIDDHARTH GAUTAM

CONTENTS

- Anatomy of Macula Lutea
- Embryology
- Blood supply
- Macular function tests

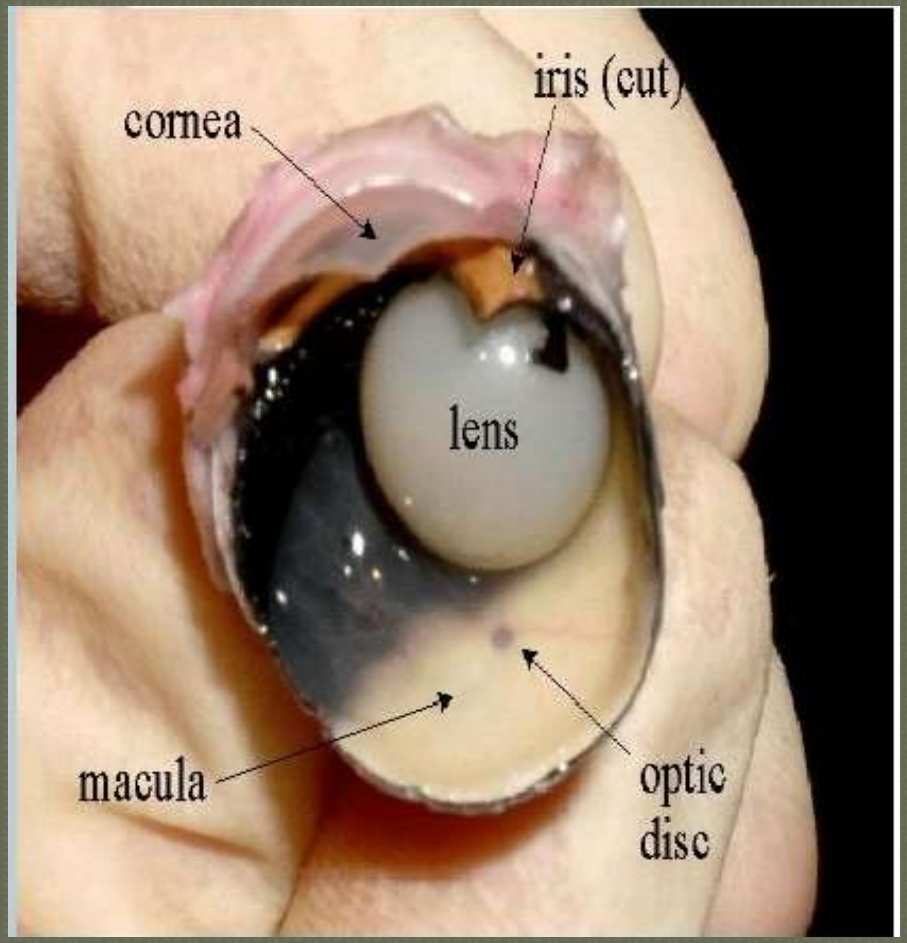
MACULA LUTEA

- **MACULA LUTEA** is a 5.5 mm circular area deeper red than rest of the fundus at the posterior pole of retina, lying inside the temporal vascular arcades, 2 disc diameters temporal to the optic disc.
- Synonyms: 1.Area centralis
  2.Yellow spot
  3.Central retina
  4.Posterior Pole
- Subserves central 15-20 degrees of visual field.

- Photopic & color vision are primary functions of this area.
- Dark appearance is due to:

→ Difference in pigmentation

→ Absence of retinal vessels in fovea



EMBRYOLOGY

- Macula develops from the optic cup
  - → Inner wall: Neurosensory retina
  - → Outer wall: RPE
- Development of retina starts by 6 weeks, all adult layers become recognizable by 5.5 months.
- Macular development is delayed till 8 months and specialization continues till several months after birth.

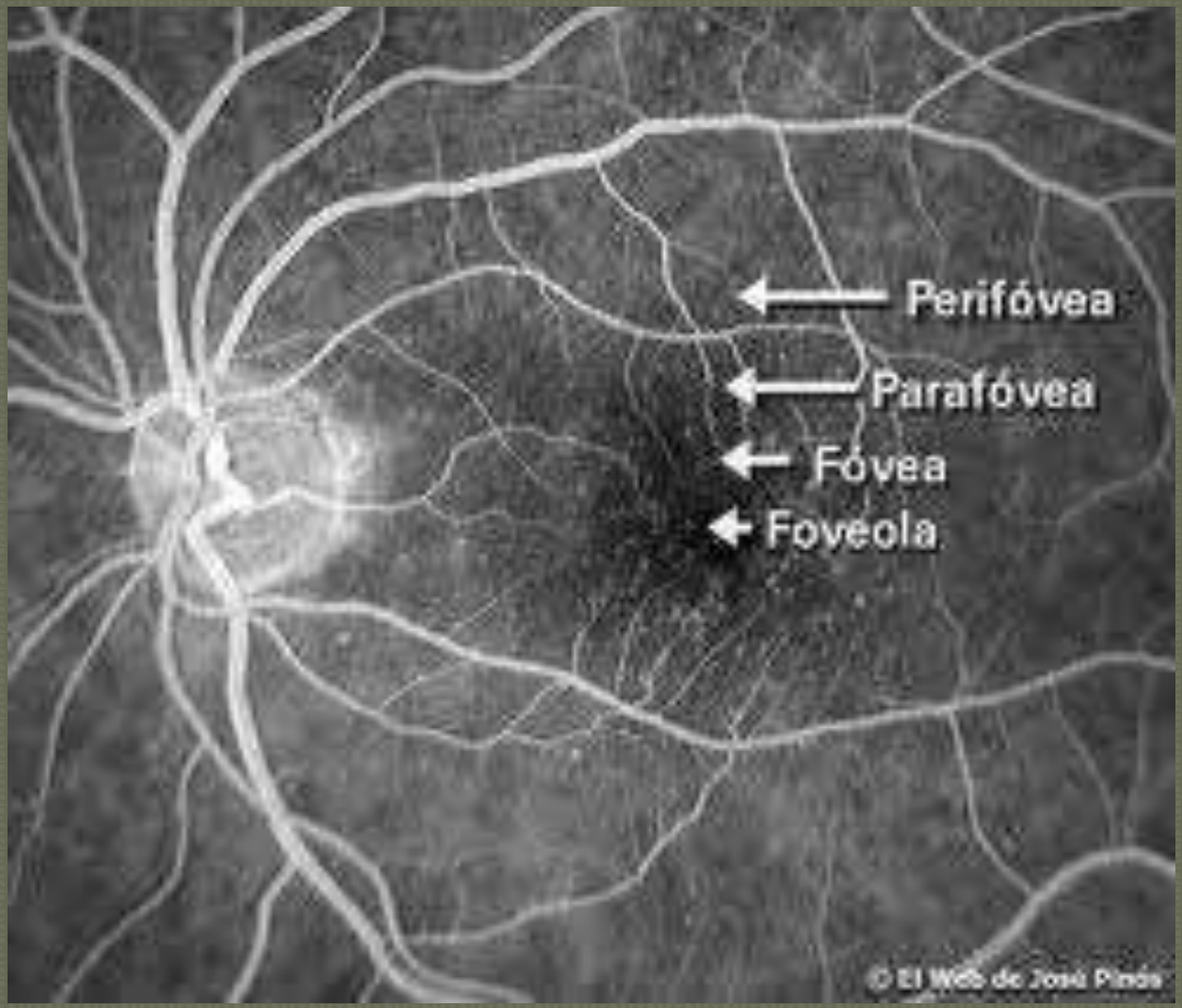
- Macula lutea can be **divisible** into:

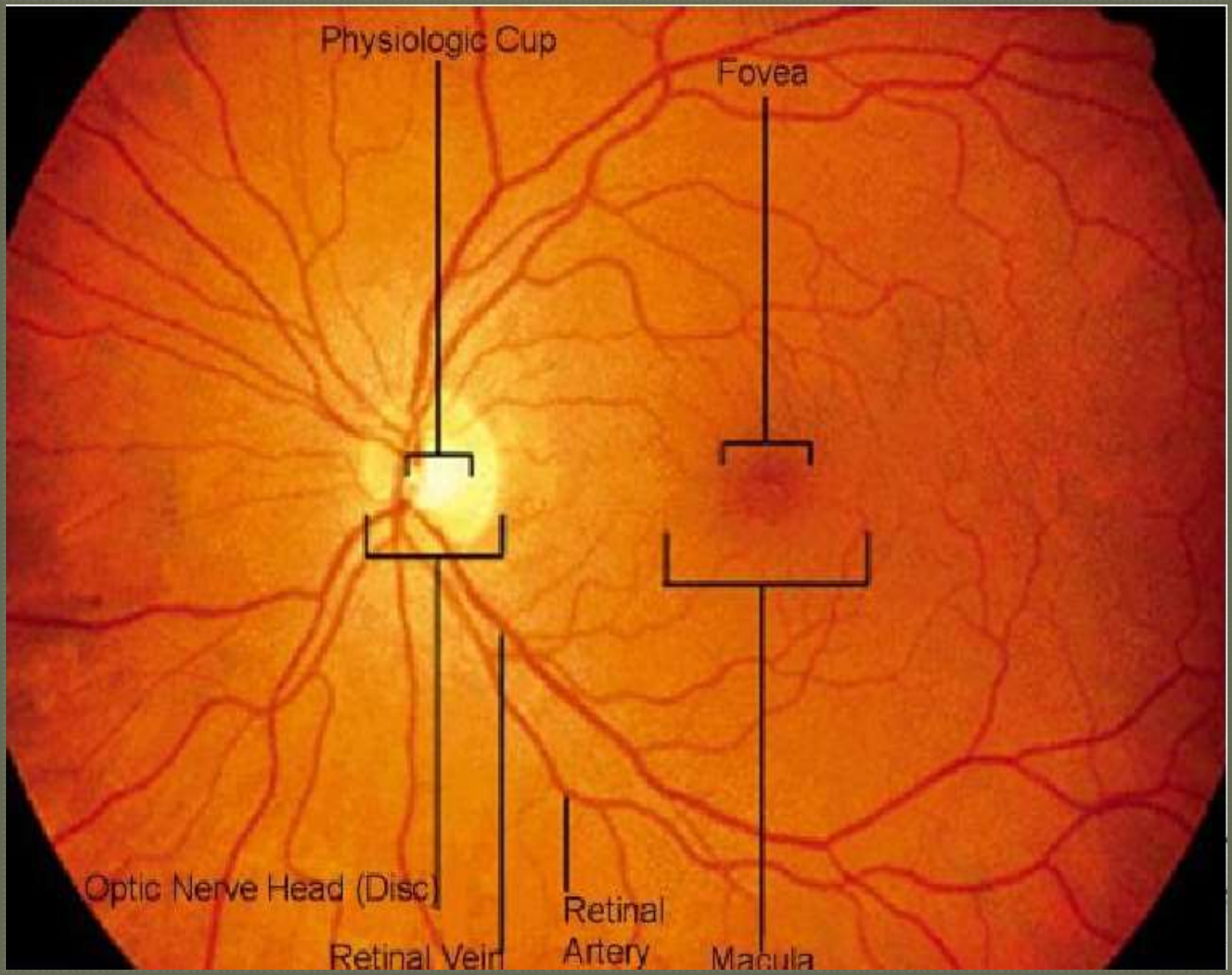
✓Foveola

✓Fovea

✓Perifoveal region

✓Parafoveal region


Perifóvea
Parafóvea
Fóvea
Foveola
© El Web de José Pinós


Physiologic Cup
Fovea
Optic Nerve Head (Disc)
Retinal Vein
Retinal Artery
Macula

FOVEA CENTRALIS

- Specially differentiated central 1.5 mm of macula in width & 0.25 mm in thickness.
- Most sensitive part of macula.
- Corresponds to 5 degree of visual field.

- **NOTE:** Outer plexiform layer in macula is oblique ,hence, CME appears stellate in macula & honeycomb appears outside macula.

SPECIAL ANATOMIC CONFIGURATION

- Densest concentration of cones
- A one to one photoreceptor-ganglion cell relationship
- Cones more elongated and slender
- Absence of rods at the foveola
- RPE cells are taller,thinner & deeply pigmented
- Presence of xanthophyll pigment

- **Xanthophyll carotenoid pigments:**

✓Located in fovea, most probably in the outer plexiform layer.

✓Leutin & Zeaxanthin are responsible for the characteristic dark appearance of macula in normal angiograms.

- This special anatomy enable the fovea for:

✓Highest discriminative ability (VA)

✓Colour perception

FOVEOLA

- 0.35 mm wide depression or pit in the central floor of fovea.
- **SITUATION:** 2 DD (3mm) away from the temporal edge of optic disc & 1mm below the horizontal meridian.
- Thinnest part of retina.
- Devoid of ganglion cells.
- Has only cones & muller cells.
- Vision is most acute at this area.

UMBO

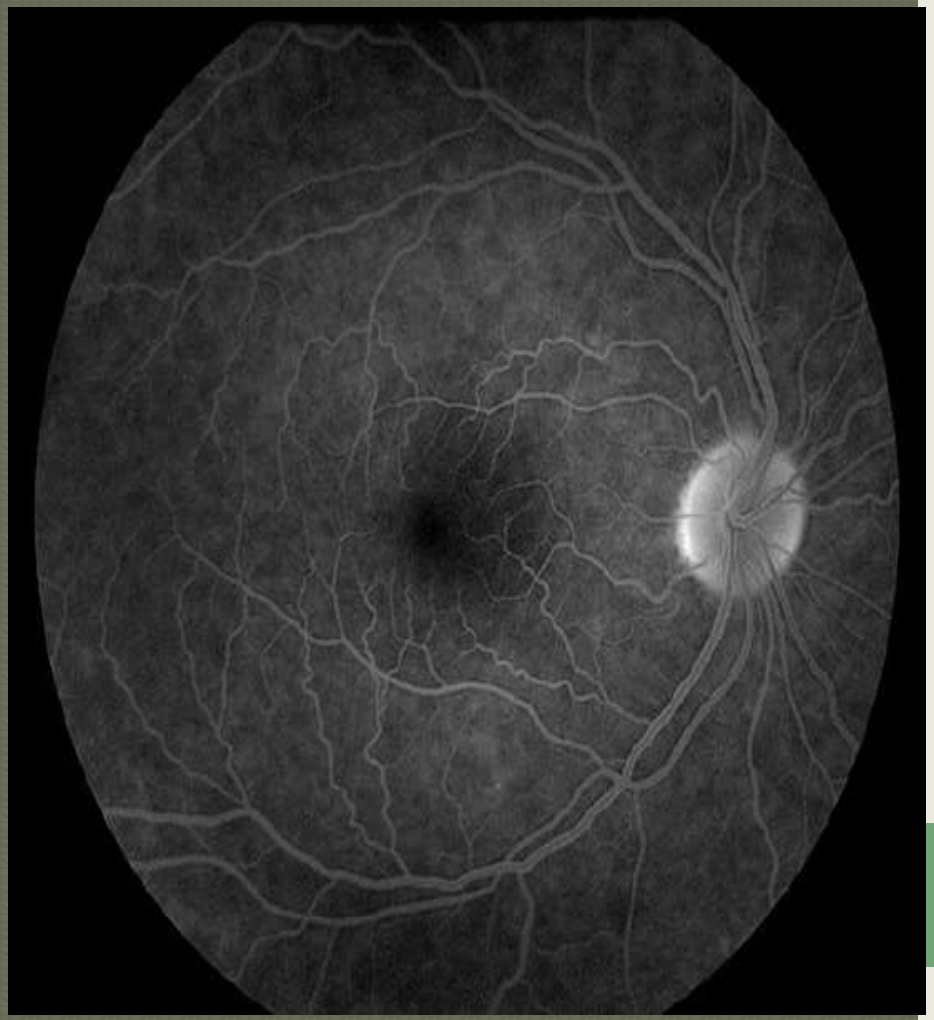
- Tiny depression in the centre of foveola.
- Corresponds to the ophthalmoscopically visible foveal reflex.

✓**FOVEAL REFLEX**: intensely bright spot of light visible ophthalmoscopically visible due to reflexion of light from the wall of foveal depression.

→ Loss of FR may be an early sign of damage.

FOVEAL AVASCULAR ZONE

- Located inside the fovea but outside the foveola.
- Extending about 0.4-0.6 mm in diameter, can be known by FFA.
- It varies with age & disease states.



- **PARAFOVEAL AREA:**

✓Portion of macula 0.5 mm in width surrounding the macula.

✓Outermost limit,where the ganglion cell layer,inner nuclear layer, and Henle layer are thickest (i.e. the retina is thickest)

- **PERIFOVEAL AREA:**
- 1.5 mm wide ring zone surrounding the parafoveal area.

BLOOD SUPPLY

- Supplied by small twigs of superior and inferior temporal branches of central retinal artery.
- Cilioretinal artery (branch from ciliary system) occasionally is seen originating in a hook shape within temporal margin of disc.

✓ **APPLIED**: When present there is retention of central vision in CRAO.

✓ Outer 4 layers→ Choriocapillaries

✓ Inner 6 layers→ Central Retinal Artery

MACULAR FUNCTION TESTS

- **Used for :**

✓Diagnosis & follow up of macular diseases.

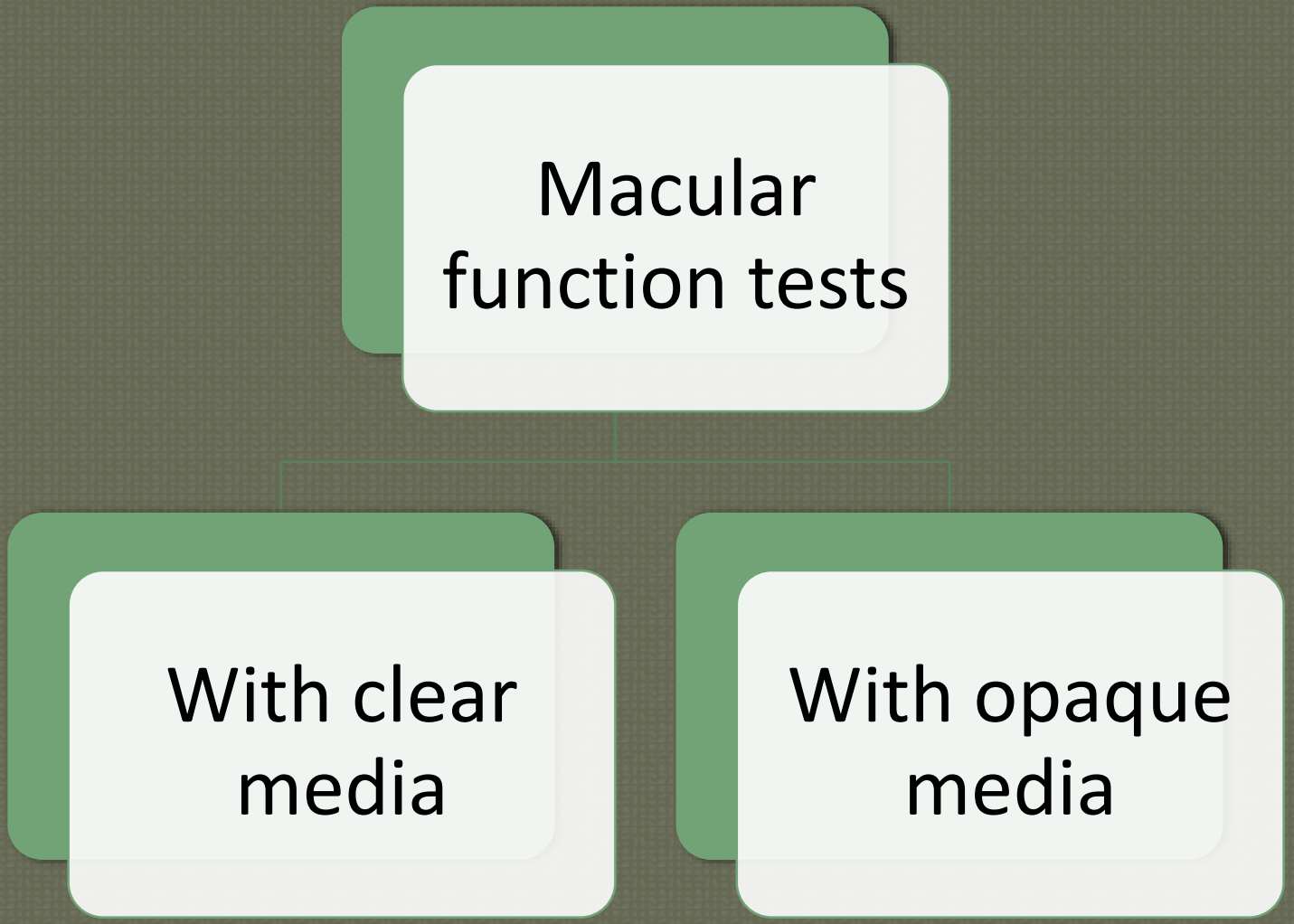
✓For evaluating the potential macular function in eyes with opaque media such as cataract and dense vitreous haemorrhage.

CLINICAL ASSESSMENT OF THE MACULA

- **Symptoms:**

1. Central vision impairment
2. Metamorphopsia
3. Micropsia
4. Macropsia

CLASSIFICATION



MFT WITH CLEAR MEDIA

1. Visual Acuity
2. Contrast Sensitivity
3. Slit lamp biomicroscopy
4. Photostress test
5. Colour Vision
6. Amsler grid
7. Two point discrimination
8. Microperimetry
9. FFA
10. OCT

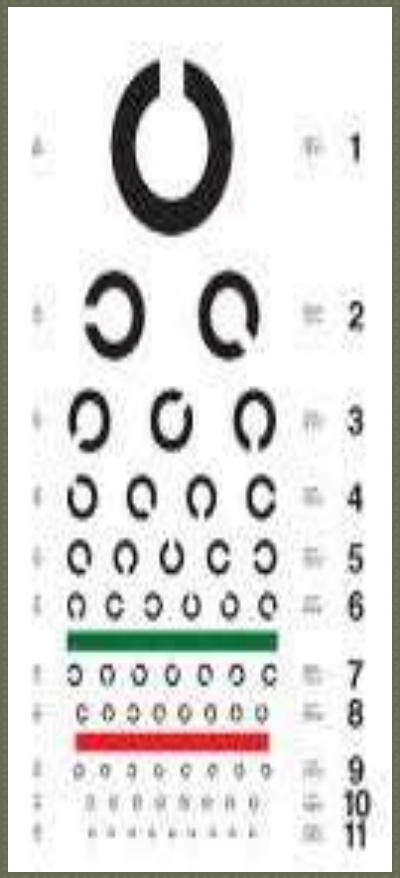
MFT WITH OPAQUE MEDIA

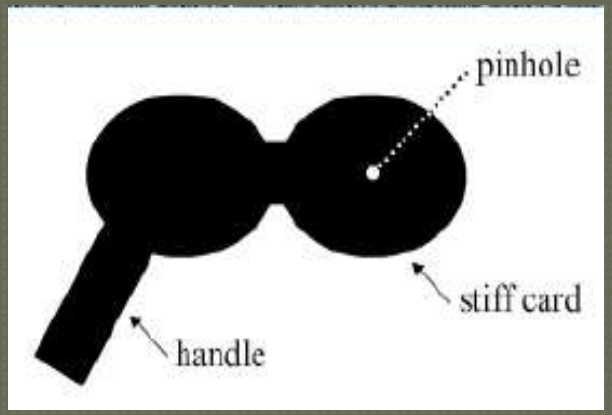
1. Maddox rod test
2. Focal ERG
3. VEP
4. Laser interferometry
5. Potential visual acuity meter test
6. Entopic phenomena

VISUAL ACUITY

- Visual acuity is measured by the visual resolution of a letter,symbol or a pattern under conditions of maximal contrast.
- In patients with macular disease VA is frequently worse when the patient looks through a pin-hole.

- There are numerous available options for determining the visual acuity in a person.
- Most commonly used test is the measurement of the central vision by the Snellens Test.
- It is based on the principal that two distant points can be visible only when they subtend an angle of 1 minute at the nodal point of the eye.




pinhole
stiff card
handle

PERCEPTION OF LIGHT(PL)

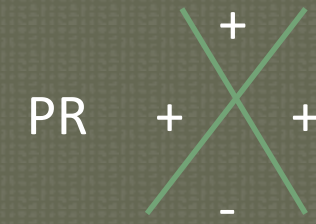
- Although many sophisticated tests are available for testing vision, perception of light (PL) must be present if any potential useful vision is present.
- It is tested by shining light directly into the patients eyes. Then the patient is asked whether he perceives any light or not.
- Accordingly the vision is noted as PL + or PL - .

PROJECTION OF RAYS (PR)

- It is a crude but a very important and easy test to perform for the functioning of the peripheral retina.
- It is tested in a semi-dark room with the opposite eye covered.
- A thin beam of light is thrown on the patients eye from four directions (up, down, medial and lateral) and the patient is asked to point to the direction of the light.

- Results are symbolised as:

If the patient correctly points to light source in all directions.



If the patient does not point to the light source in any one direction.

CONTRAST SENSITIVITY

- Contrast sensitivity is a measure of the minimum amount of contrast needed to distinguish a test object.
- Indirectly assesses the quality of vision.
- Can detect early/subtle visual loss when VA is normal.

USES OF CONTRAST SENSITIVITY

- To detect retinal conditions like DR, ARMD and other retinal, macular and optic nerve diseases.

- Optical conditions like refractive error, refractive surgery, cataract and intraocular lens implantation and normal aging of the eye.

CONTRAST SENSITIVITY GRATING

- Spatial frequency is the number of dark light cycles per visual angle.
- In macular diseases, there is a marked impairment for the intermediate and higher spatial frequencies.


PELLI-ROBSON CONTRAST SENSITIVITY CHART
Distributed by HS Clement Clarke
V R S K D R
N H C S O K
S C N O Z V
C N H Z O K
N O D V H R
C D N Z S V
K C H O D R

SLIT LAMP BIOMICROSCOPY

- With a strong convex lens affords excellent visualization of the macula.

PHOTO-STRESS TEST

- This test can also be performed during routine eye examination to differentiate between macular or optic nerve pathology.
- **Principle**

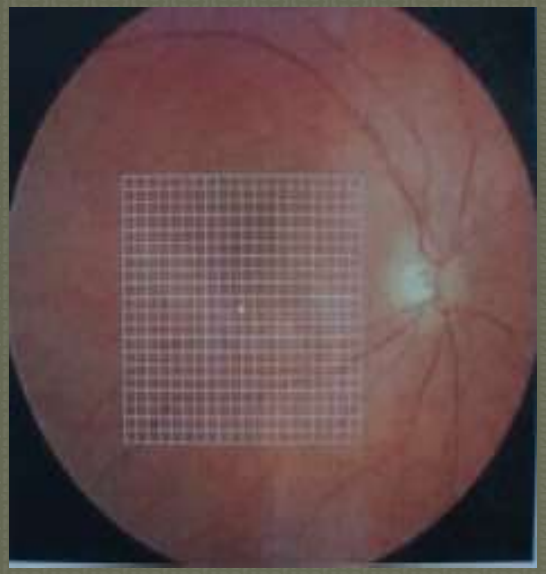
  Photostress testing is a gross test of dark adaptation in which the visual pigments are bleached by light. This causes a temporary state of retinal insensitivity perceived as scotoma by the patient. The recovery of vision is dependent on the ability of photoreceptors to re-synthesize visual pigments.

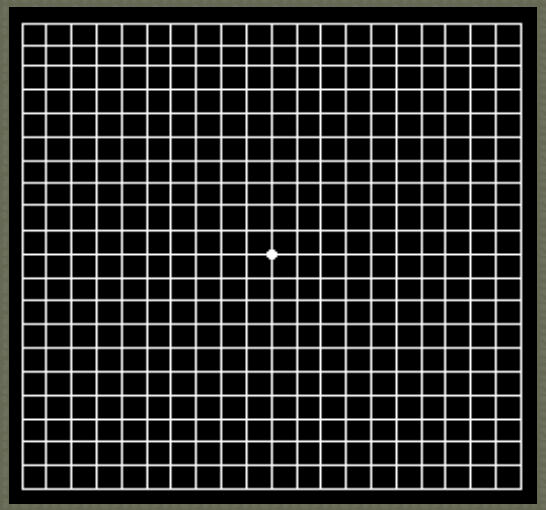
TECHNIQUE

- BCVA is determined.
- An indirect ophthalmoscope is held about 3 cm away for 10 sec.
- The photostress recovery time (PSRT) is the time taken to read any 3 letters of pre–test acuity line.
- Recovery time is 15 to 30 secs in normal eyes.
- More than 50 secs is an indication of macular disease but not in optic neuropathy.

AMSLER GRID TEST

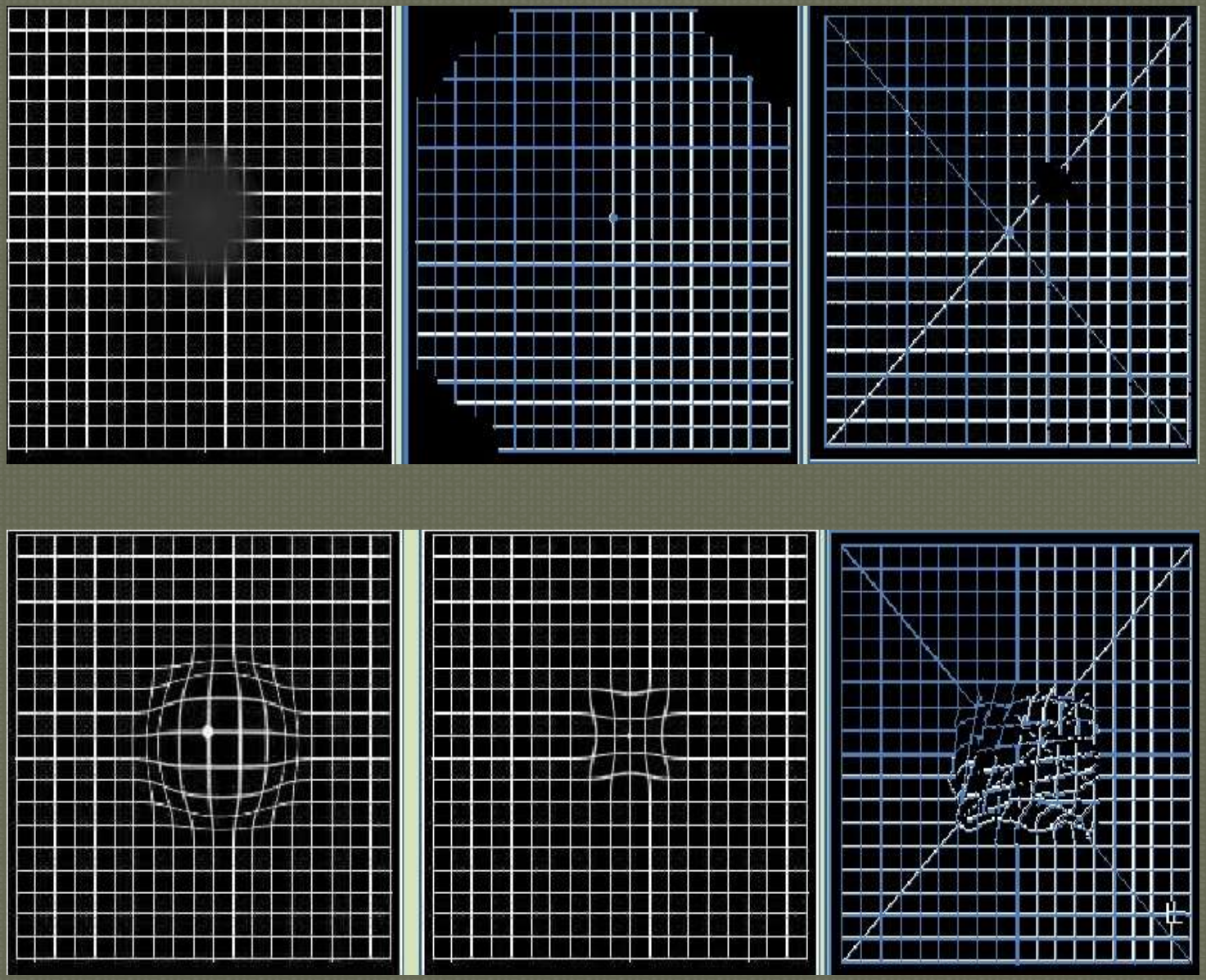
- Evaluates the 10˚of visual field centered on fixation.
- Used in screening and monitoring macular diseases.
- Square 10*10 cm divided into 400 5*5 mm squares to be held at 30 cm.





PROCEDURE

- Reading glasses are worn & 1 eye is covered.
- Patient is asked to see the central spot.
- Presence of abnormalities like blurred areas, holes, distortions, or blank spots are noted.
- Patient with maculopathy reports that the lines are wavy whereas patient with optic neuropathy remarks some lines are missing or faint.



TWO POINT DISCRIMINATION

- This test gives an idea about the macular function.
- The patient is asked to look through an opaque disc perforated with two pinholes behind which a light is held. The holes are 2 inches apart and are held 2 feet away from the eye.
- If the patient can perceive two lights, it indicates normal macular function.

COLOUR VISION

- Colour vision is the function of three populations of retinal cones.
- Blue (tritan) 414-424 nm
- Green (deuteran) 522-539nm
- Red (protan) 549-570nm
- Normal person possess all these three cones and called trichromat.

- Acquired macular diseases tends to produce blue yellow defects and optic nerve lesions red green defects.
- Deutran anomaly is the most common and those subjects can not differentiate between red and green colours.

TESTS

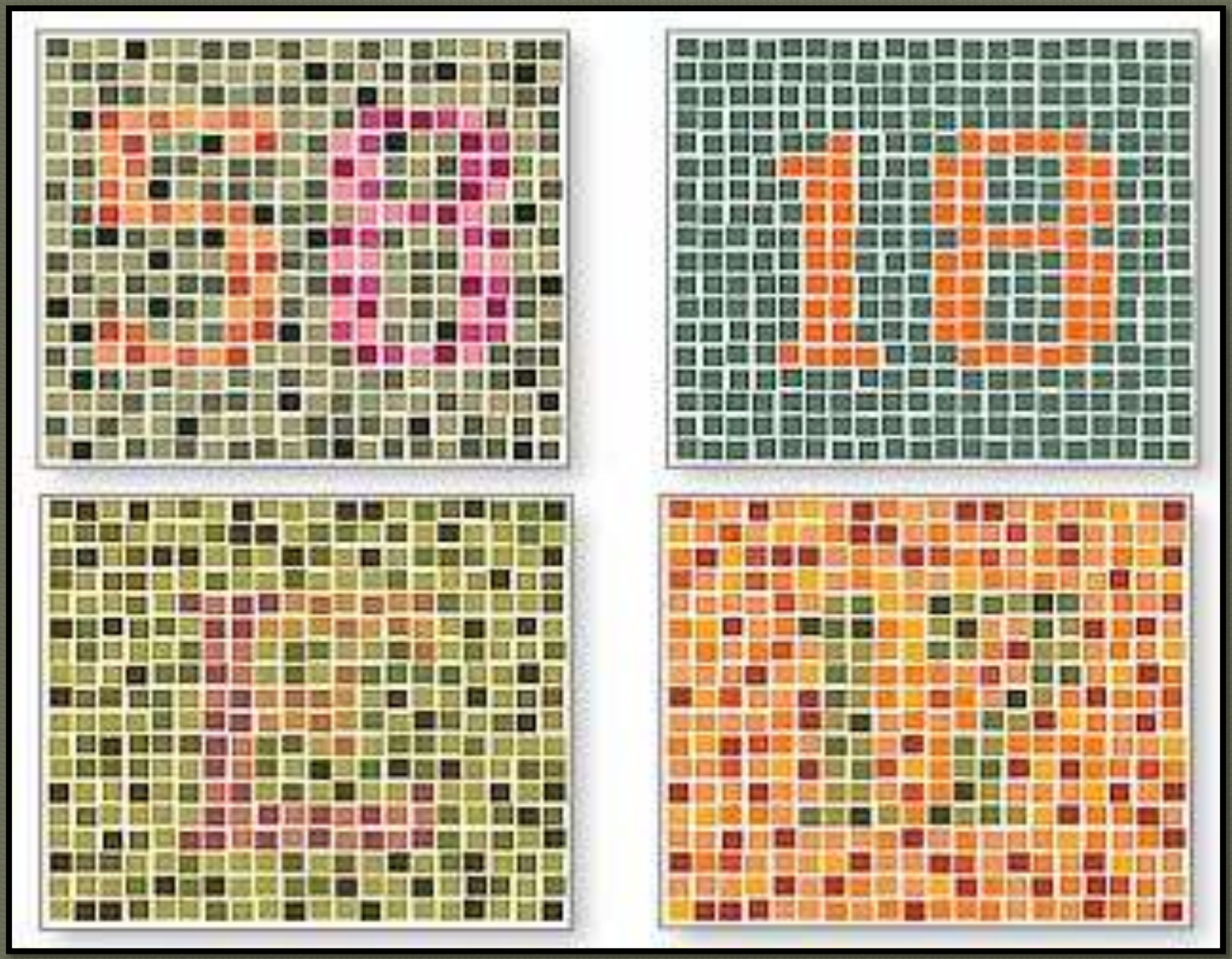
1. Pseudo-isochromatic chart test
2. The Lantern Test
3. Farnsworth-Munsell 100 hue test
4. City university colour vision test
5. Nagel’s anomaloscope test

- Of these the **pseudo-isochromatic** chart test is most widely and frequently used.

Ishihara Pseudo-isochromatic colour vision test plates

- This test consists of a series of plates designed to provide a quick and accurate assessment of colour vision deficiency of congenital origin. Most cases are characterised by a red-green deficiency which may be of two types; a protan type which may be absolute (protanopia) or partial (protanomalia) and secondly a deutan type which may be absolute (deuteranopia) or partial (deuteranomalia).
- In protanopia the visible range of the spectrum is shorter at the red end compared with that of a normal person, and that part of the spectrum which appears to the normal blue-green, to those with protanopia appears as grey.

- In deuteranopia the part of the spectrum which appears to the normal as green appears as grey. In protanomalia and deuteranomalia these parts of the spectrum appear as a greyish indistinct colour.
- For those with red green deficiencies, blue and yellow colours appear to be very clear compared to red and green. This is made use of in the Ishihara test. An absolute failure to appreciate blue and yellow is termed tritanopia and if partial tritanomalia. The Ishihara plates are not designed to detect these deficiencies.



- The plates are designed to be used in adequate daylight conditions and the introduction of direct sunlight or the use of electric light may produce some discrepancy in the results because of an alteration in the appearance of the colours.
- The plates should be held 75cm from the subject and tilted so that the plane of the plate is at right angles to the line of vision. Each plate should be identified within three seconds. In practice for those patients unable to read numerals those plates near the end of the book with winding lines between two X’s should be used. The lines should be traced with a brush in less than ten seconds.

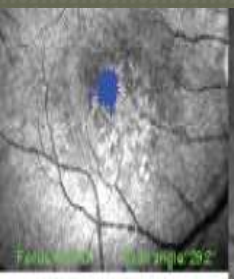
Plate number	Normal	Points with red-green defects		Inference
1	12	12		Both subjects with normal and
2	8	3		defective color vision read plate
3	6	5		1 as 12.
4	29	17		
5	57	35		Subjects with red-green defects
6	5	2		read these plates as those in
7	3	5		abnormal column. Totally color
8	15	17		blind are unable to read.
9	74	21		
10	2	X		Majority of subjects with color
11	6	X		vision deficiency read these plates
12	97	X		incorrectly.
13	45	X		
14	5	X		Subjects with normal color vision
15	7	X		do not see any number. Those with
16	16	X		red green deficiency read the
17	73	X		numbers given in the abnormal
18	X	5		column.
19	X	2		
20	X	45		Subjects with protanopia read
21	X	73		these plates as given in abnormal
		Protan	Deutran	column(1), those with deutrano-
22	26	6	2	maly read them as given in column
23	42	2	4	(2).
24	35	5		3
25	96	6		9

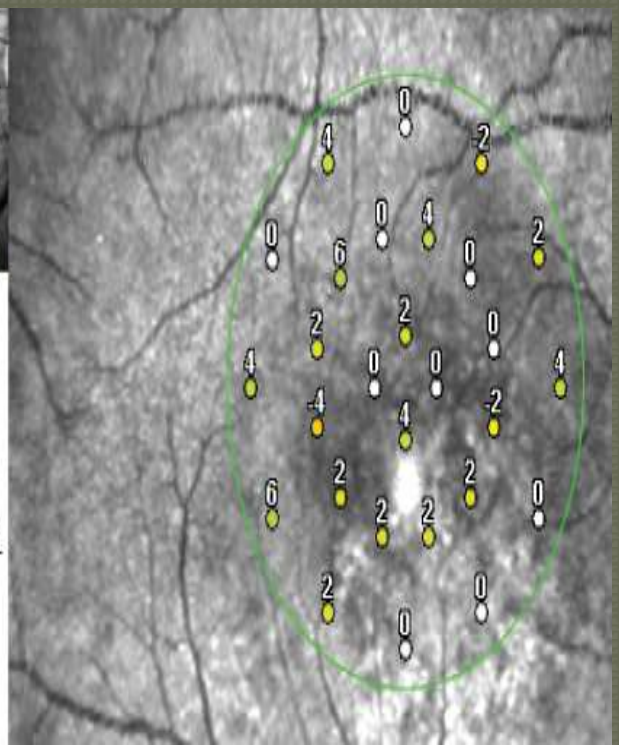
MICROPERIMETRY

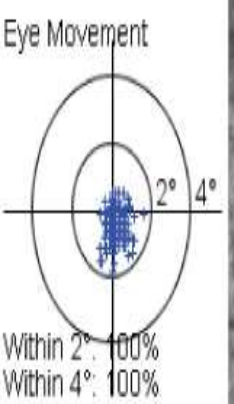
- The principle of microperimetry rests on the possibility to see —in real time— the retina under examination (by infrared light) and to project a defined light stimulus over an individual, selected location.

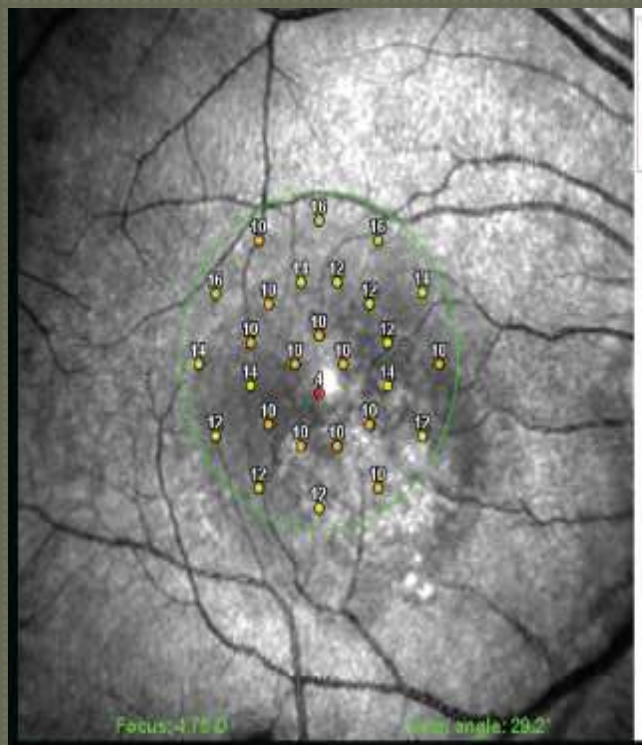
- SLO Microperimetry was the first technique which allowed to obtain a fundus-related sensitivity map.
- It uses a near infrared diode laser (675nm)beam that rapidly scans the posterior pole.
- The reflected light is detected by a confocal photodiode and the digitized image is stored in a computer.


optomap

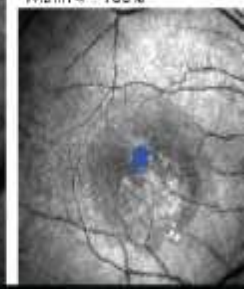





Eye Movement
2°
4°
Within 2°: 100%
Within 4°: 100%




Legend
Not seen at given level
Seen at given level
Not projected
Attenuation scale (dB)
Eye Movement
2°
4°
Within 2°: 100%
Within 4°: 100%



LIMITATIONS OF SLO MICROPERIMETRY

- SLO fundus perimeter did not allow to perform fully automatic examination.

- Moreover, automatic follow-up examination

to evaluate exactly the same retinal points tested during baseline microperimetry was not available with this instrument.

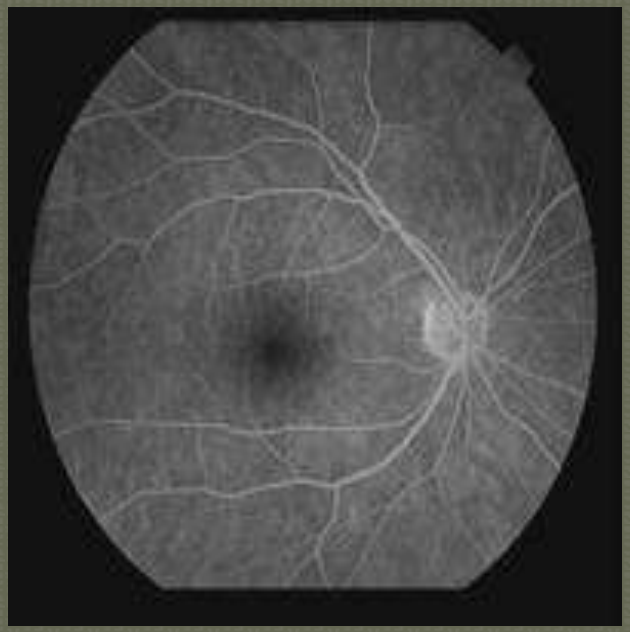
MP1 MICROPERIMETRY

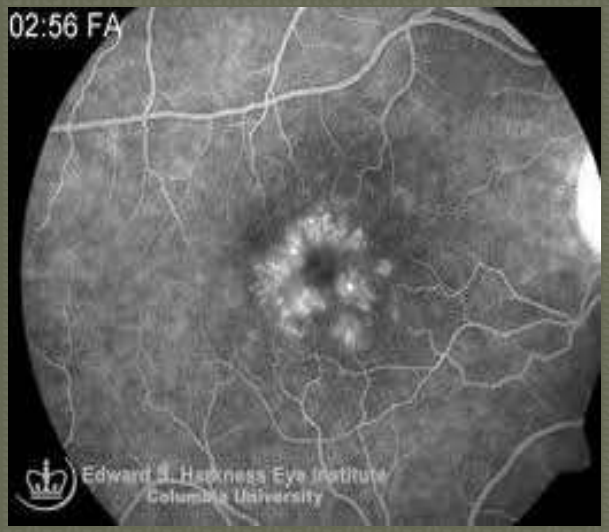
- The limitations of SLO have been overcome by MP1 microperimeter a recently developed automatic fundus perimeter
- MP1 microperimeter automatically compensates for eye movements during the examination via a software module that tracks the eye movements.

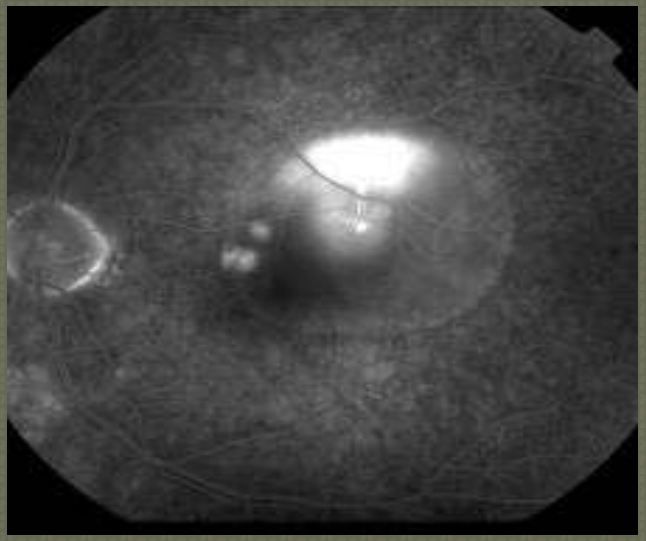
FLUORESCEIN ANGIOGRAPHY

- Dark appearance of the fovea on FFA is caused by FAZ and blockage of the choroidal background by xanthophyll and dense RPE.

- FFA is a very useful tool in diagnosing macular disorders e.g. diabetic maculopathy, CSR and can reveal the functionality of the lesion e.g. ischemic maculopathy.




02:56 FA
Edward S. Harkness Eye Institute
Columbia University



OPTICAL COHERENCE TOMOGRAPHY

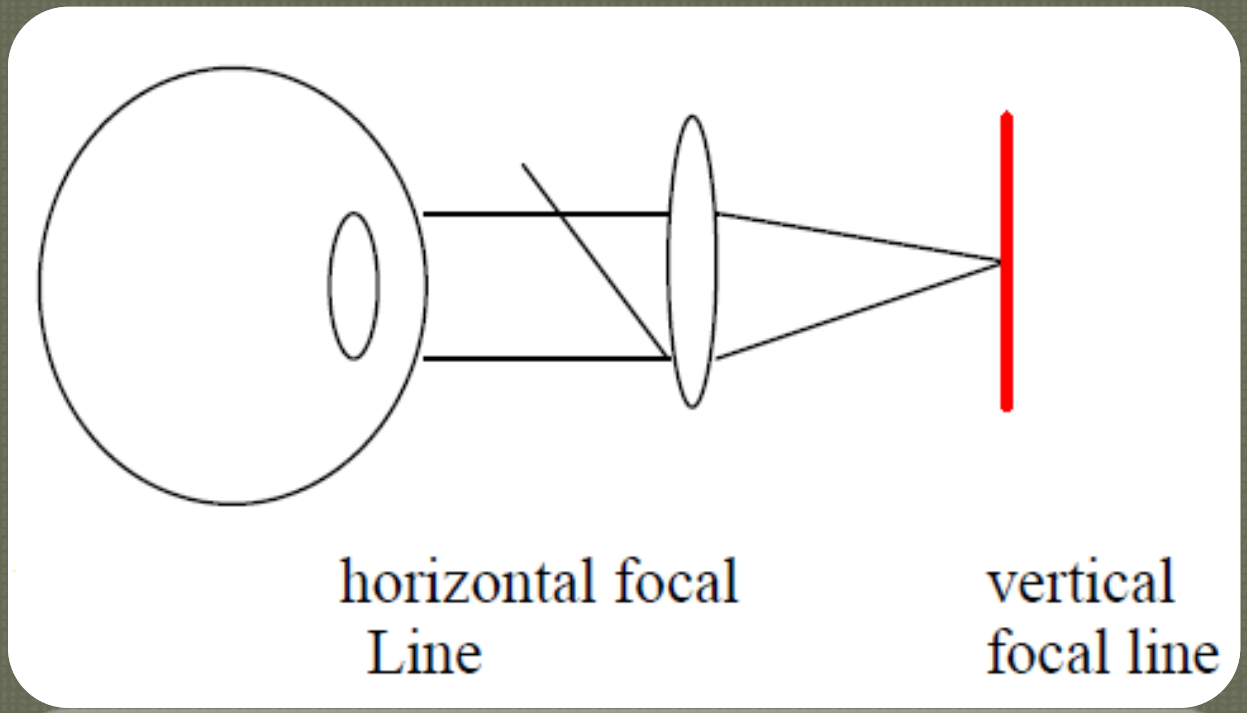
- It is non invasive noncontact imaging that produce high resolution cross sectional image.
- Useful in diagnosing macular disorders and to delineate retinal layers and detect subtle anatomical changes.

MADDOX ROD TEST

- Maddox rod in combination with a bright light source is a valuable dark room procedure for assessing macular function.

PRINCIPLE

- It is a high power cylindrical lens used to form a line image from a point source of light.
- Every astigmatic lens produces two focal lines perpendicular to each other.
- The real focal line produced by a Maddox rod is formed so close to the patient’s eye that patient cannot focus on it ; the second focal line is a virtual focal line passing through the point light source which is perceived by the patients.


horizontal focal
Line
vertical
focal line

TECHNIQUE

- Maddox rod can be used as a simple test of macular function in-patient's who do not have totally opaque ocular media.
- Maddox rod is held in front of eye to be tested and light source is held approx. 14 inches or 35cm away.

- a) If patient observes an unbroken red line, one may assume macular integrity.
- b) If patients observes a discontinuity in red line, this represents a large scotoma and should raise the possibility of significant macular disease.

ELECTRORETINOGRAM

- The clinical electroretinogram is the recording of the electrical potential waveform generated by the preganglionic retina in response to a flash of light.

TECHNIQUE

- It is measured in dark adapted eye with:

1. Active Electrode:

   On the cornea-embedded in a contact lens.

2. Reference Electrode:

   on the forehead- serving as a negative pole.

3. Ground Electrode:

   On the ear lobule.

MEASUREMENT

- ERG is measured in two components:

1. Amplitude:

   a wave: from baseline to peak of a wave

   b wave: from a wave peak to b wave peak.

2. Time Sequence:

   Latency: time interval between onset of stimulus and beginning of a wave response. N- 2 sec

   Implicit time: time from onset of light stimulus and maximum response. N- less than 1/4th sec.

CLINICAL APPLICATION

- Diagnosis and prognosis of retinal disorders such as retinitis pigmentosa, retinal ischaemia, Leber’s congenital amaurosis etc
- Assessing retinal function when fundus examination is not possible eg: dense cataract
- Assessing retinal function in babies when impaired vision is suspected.

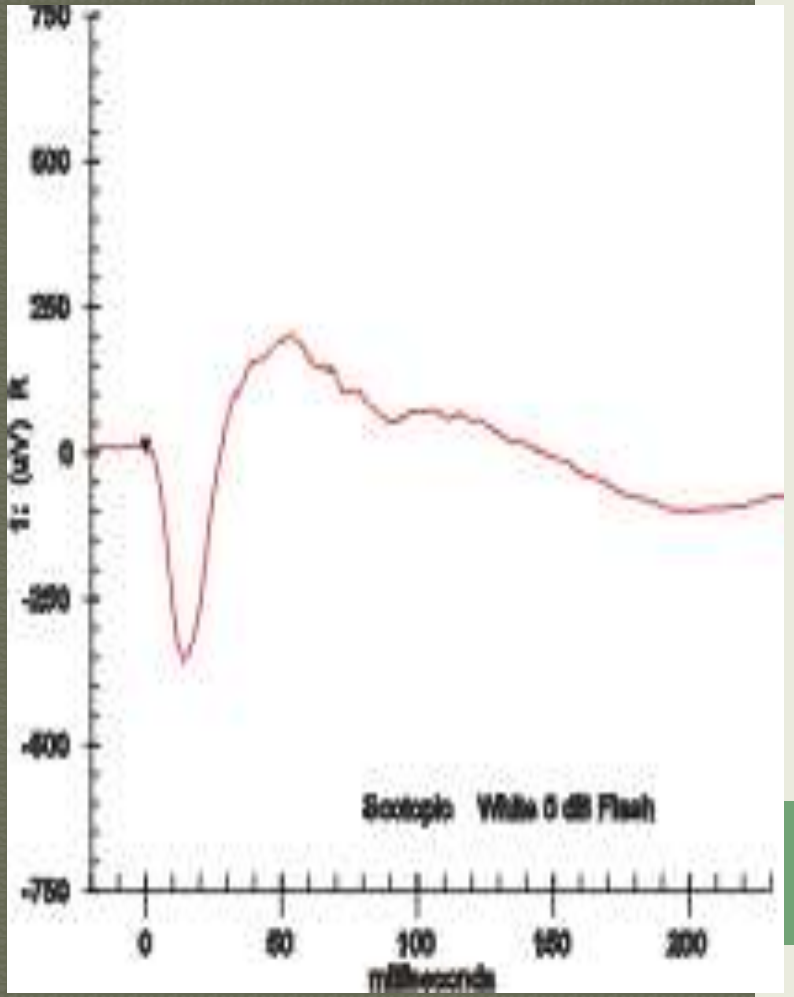
NORMAL ERG

- It consists of the following waves:

  1- a wave: It is the negative wave arising from the rods and cones.

  2- b wave: It is a large positive wave which is generated from the Muller cells, but represents the activity of the bipolar cells.

  3- c wave: It is also a positive wave representing the metabolic activity of the pigment epithelium.



ABNORMAL ERG RESPONSE

1. Supernormal response: characterised by response above the normal upper limit. It is seen in
   - Subtotal circulatory disturbance
   - Early siderosis bulbi
   - Albinism
2. Sub-normal Response: b-wave response is subnormal. This indicates that a large area of retina is not functioning, such as in early cases of retinitis pigmentosa, retinal detachment, vitamin A deficiency.

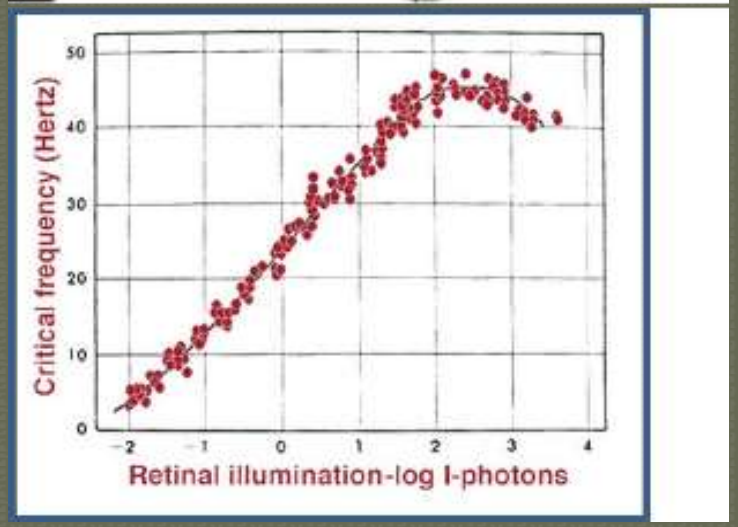
3. Extinguished response: this is seen when there is complete failure of rods and cones eg complete retinal detachment, advanced retinitis pigmentosa.

4. Negative response: this indicates a gross disturbance in retinal circulation eg CRAO, CRVO, arteriosclerosis.

MAXWELL OPHTHALMOSCOPE

- It is a hand held foveal ERG.

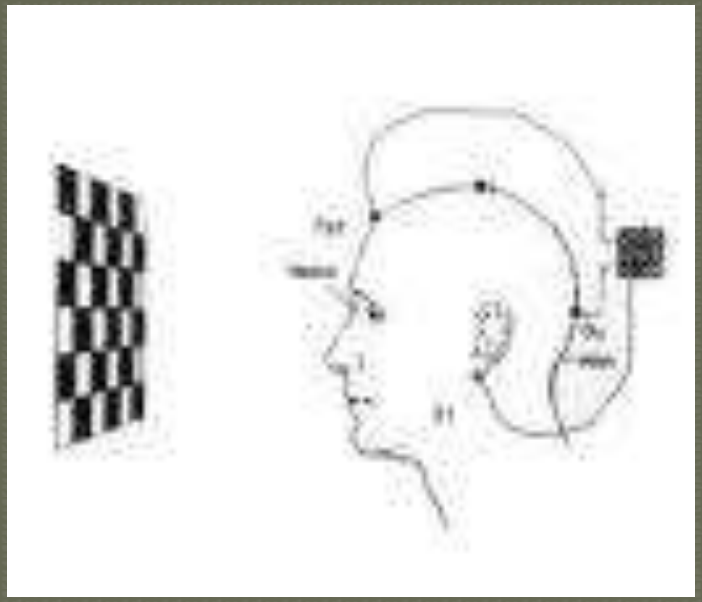
- It employs a 3-4 degrees whit flickering light focused on the fovea with a 10 degrees annulus of constant white light to desensitize surrounding retina.

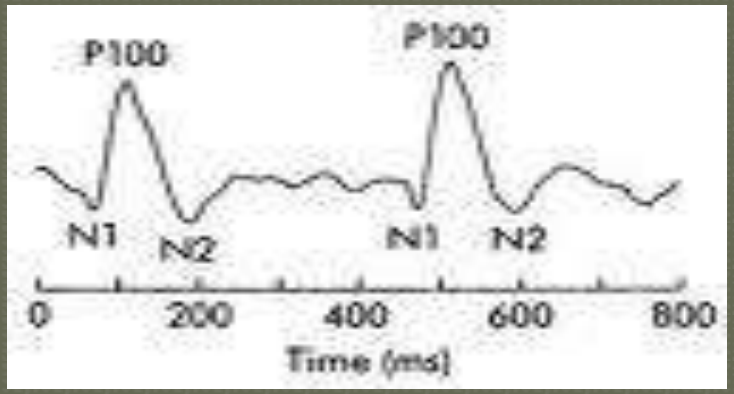


VEP

- VEP is a measure of the electrical potential generated in response to a visual stimulus.
- It represents integrity of entire visual pathway from retina to occipital lobe so can not differentiate between macula ,ON and cortical pathology.
- Two types of stimulus either by flash of light or by patterned stimuli .

- If the issue is the V/A then the amplitude is measured.
- If the issue is the lesion in the visual pathway then the latency is measured.





CLINICAL APPLICATION

- Optic nerve disease
- Visual acuity measurement in infants, mentally retarded and aphasic patients
- Malingering and hysterical blindness
- Assessment of visual potential in patients with opaque media
- Amblyopia
- Glaucoma
- Refraction

LASER INTERFEROMETRY

- Utilizes coherent white light or helium-neon laser generated interference stripes or fringes that are projected onto the retina through the ocular media.
- Brightness is increased in patients with dense cataracts.
- The laser interferometer resolving power is converted to standard visual acuity.

LIMITATIONS

- 1. Subjective.
- 2. Laser fringe vision>vision of letter acuity.
- 3. Over predicts visual potential in amblyopes.

POTENTIAL VISUAL ACUITY METER TEST

- PAM introduced in1983
- This is attached to a slit lamp and projects a reduced Snellen's chart via narrow beam of light through a pinhole clear area in the cataract towards the macular region.
- The resulting potential acuity is the smallest line where the patient was able to read three characters.

LIMITATION

- Subjective
- Methods that require an alert and cooperative patient and skilled compassionate examiner.
- But it is easier than laser interferometry.

ENTOPIC PHENOMENA

- It is referred to visual perceptions that have their origin in the structure of an observer's eye.
- Three types are used for testing the macula in opaque media:
- 1. PURKINJE VASCULAR E.P
- 2. Flying spot(blue field entoptic phenomenon)
- 3. Haidinger’s Brushes

PURKINJE VASCULAR E.P

- This test is based on the ability to appreciate the retinal vasculature and can even be performed with a pen torch at the bed side.
- First described by Goldmann who used a vertical light source 7mm away from limbus. Goldmann et al reported that the appearance of Purkinje vessel shadows is shown to give post operative visual acuity of 6/12.

PRINCIPLE

- This is a subjective test to assess the function of retina.
- A rapidly oscillating point source of light when directed over the closed lid stimulates perception of purkinje vascular tree.
- Due to rapid movement of light source the shadow of retinal vasculature falls on photoreceptors and can be appreciated as receptors fail to adapt rapidly.

TECHNIQUE

- This test is useful in comparing two eyes of one patient.
- The involved eye with opaque media is compared with assumed normal eye.
- The patient’s ability to detect shadow images of the retinal vasculature provides a rough indication of attached retina.

BLUE LIGHT ENTOPTOSCOPY

- **Principle:**
- This test is more specific for macular function and is based on the ability of the patient to observe the flow of white blood cells in the parafoveal capillaries which appears as shadows.
- Blue light is absorbed by Red blood cells but not the white blood cells.

TECHNIQUE

- 1) The patient is asked to view an intense, homogenous blue light background
- 2) If the patient sees shadows macular function is probably intact.
- This test has a limitation as it requires special apparatus and patients find the instructions difficult to comprehend hence rarely used.

THANK YOU..