Glaucoma and the Optic Nerve

Naida Jakirlic, OD, FAAO
Western University of Health Sciences
College of Optometry

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Learning objectives

- Review the anatomy of the optic nerve
- Recognize the appearance of the healthy optic nerve
- Ascertain the critical components of optic nerve assessment
- Identify possible glaucomatous changes of the optic nerve, peripapillary region, and RNFL
- Identify the cardinal features of glaucomatous optic neuropathy
- Analyze optic nerve images to solidify today's discussion

What is glaucoma?

- A *progressive optic nerve disease* characterized by *retinal ganglion cell death* and resultant *axon loss* seen as *excavation of the optic nerve* head with consequent defects in retinal sensitivity that can be measured with visual field tests

What is glaucoma?

- Optic neuropathy
- Axon loss
- Excavation of the optic nerve
- Resultant VF defects

Glaucomatous damage may be due to

- Elevated IOP
- Poor perfusion pressure to the ONH
- Obstruction of axoplasmic flow within the ganglion cell axons
- Anatomic weakening of the lamina cribrosa
  - Myopia
  - Optic nerve pits
- Programmed cell death of the ganglion cell axons (apoptosis)

Pre-perimetric glaucoma?

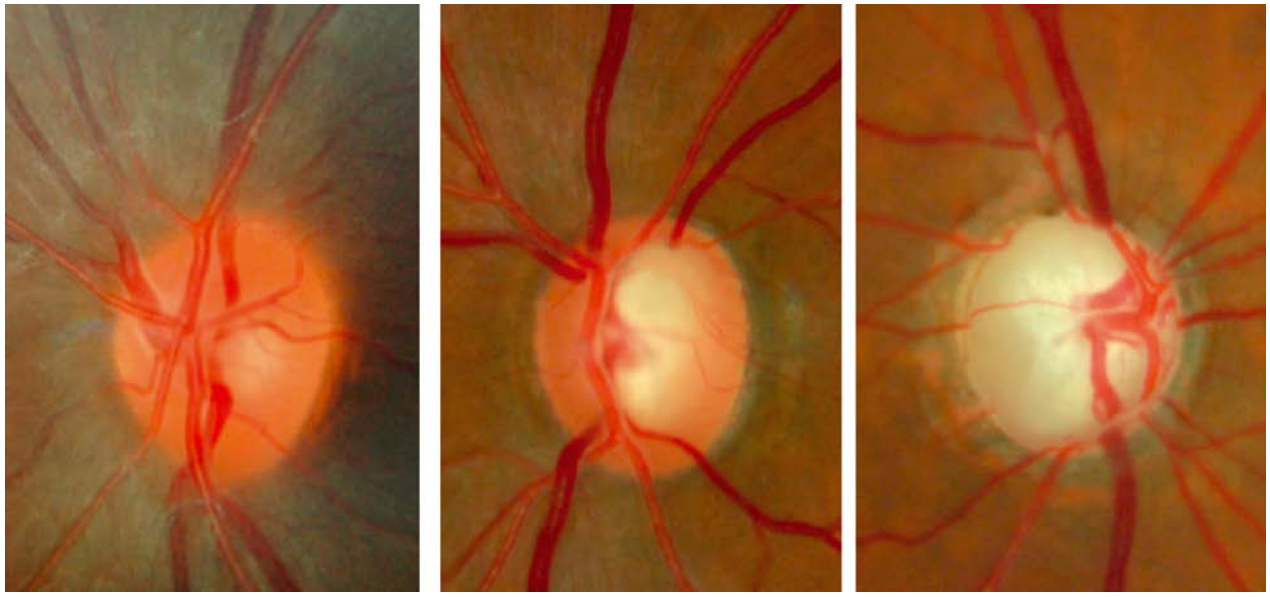
20-40% of ganglion cells are lost before VF defects are detected on standard automated perimetry

So what?

Assessment of the ONH is *critical* for early diagnosis and management to prevent VF defects *before* they occur

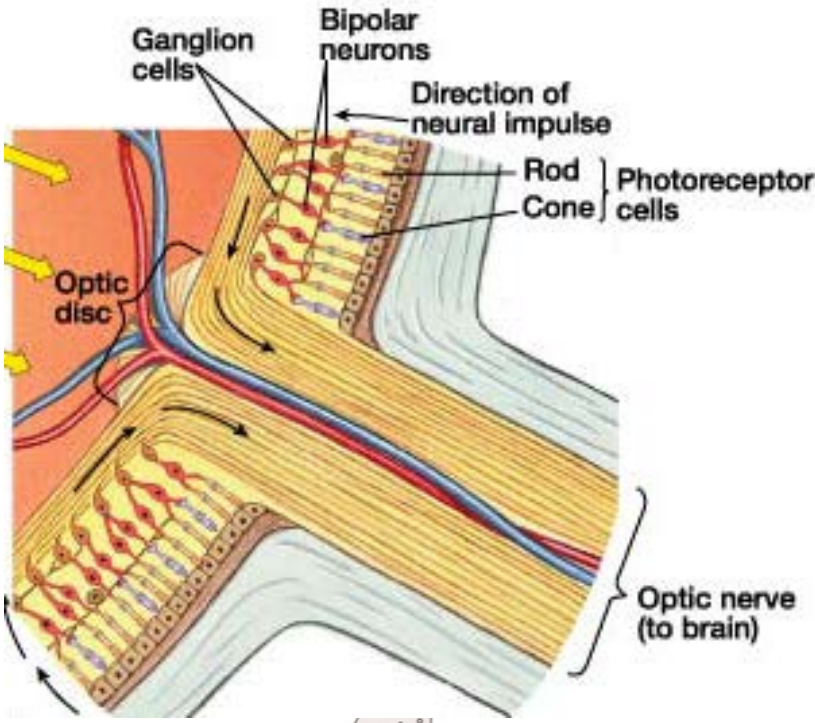
Optic Nerve Head (ONH)

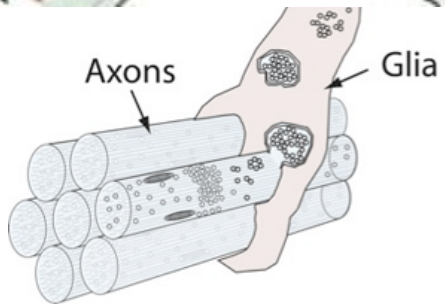
- Careful evaluation of the ONH has high specificity and good precision for glaucoma diagnosis
- It is one of the most important aspects of glaucoma assessment



Anatomy of the optic nerve

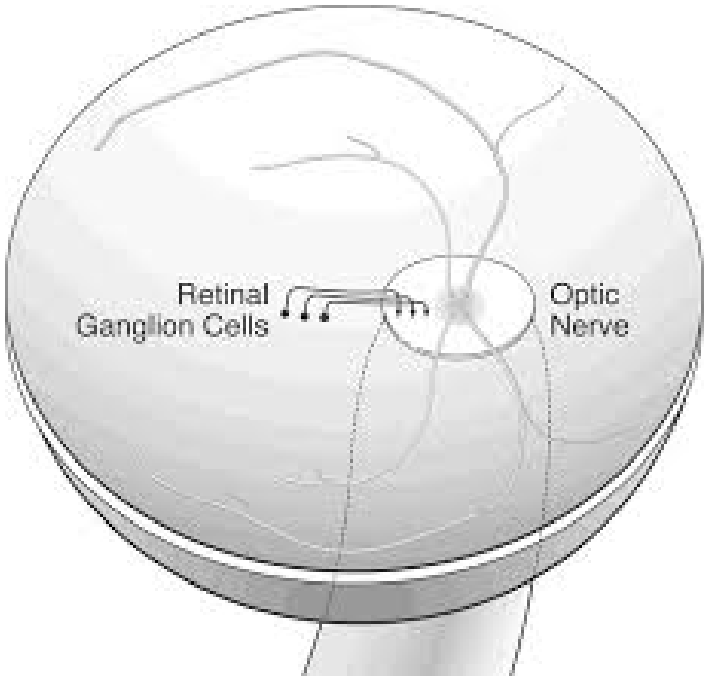
- Ganglion cell axons make up 90% of neuroretinal rim tissue of the optic disc
  - 1-1.5 million axons leave via the ONH through the scleral canal
  - Grouped into bundles by glial cells
- Remainder of neuroretinal rim is composed of capillaries and astrocytes
- Axons in superior and inferior poles have less structural support

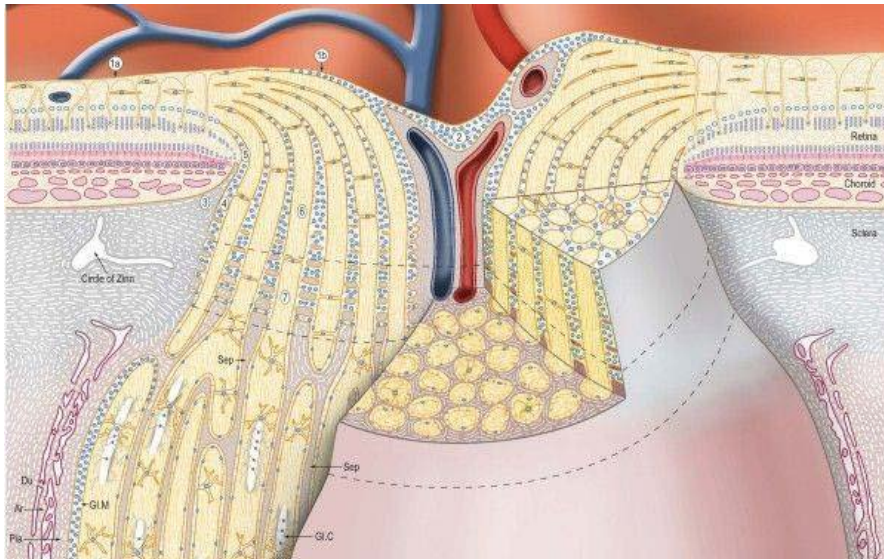




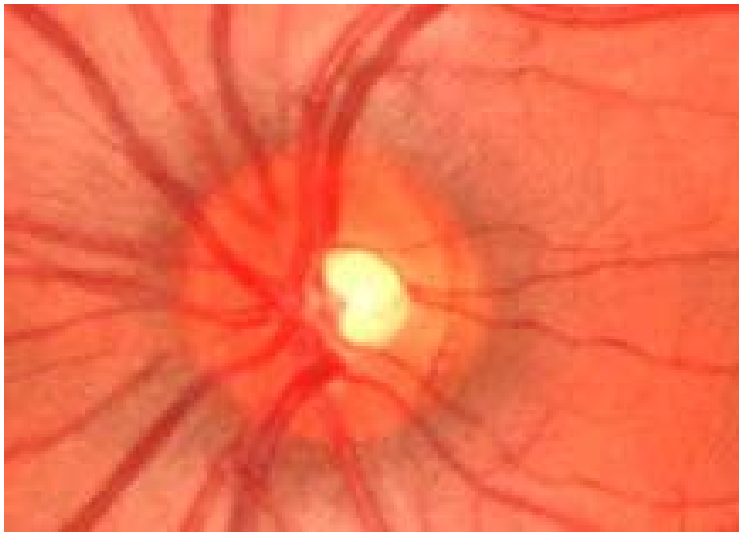
Anatomy of the ONH

- Four distinct layers of the ONH
  - Surface layer
  - Prelaminar ONH
  - Laminar ONH
  - Retrolaminar ONH

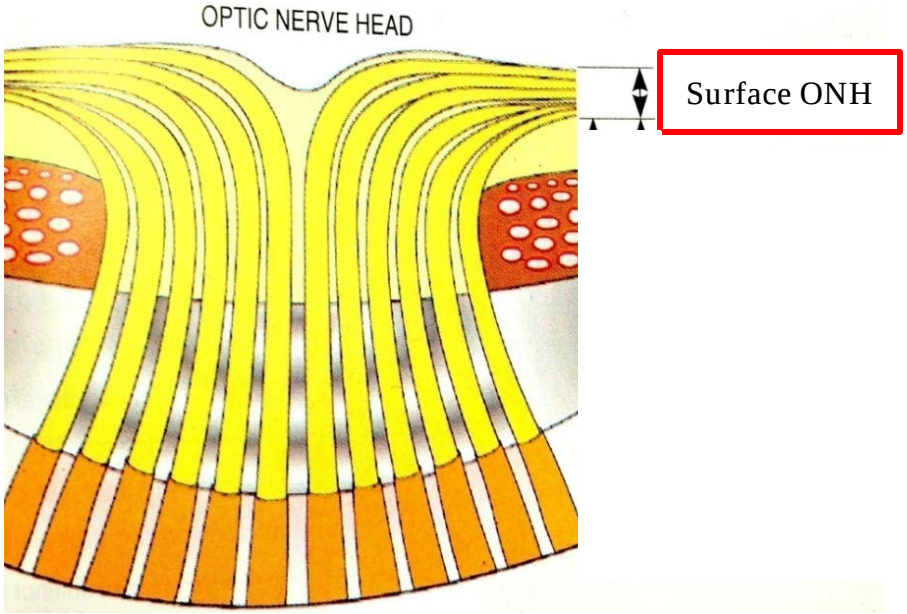




Anatomy of the ONH

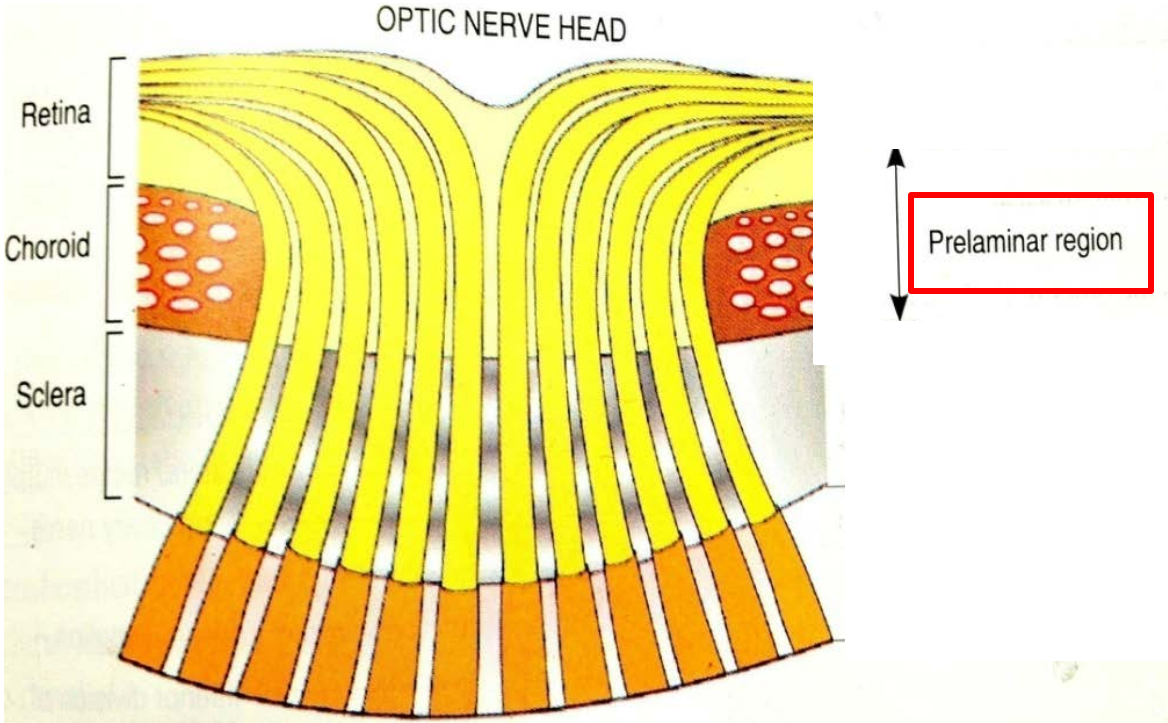


- **Surface layer**
  - Anterior limit of the ONH
  - Point of contact with the vitreous
  - Peripheral edge is defined by anterior limits of the scleral ring
  - Posterior limit: axonal bundles have completed 90 degree turn from the plane of the retina and reached the level of the choroid



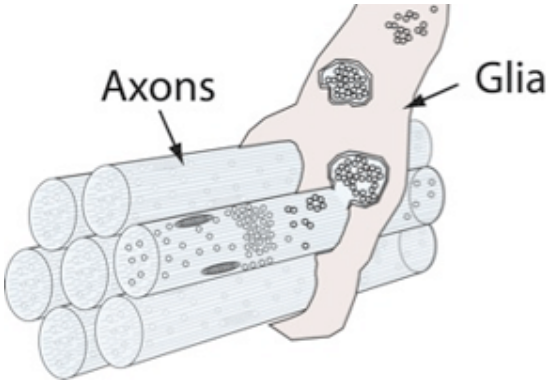
Anatomy of the ONH

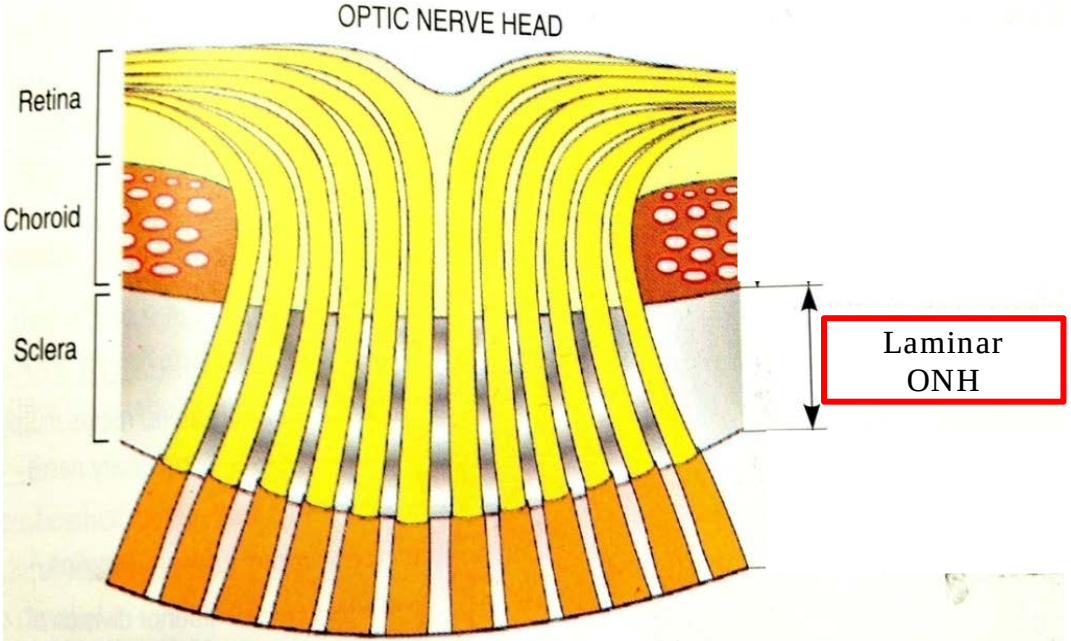
- **Prelaminar ONH**
  - Indistinct segment of axons surrounded by outer retina, choriocapillaris, and choroid



Anatomy of the ONH

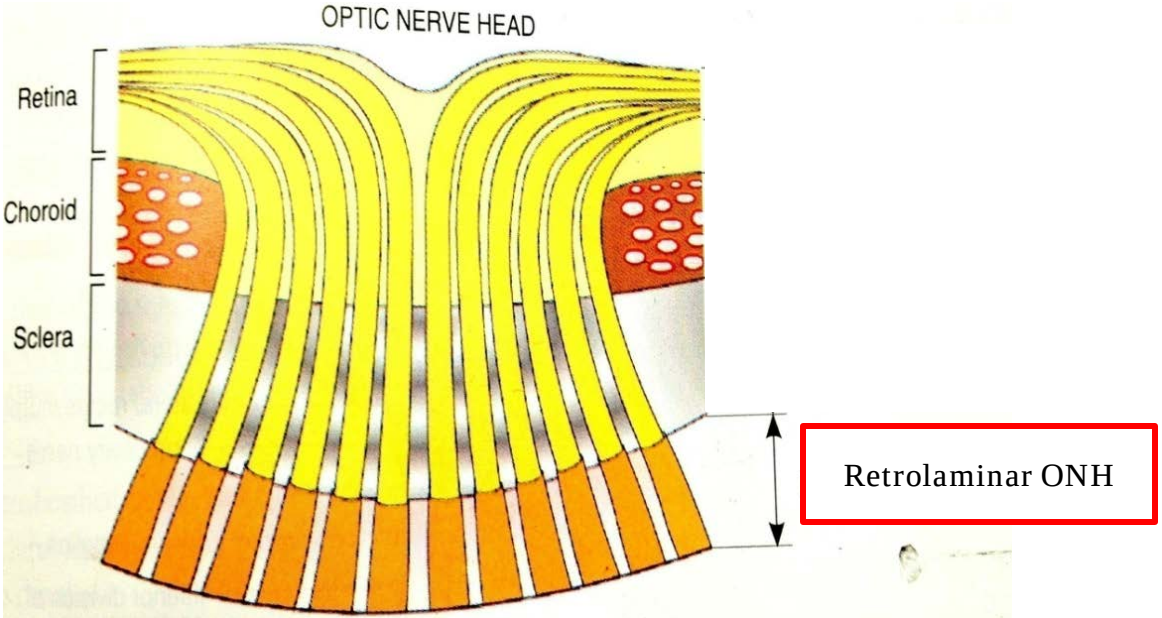
- **Laminar ONH**
  - Ganglion cell axon bundles wrapped in glial cells and confined in rigid pores of the lamina cribrosa



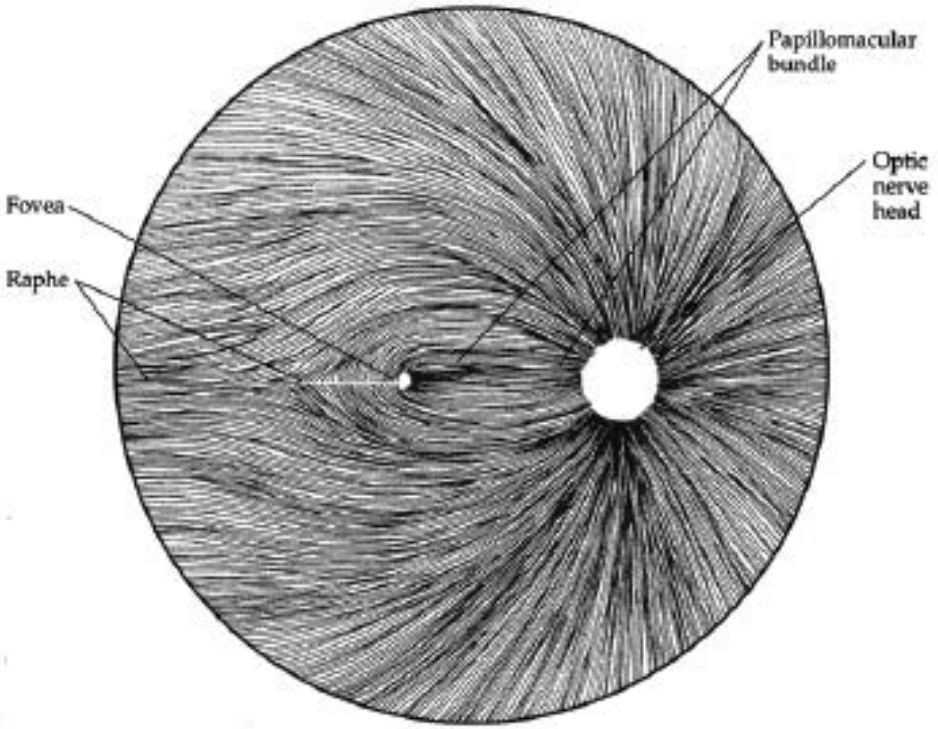


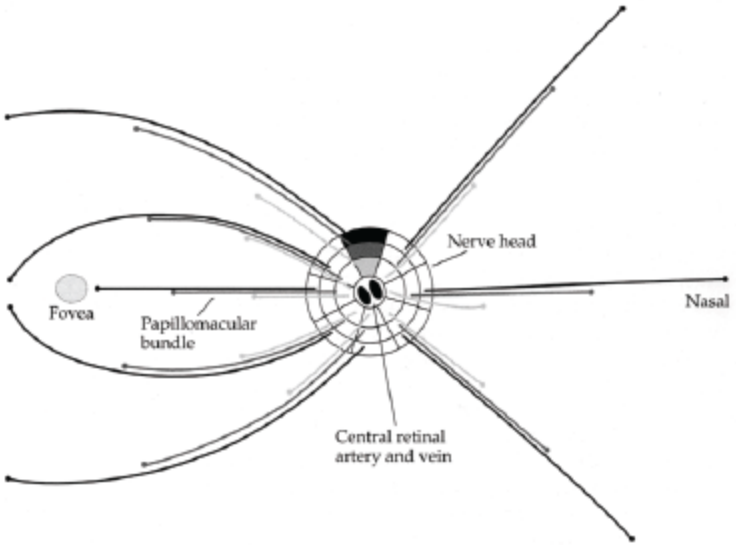
Anatomy of the ONH

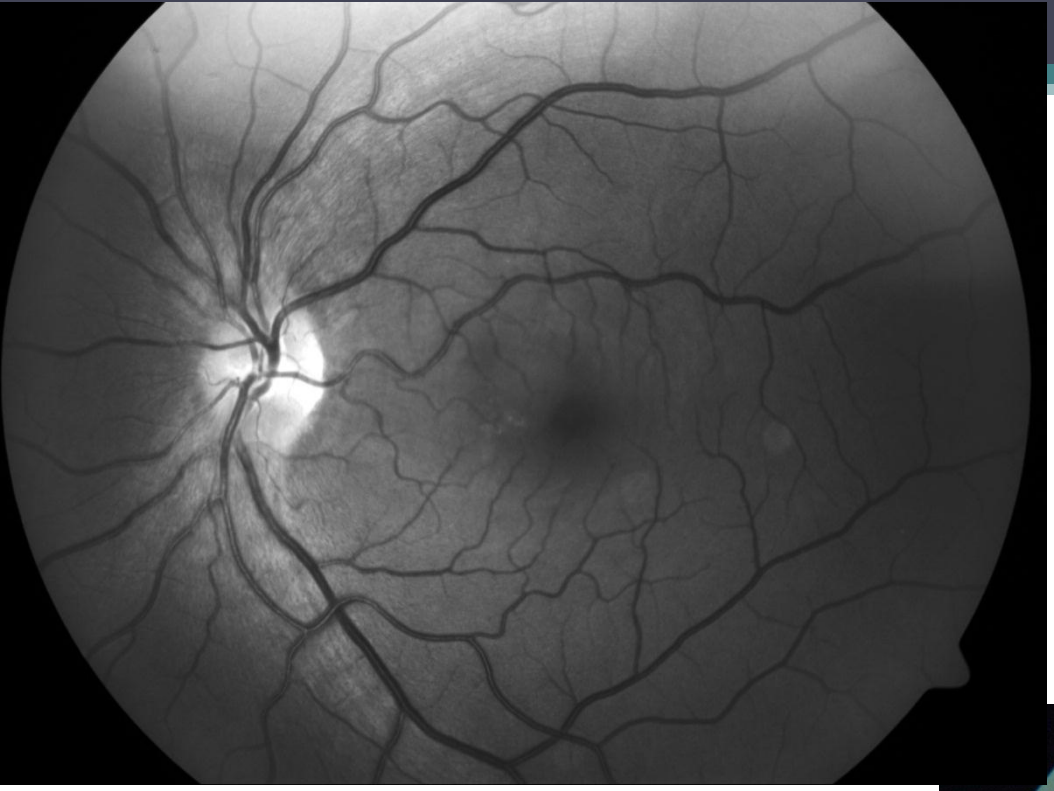
- **Retrolaminar ONH**
  - Posterior to lamina cribrosa
  - ONH thickness is doubled by presence of myelinating oligodendrocytes

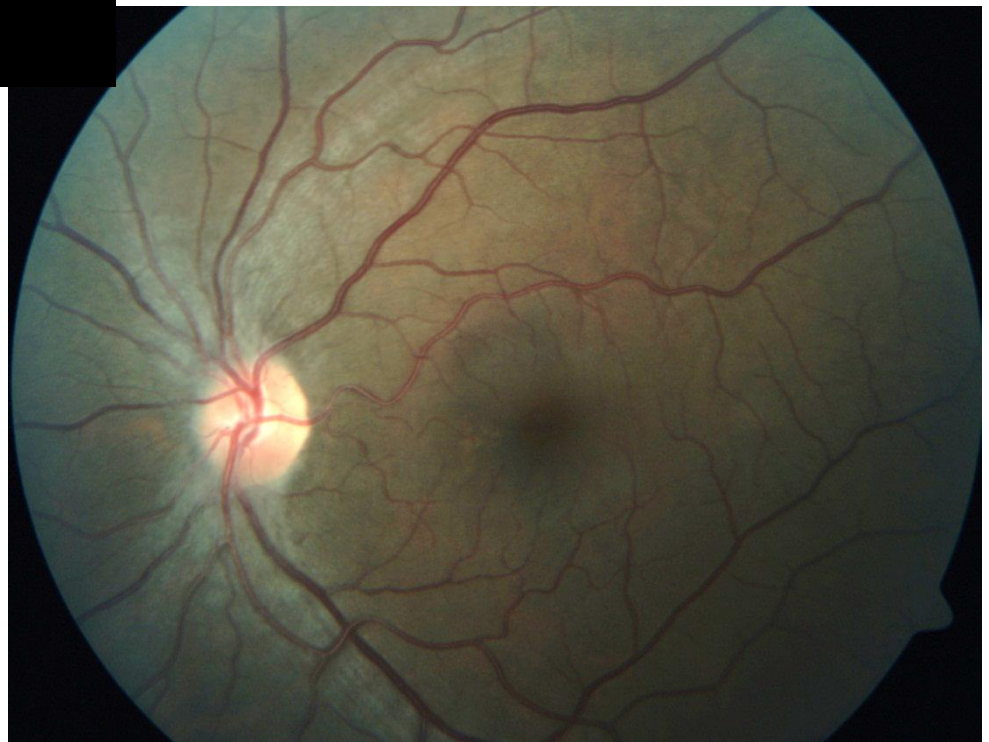


RNFL distribution





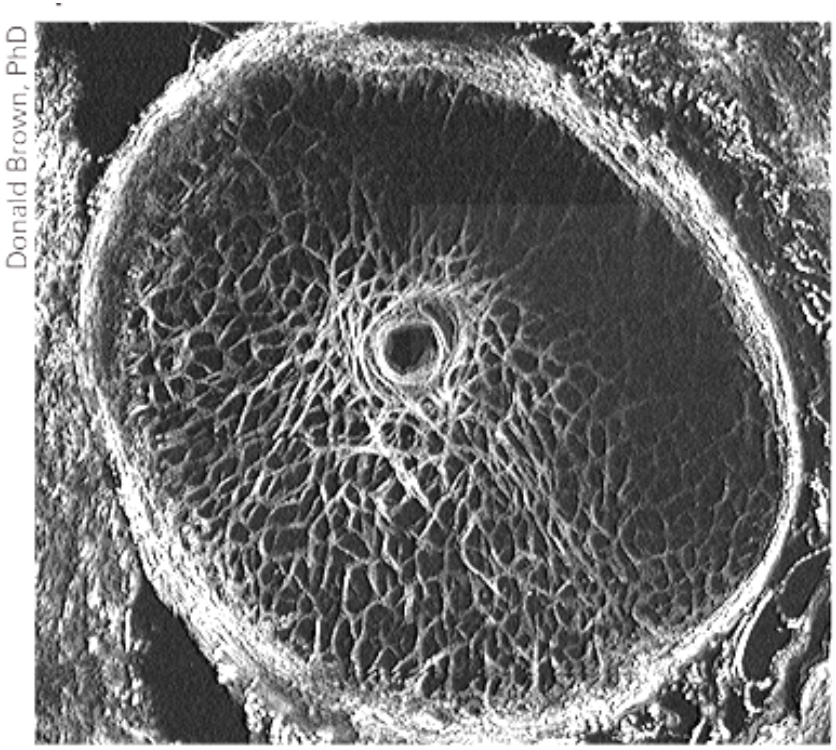


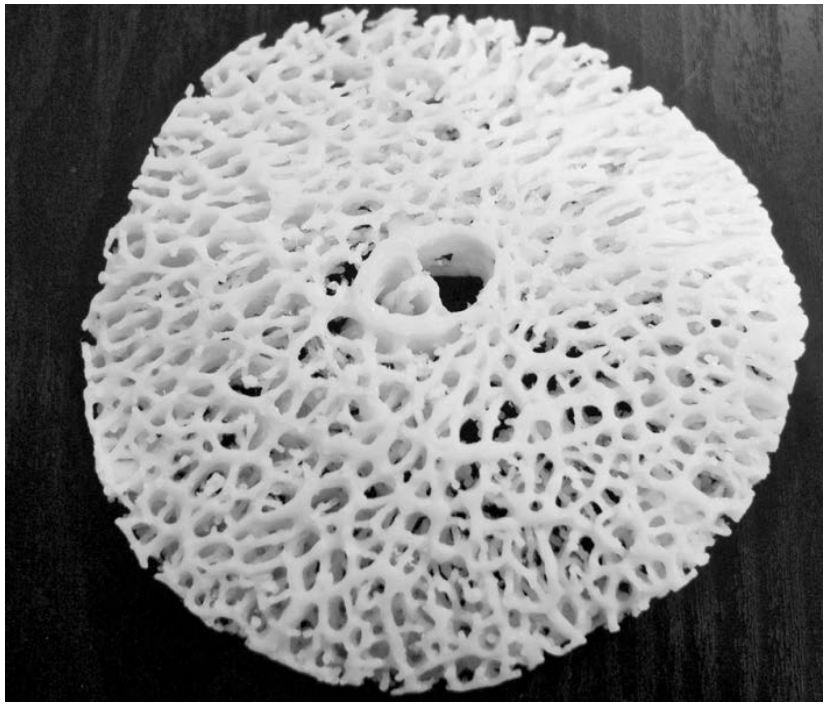


Lamina cribrosa

- Composed of several sheets of connective tissue
  - Fenestrated to allow passage of nerve fiber bundles carrying ganglion cell axons
- Variable number of pores: 200-600
  - Larger pores at superior and inferior poles - may provide less support than smaller fenestrations in nasal and temporal regions, resulting in greater damage to RGC axons in these areas
- Laminar dots become more exposed and numerous with progressive axon loss

Lamina Cribrosa

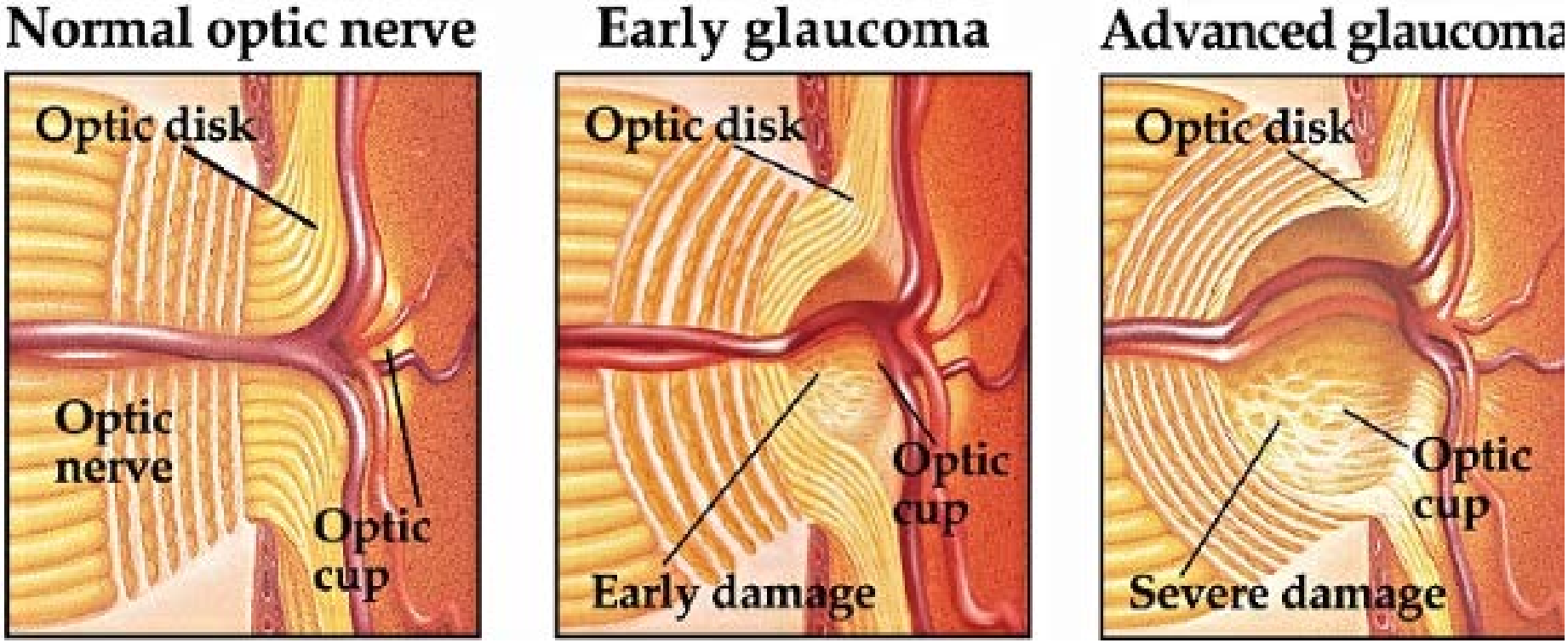


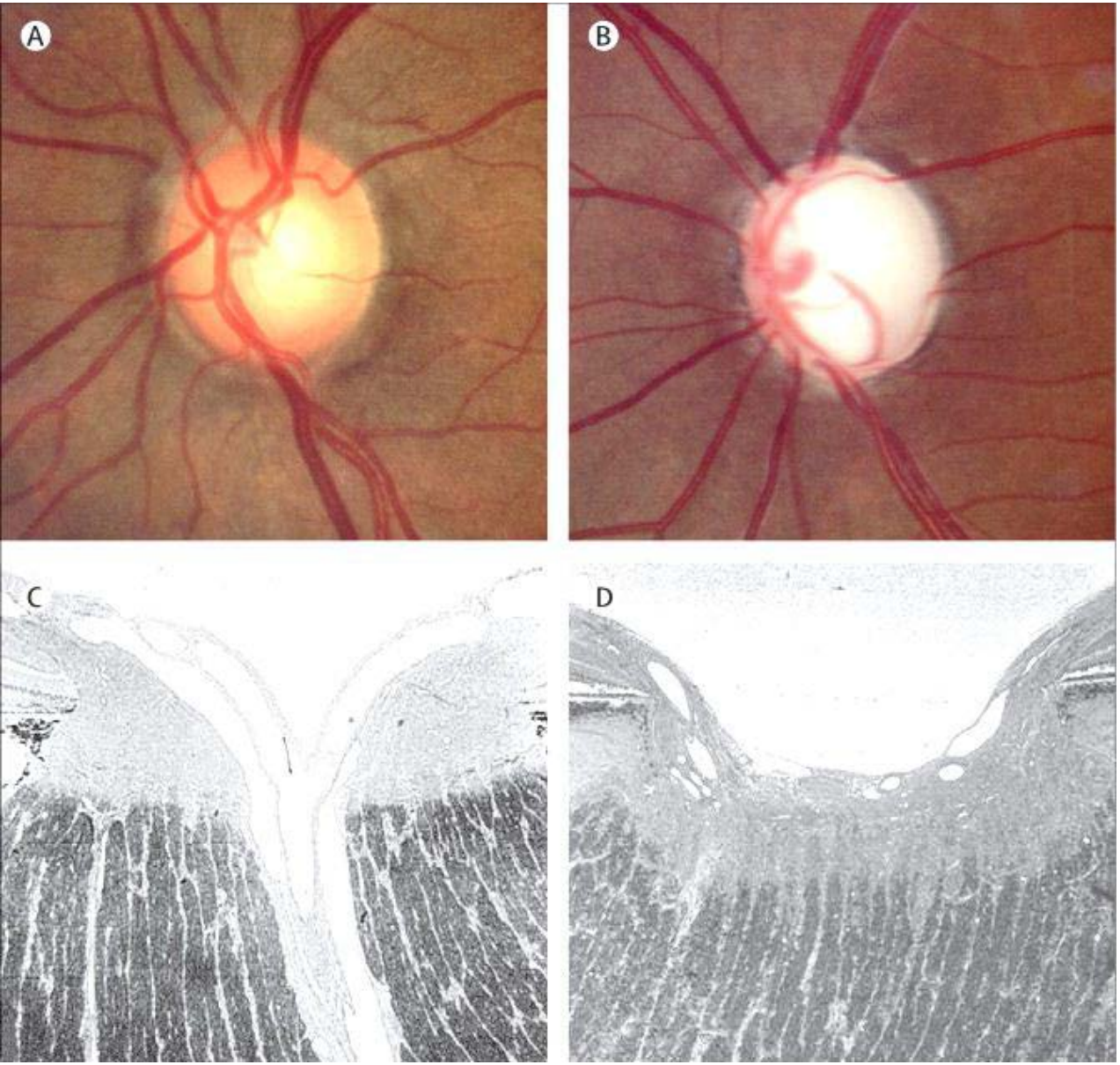


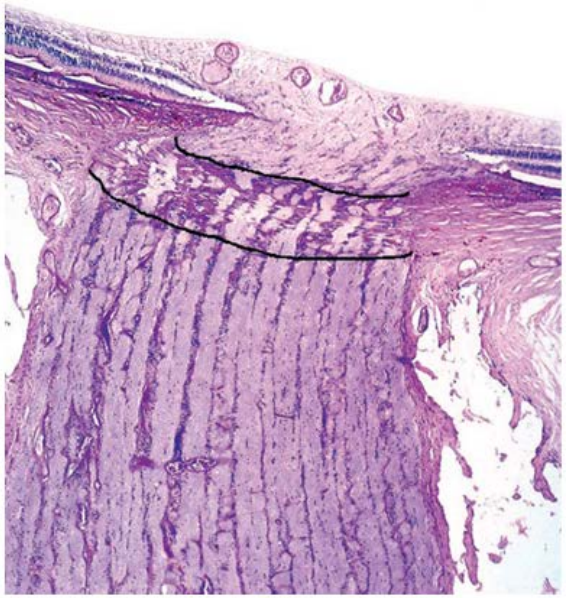
Changes in the lamina cribrosa

- Normally pores are obscured by nerve fibers
- As nerve fibers undergo atrophy, pores become more visible
  - AKA laminar dot sign
  - Can be present in healthy eyes
- Thinning and backward bowing of lamina cribrosa occurs with deepening of cup

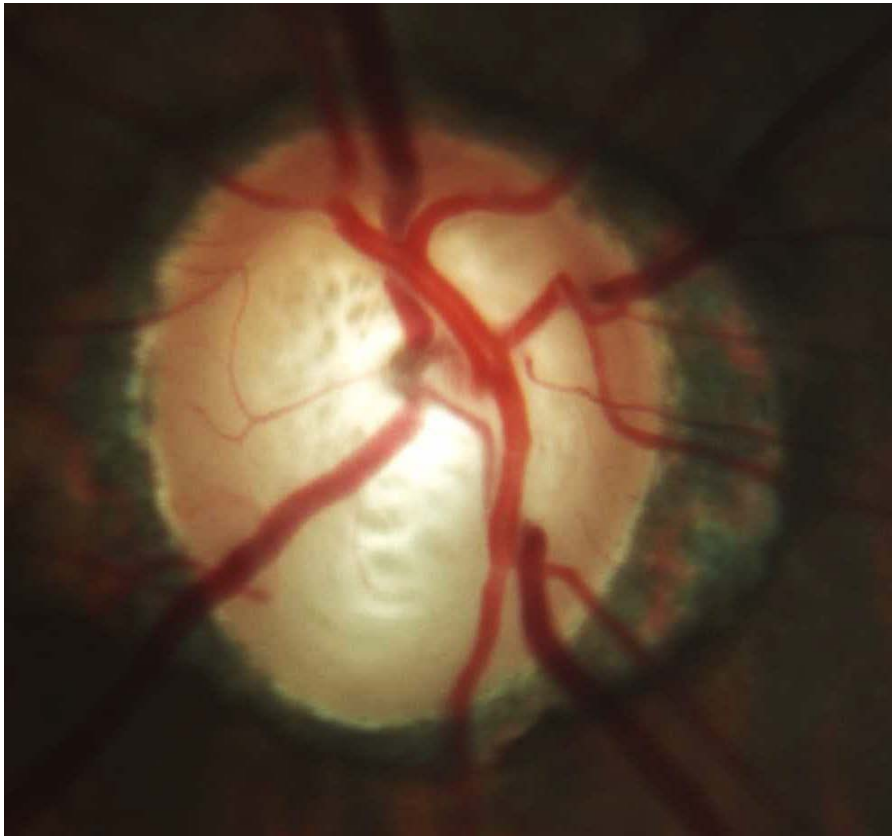
Thinning and backward bowing of LC




A
B
C
D

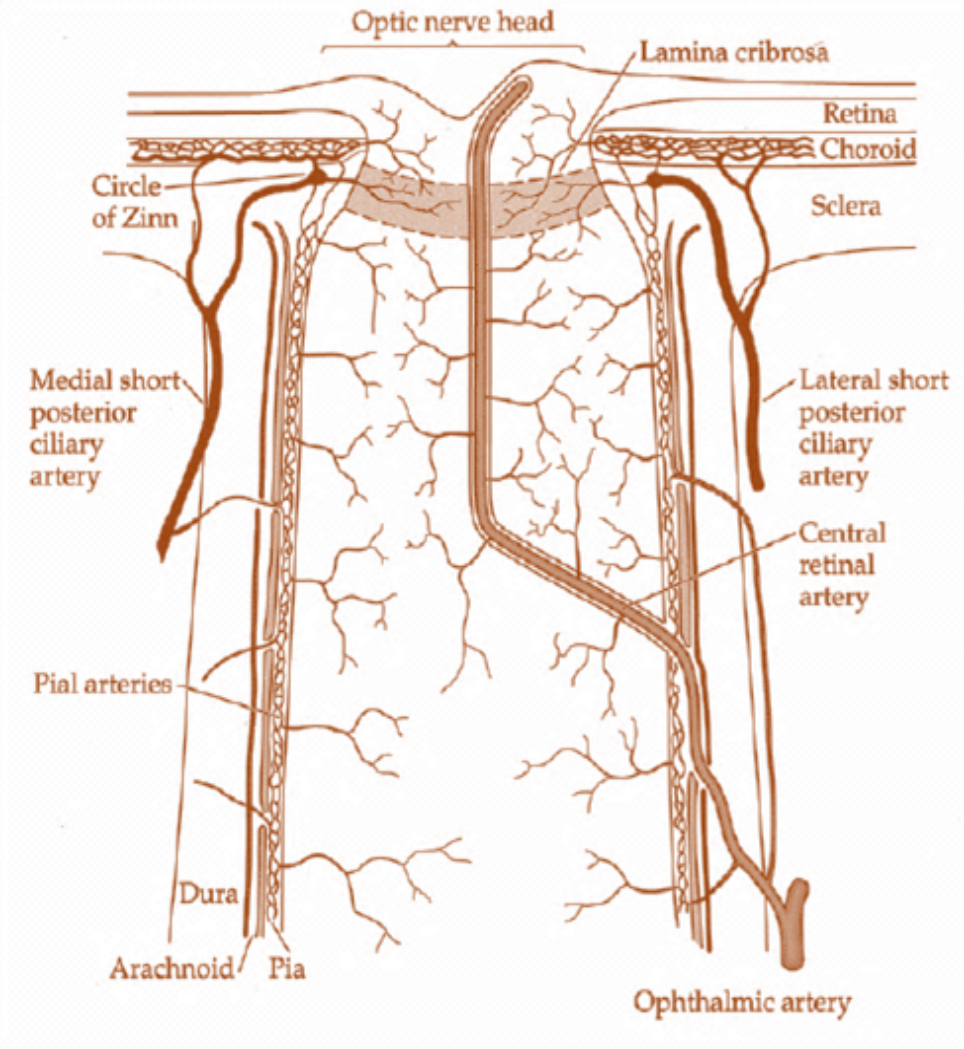


Laminar dot sign

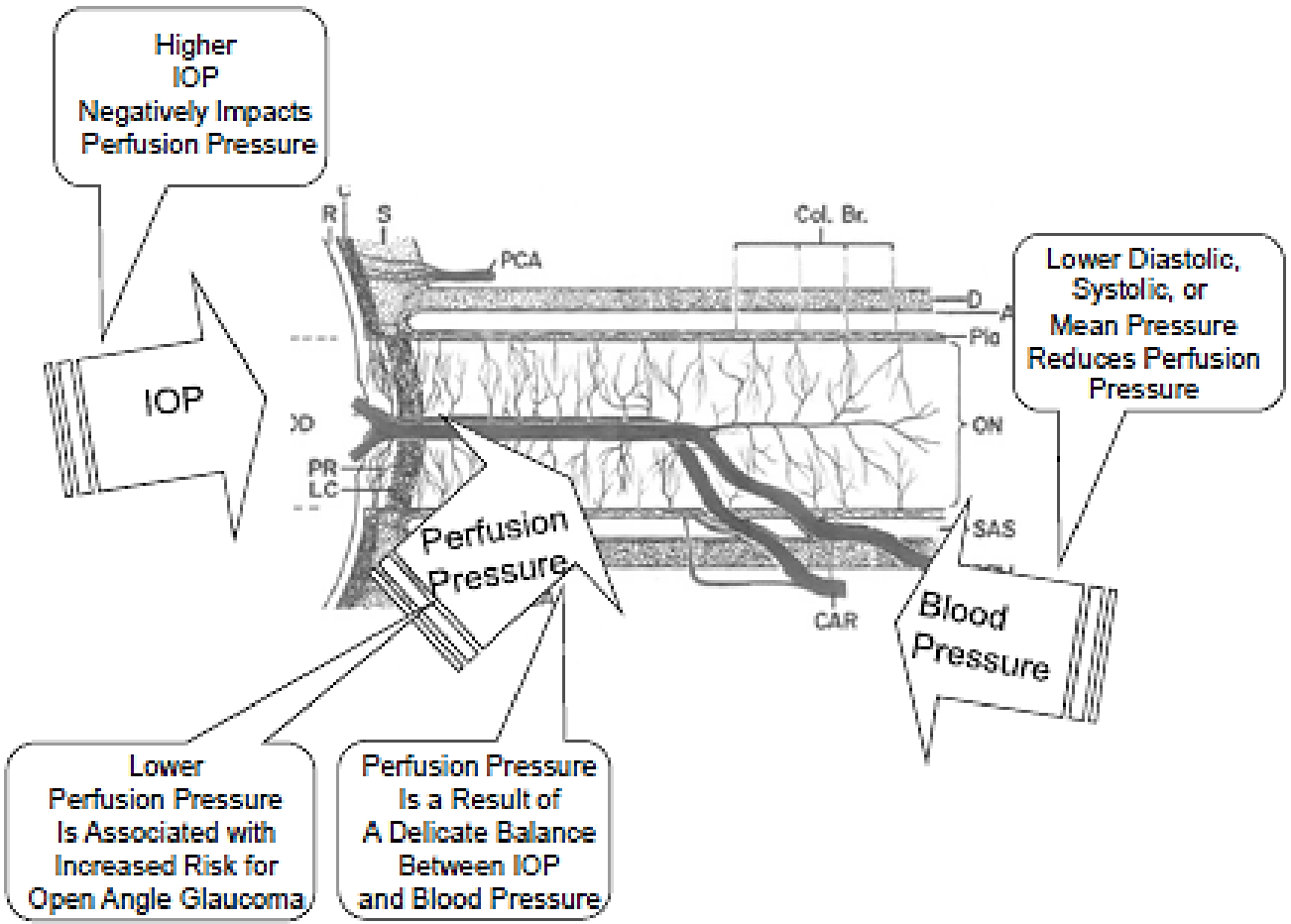


ONH Blood supply

- Superficial ONH
  - Branches from CRA
- Pre-laminar ONH
  - Short posterior ciliary arteries (SPCA)
- Laminar ONH
  - Circle of Zinn-Haller: anastomoses of adjacent SCPA's
- Retro-laminar ONH
  - SPCA
  - Pial vascular plexus
  - Axial vasculature from CRA

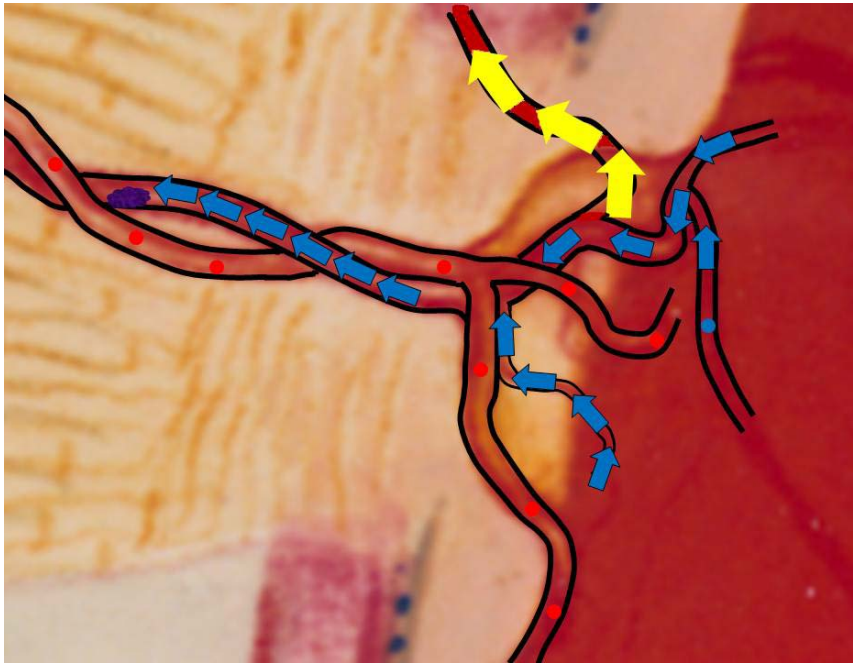


Ocular perfusion pressure



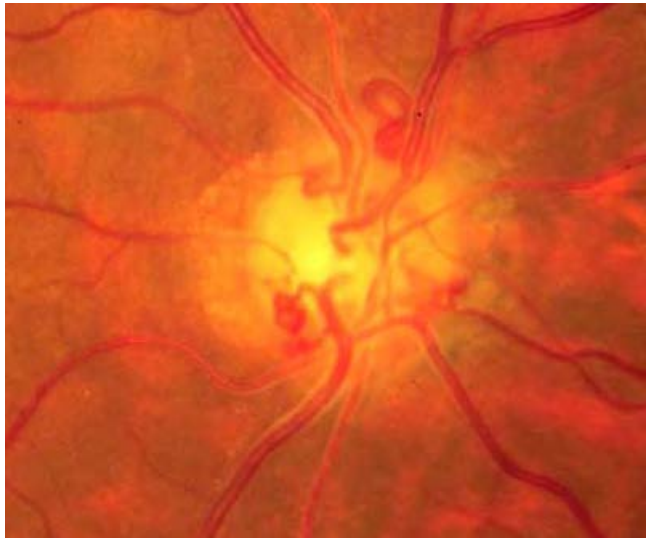
Venous drainage

- Via central retinal vein
- In chronic glaucoma, shunt vessels may appear due to disturbed retinal circulation
  - AKA optociliary shunt vessels
  - Pre-existing capillaries that become more visible as they dilate to re-route blood around an area of obstruction

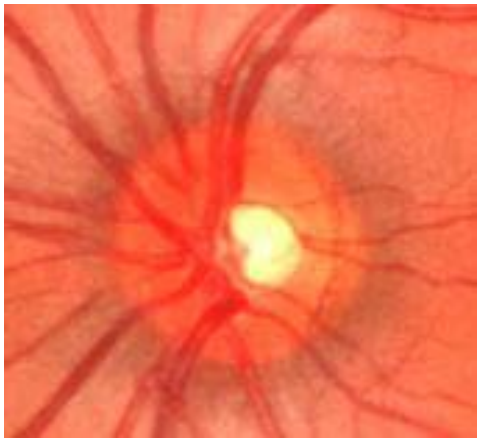


Optociliary shunt vessels

- Differential diangoses
  - CRVO
  - Optic nerve sheath meningioma
  - Chronic glaucoma
  - Chronic papilledema
- Different from neovascularization of the disc
  - Do not leak on FA



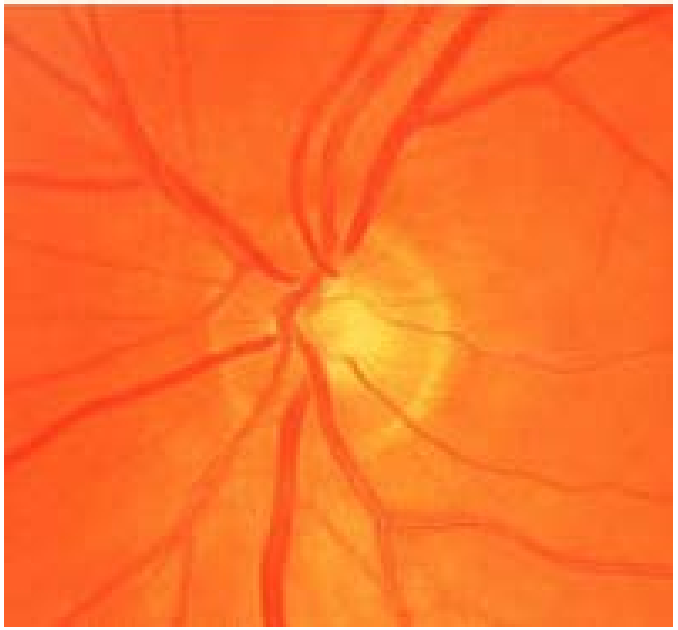
Optic cup

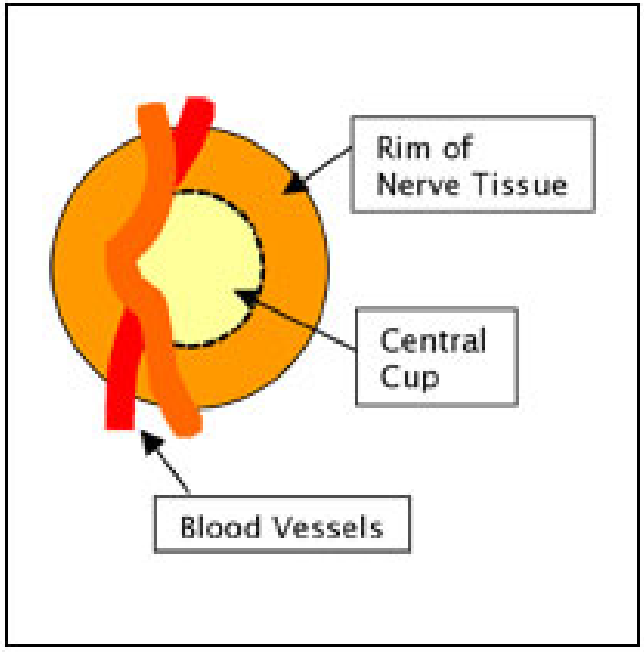


- Central excavation in the ONH
- Devoid of axons and capillaries
  - Pale due to visibility of collagenous lamina cribrosa
  - Size is dependent on number of nerve fibers leaving the eye and the size of the scleral canal
- Cup depth usually depends on cup size
  - Small cup = shallow
  - Large cup = deep

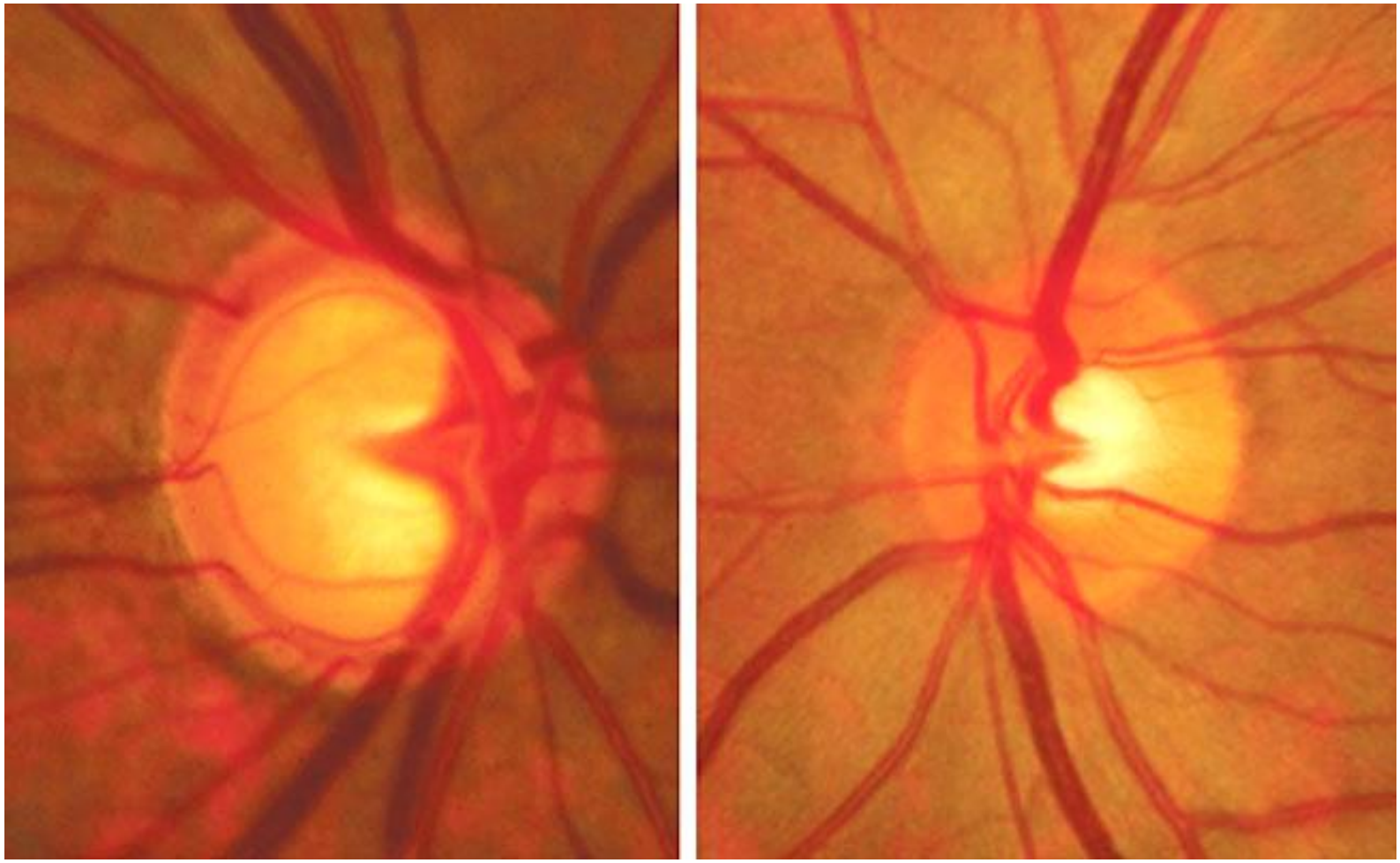
Optic cup

- High inter-individual variability
- Lies below the level of the neural rim
- Bottom is formed by the LC
- Border between cup and rim is determined by contour, not the color
  - Point of deviation of vessels on the surface of the ONH
  - Area of pallor of the cup usually corresponds to the borders of the cup

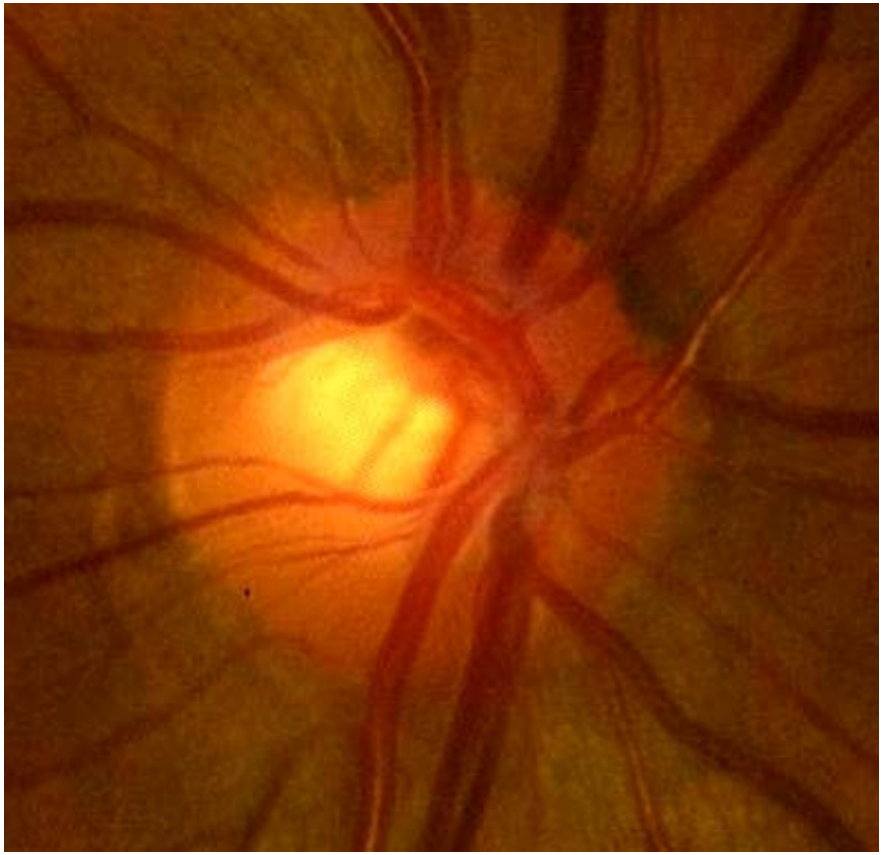




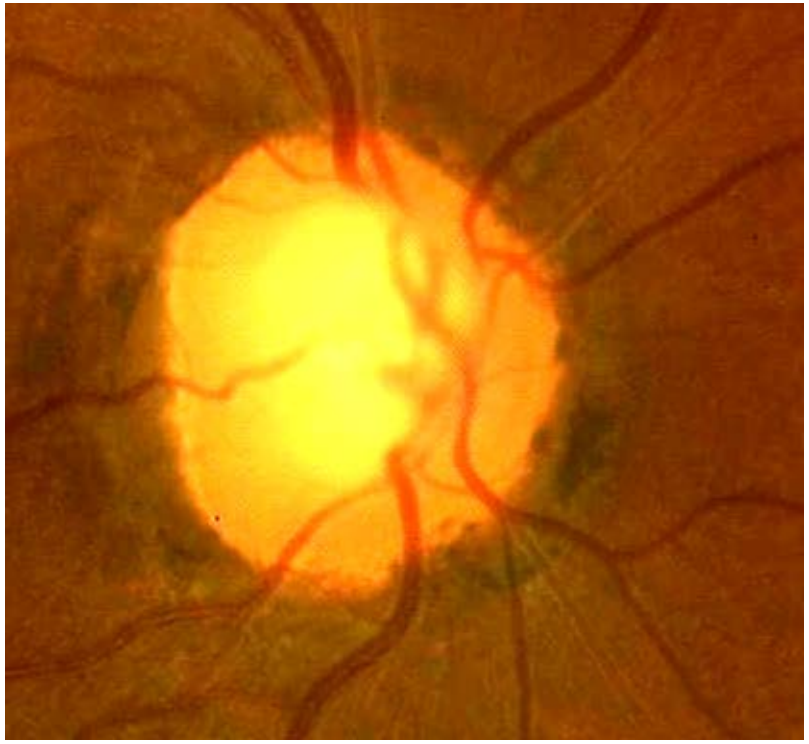
Contour vs. color

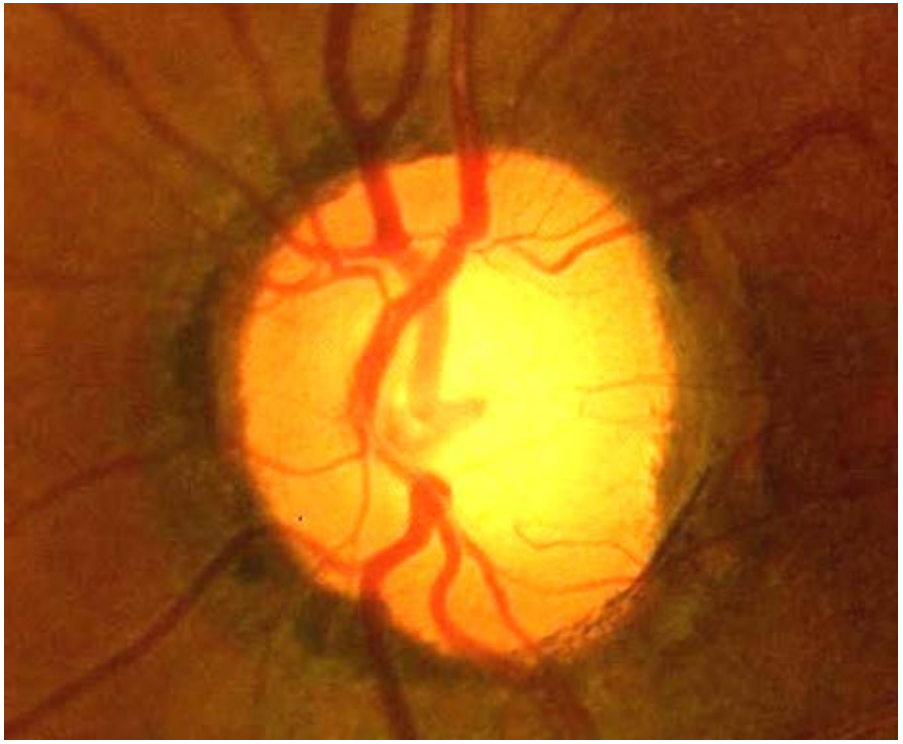


Contour < color



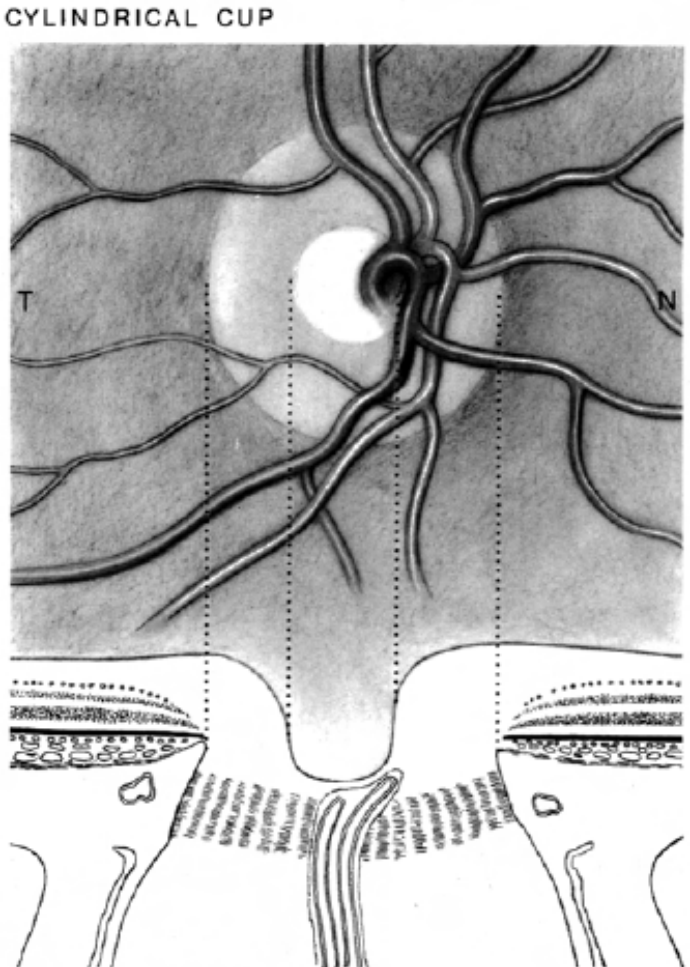
Contour = color





Contour vs. color

Optic cup variants



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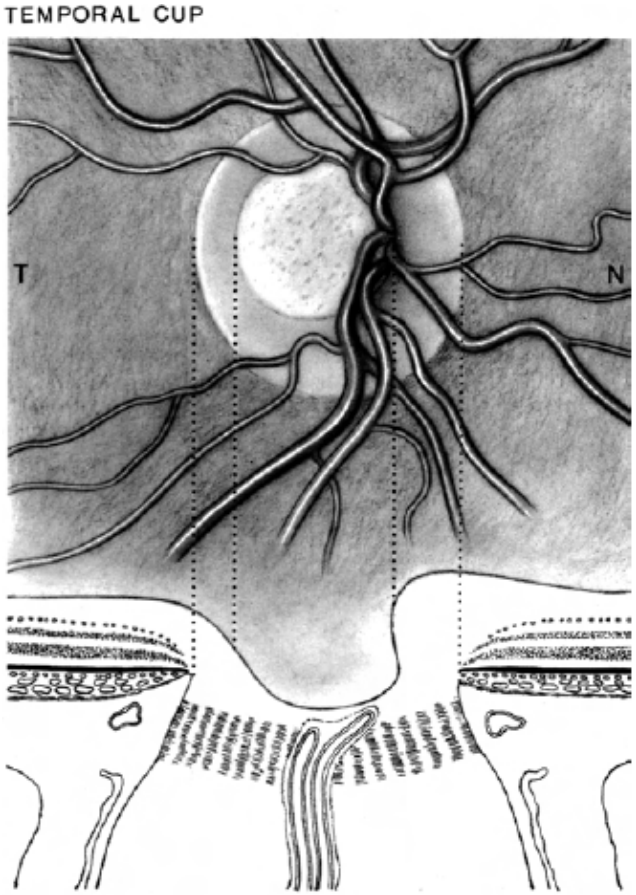

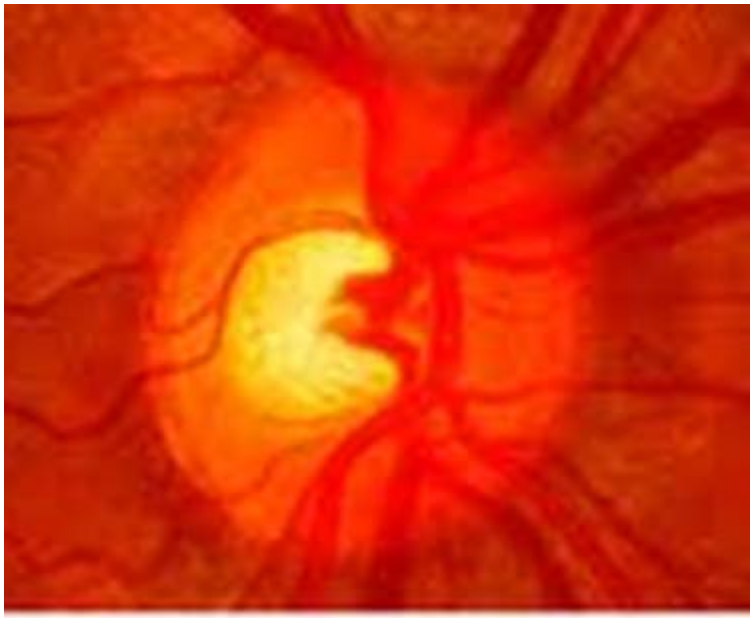

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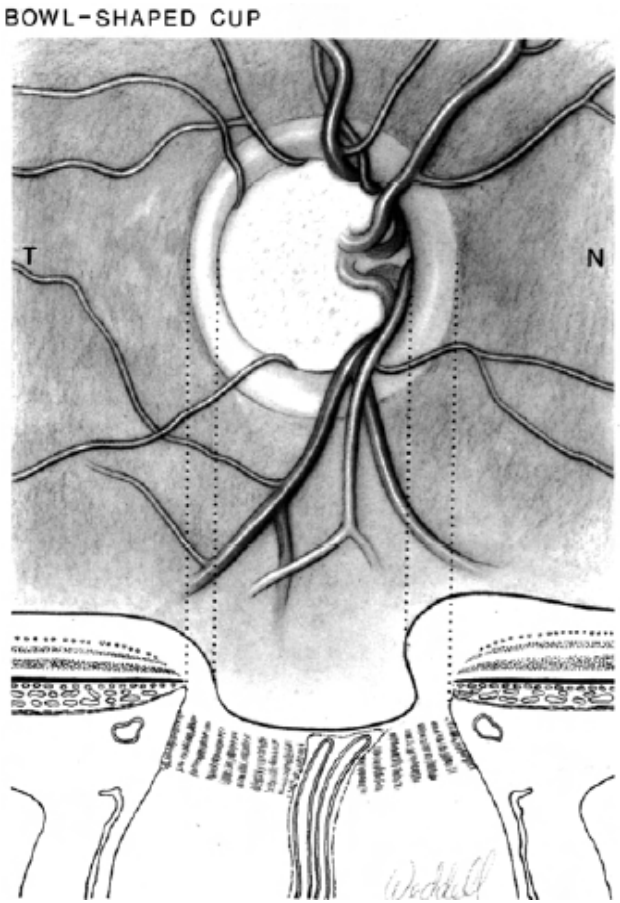
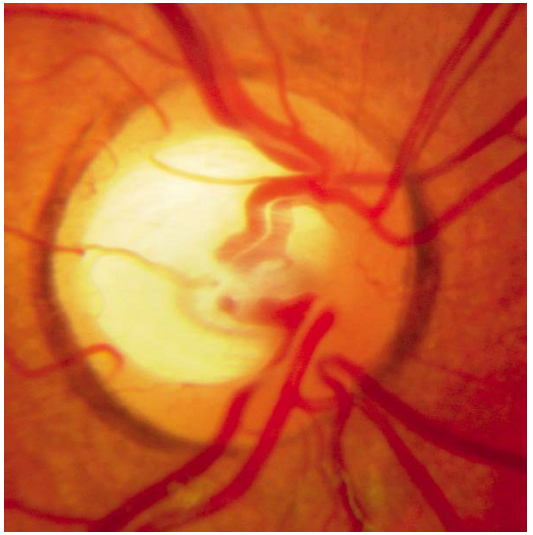


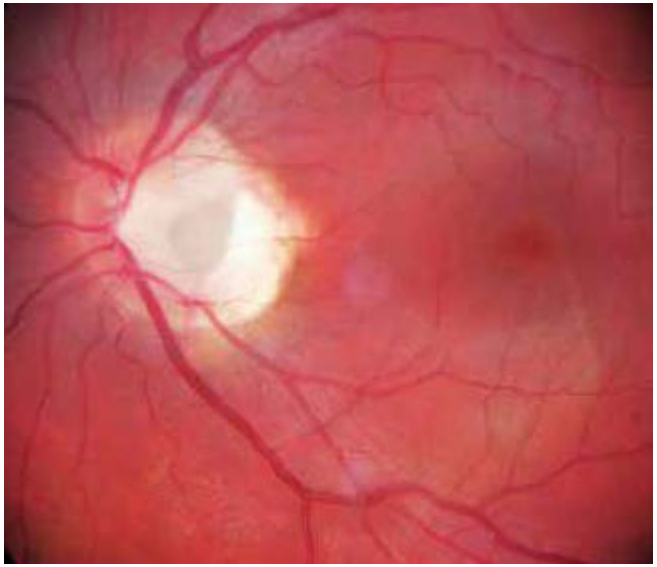


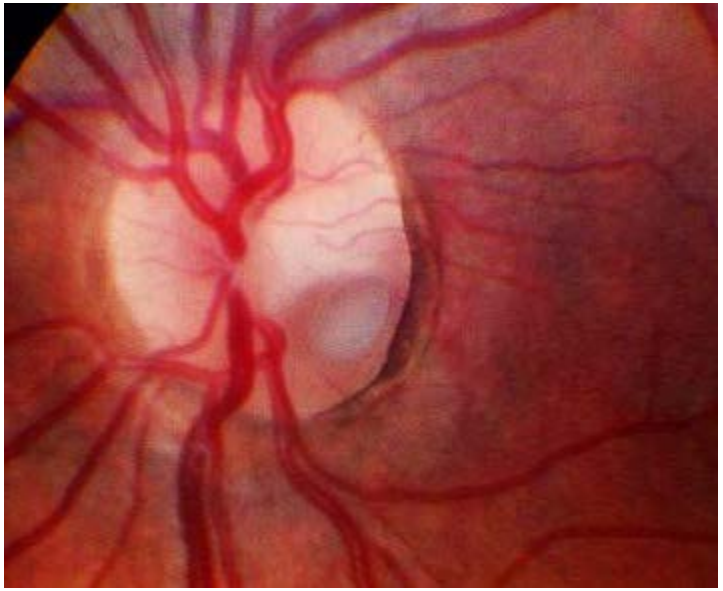
Changes in the optic cup

- Increased size
- Increased depth
- Visualization/increase in laminar dots
- Vertical enlargement
  - Localized neuroretinal rim loss at superior and inferior poles
- Asymmetry between two eyes greater than 0.2
  - In the absence of disc size asymmetry

Optic pit

- Localized weakening in the lamina cribrosa
- Usually located infero-temporally
- More prevalent in NTG
- Will have a corresponding but stable VF defect



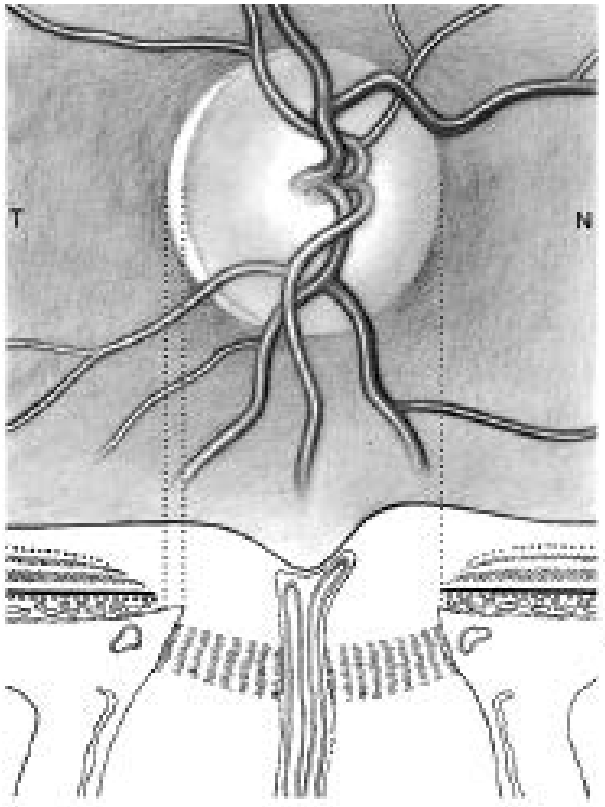


Neuroretinal rim

- Point of exit of nerve fiber bundles from the eye through the scleral canal
- Healthy rim tissue should be pink due to presence of pre-laminar capillaries
- May be difficult to assess in high myopes, patients with tilted discs, and nerves with significant pallor

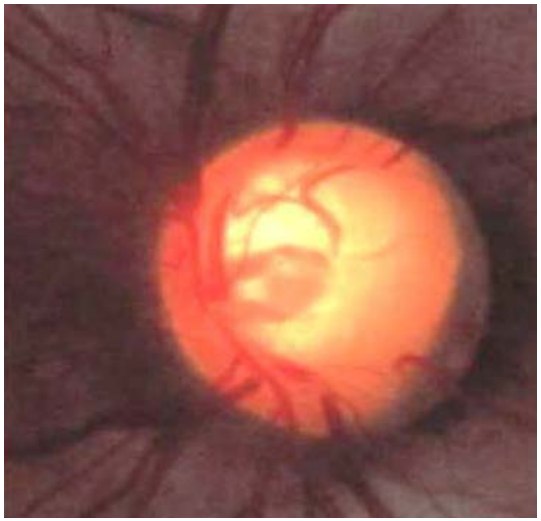
Peripapillary area

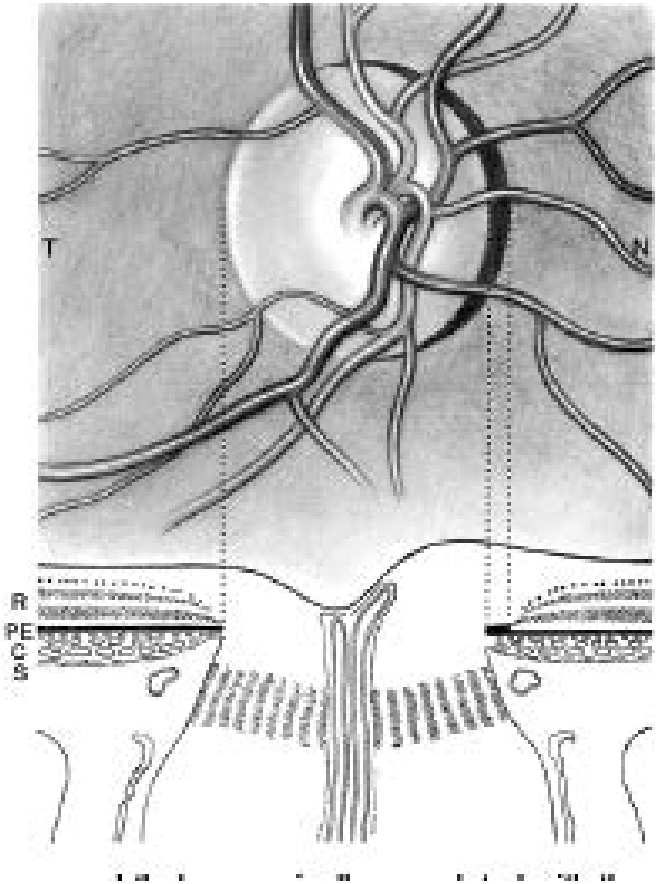
- Elschnig's scleral ring
  - Thin white ring outside of disc margin
  - AKA scleral lip
  - Anterior extension of sclera between the choroid and the optic nerve – RPE and choroid stop short of the disc



Peripapillary area

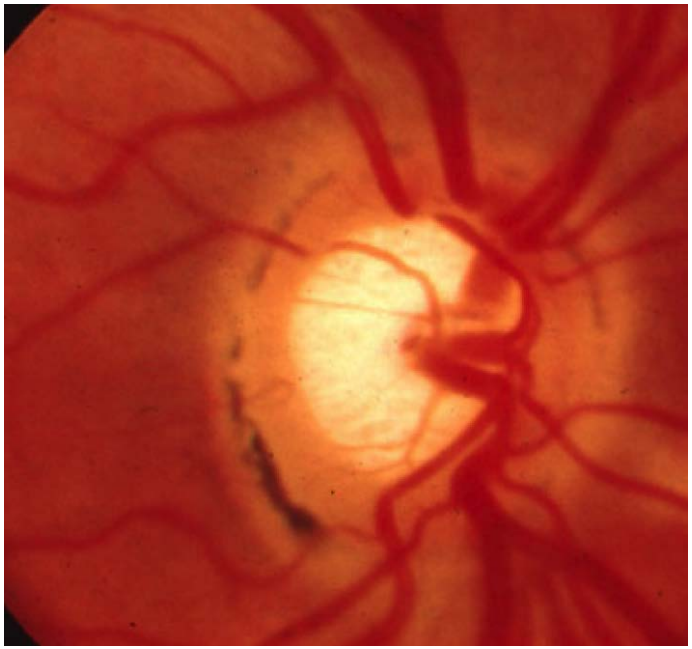
- Choroidal crescent
  - RPE stops short of the disc
  - Underlying choroid visible
  - Usually slate-gray in color





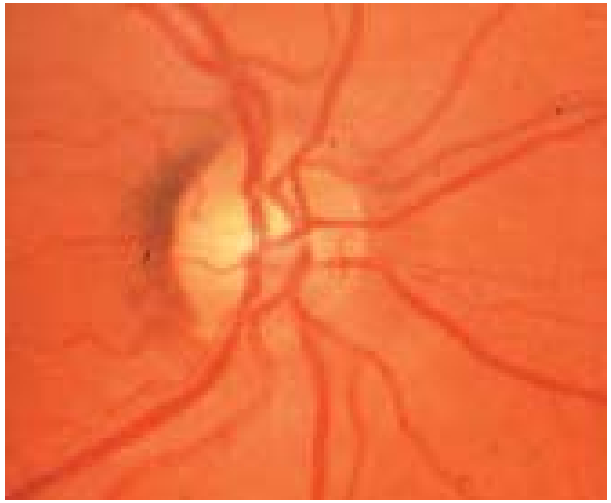
Peripapillary area

- Peripapillary RPE hypertrophy
  - Darker than choroidal crescent
  - Increased amount of peripapillary RPE pigment
  - Normal variant



Peripapillary area

- Grey crescent: located within scleral lip on the neuroretinal rim
  - Caution: may lead to false interpretation of neuroretinal rim – may be interpreted as thinner than it truly is
  - May be pigmentation within the neural tissue cells – melanocytes, RPE cells, or free pigment granules
  - Normal finding



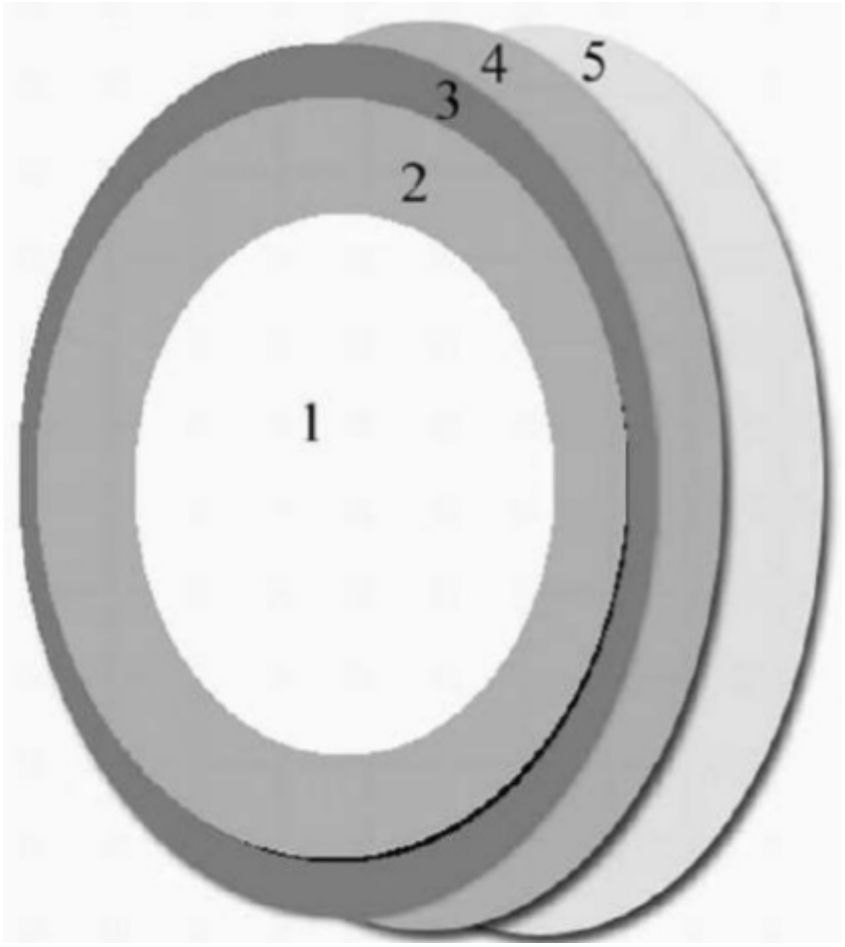
vs.

Peripapillary area

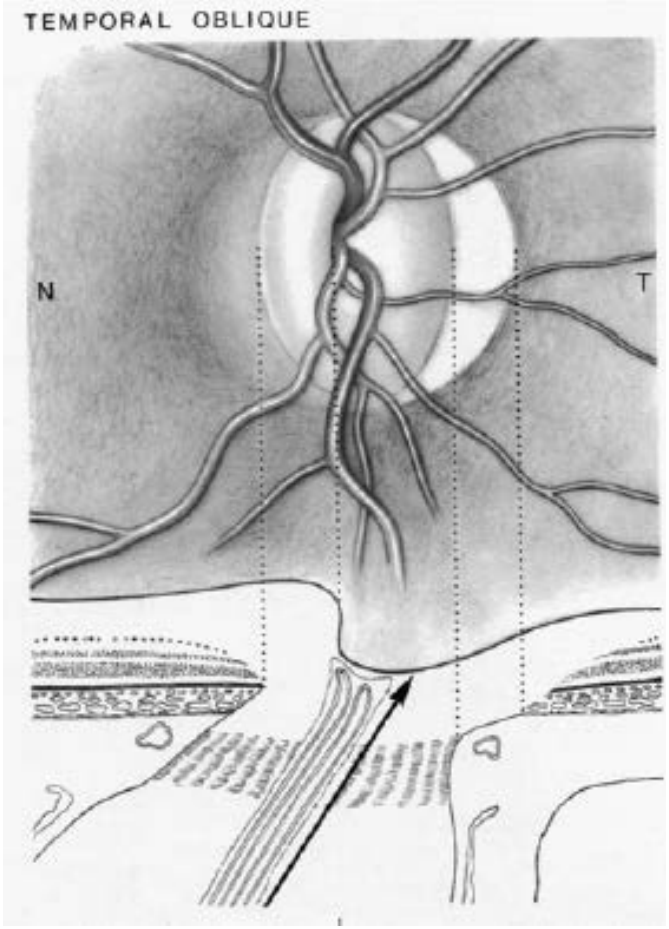
- Zone alpha
  - Found in normals
- Zone beta
  - More common in glaucoma patients

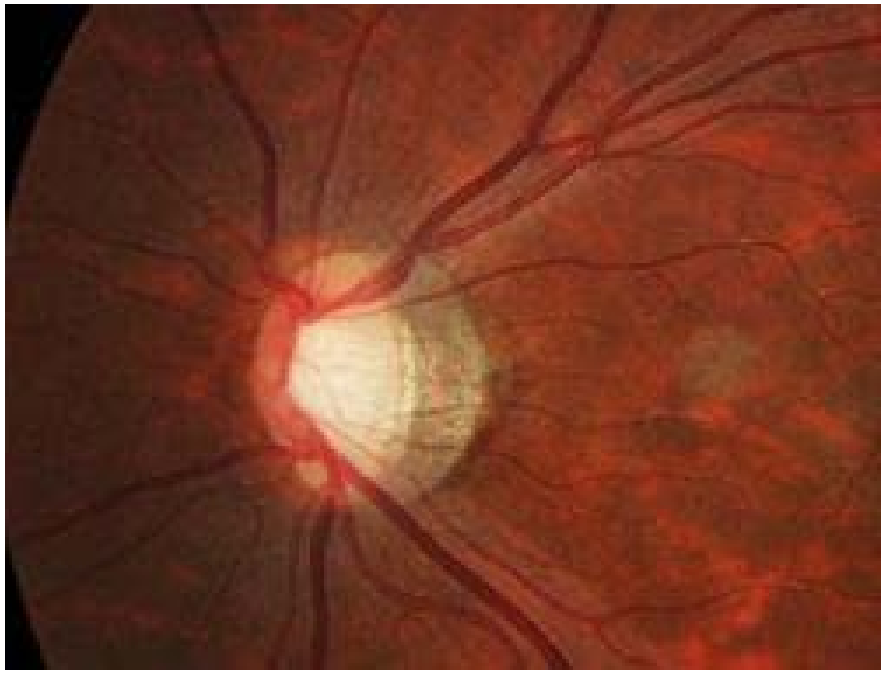
Peripapillary zones

- 1 = cup
- 2 = neuroretinal rim
- 3 = scleral crescent
- 4 = zone beta
- 5 = zone alpha

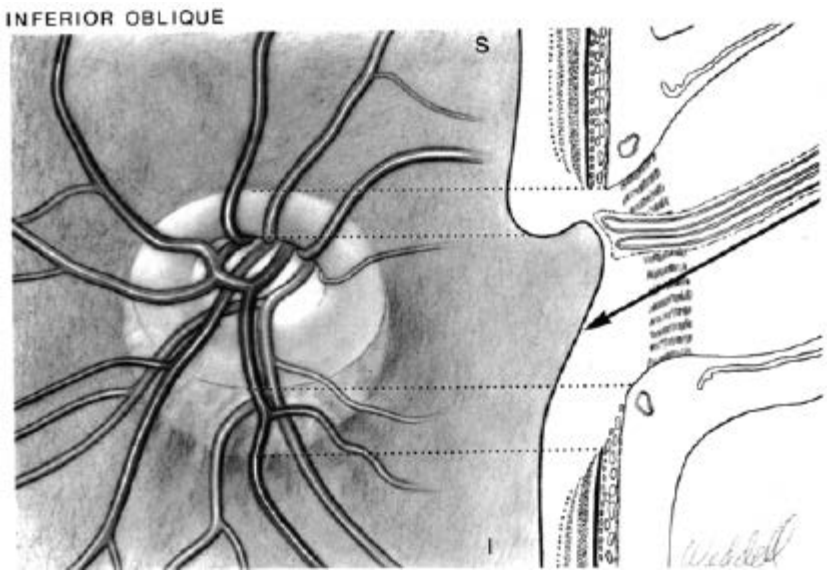


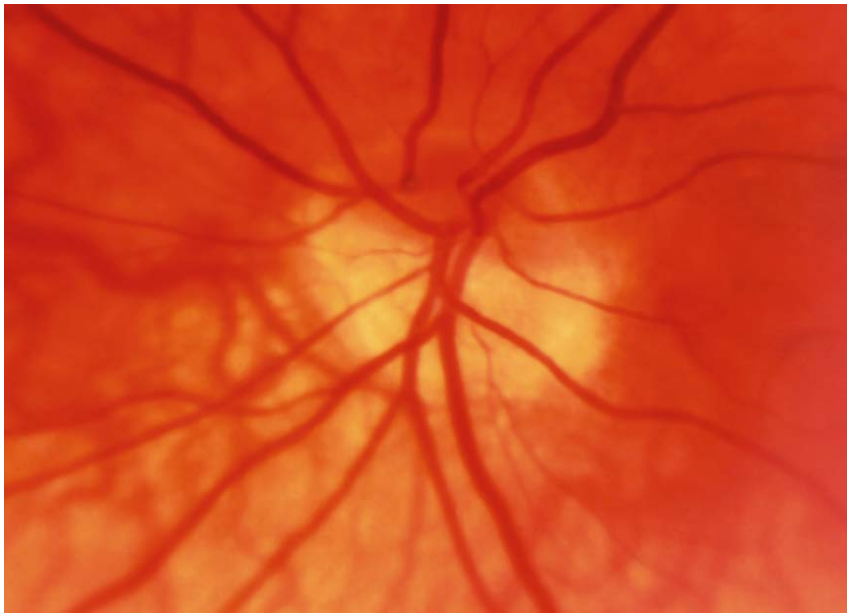
Optic nerve variants





Optic nerve variants

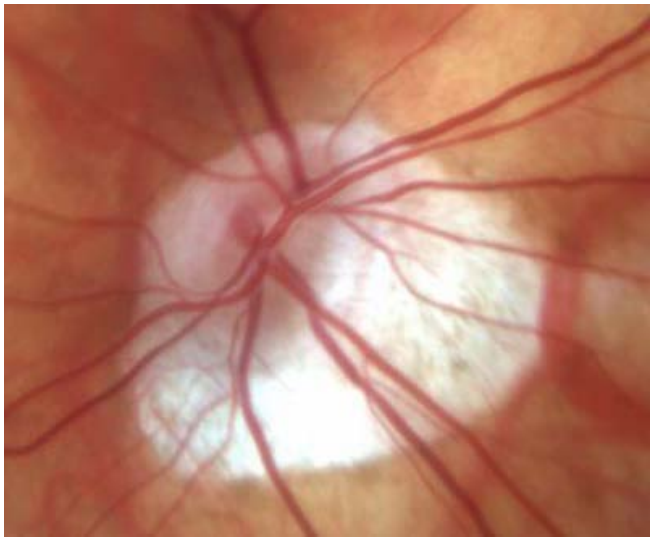


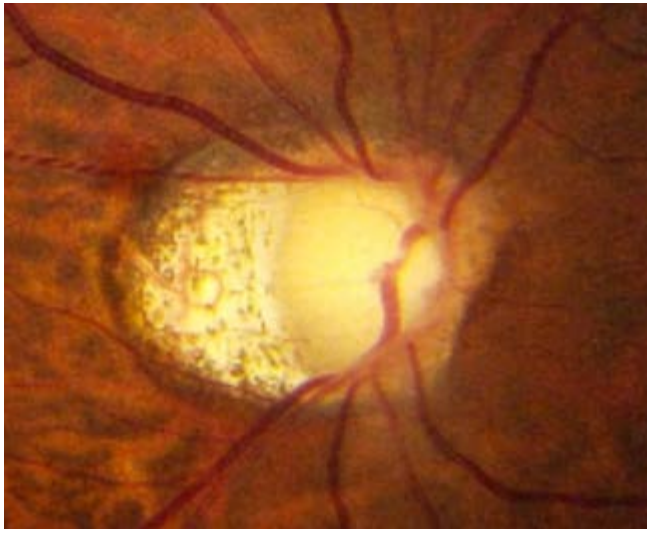


Caution: myopic nerves

- Certain features of highly myopic discs interfere with interpretation of the neuroretinal rim and amount of cupping
  - Large disc area
  - Oblique insertion of optic disc causing distorted view of the temporal rim
  - Tilt makes assessment of superior and inferior poles difficult
  - Shallow cupping makes C/D ratio difficult to assess

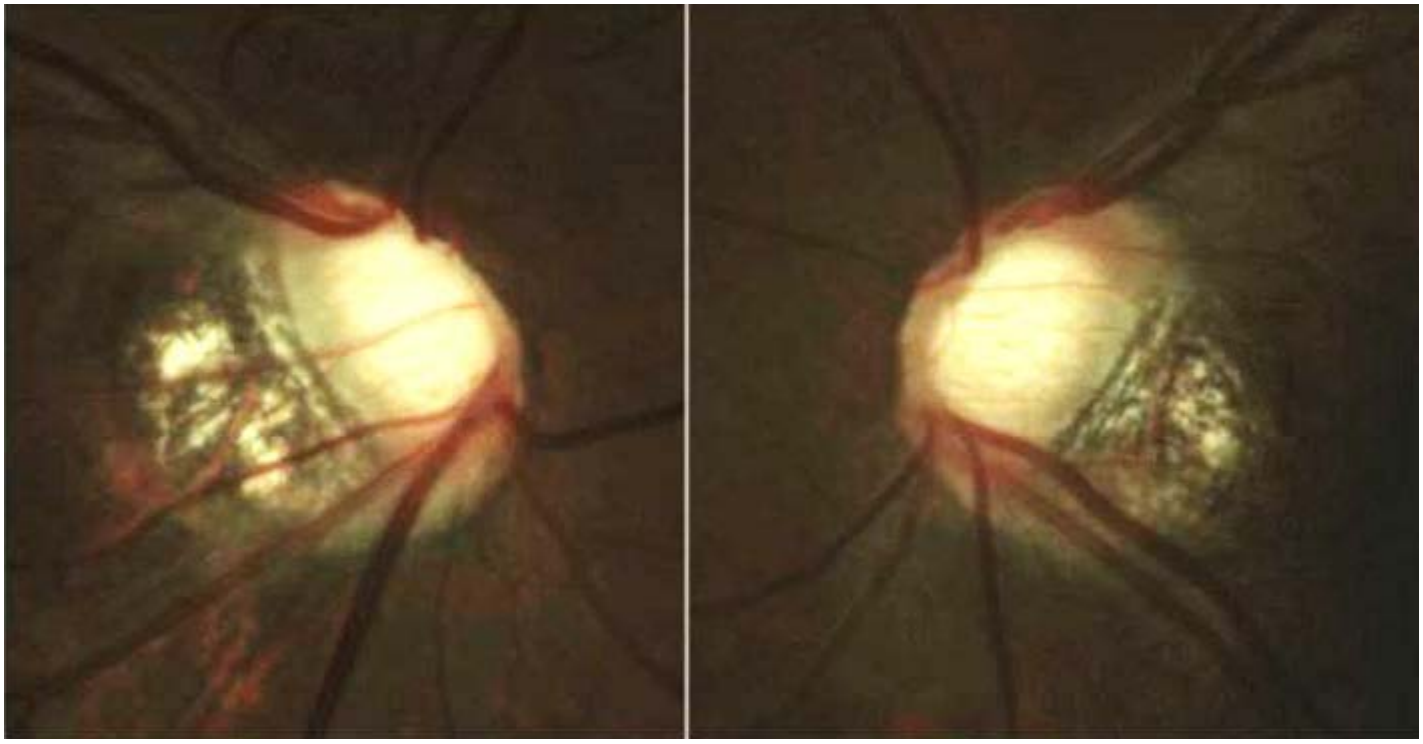
Caution: myopic nerves & oblique insertion





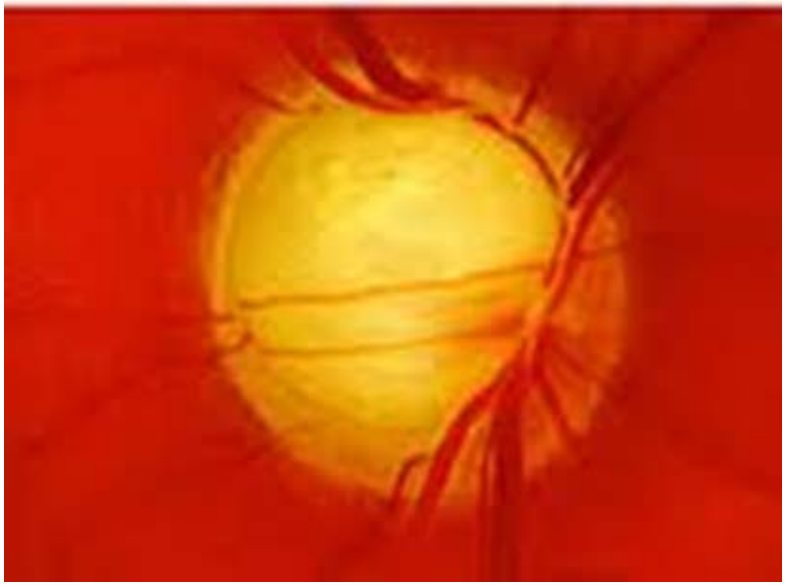
Caution: myopic nerves

- Wide temporal peripapillary crescent causes difficulty in assessing temporal rim
- In this case, look at asymmetry and the integrity of the nasal rim



Myopic nerves: pearls and pitfalls

- Photodocumentation is vital to evaluate for change
  - Serial imaging with OCT to monitor for change is extremely beneficial
  - Caution: normative databases on imaging technologies do not apply
- Any change in VF status is suspicious
- May have higher risk of converting into glaucoma due to weakened lamina cribrosa
- May be more vulnerable to even slight IOP increase due to longer globe, thinner LC, and thinner scleral wall



Optic disc evaluation in glaucoma

Goals of optic disc evaluation

- Diagnose: distinguish between normal and abnormal
- Quantify: how much damage has occurred
  - 20-40% of ganglion cell axons can be lost before reproducible VF loss appears on automated perimetry
  - Ganglion cells die at the level of the lamina cribrosa, with retrograde atrophy back to their cell bodies in the retina
- Monitor for change
  - Stable
  - Worsening
- Quantify rate of change: slow vs. rapid

Optic disc evaluation

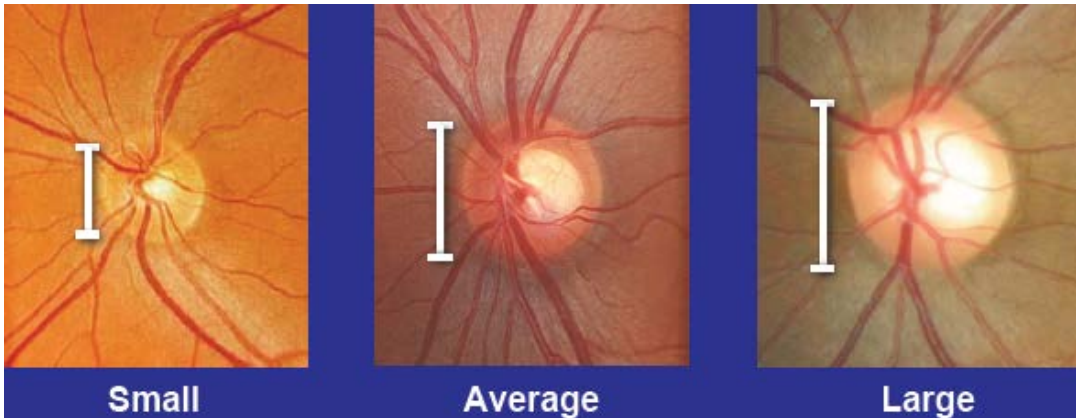
- Slit lamp biomicroscopy: ideal
  - Stereoscopic view
  - Measuring optic disc size
- Direct ophthalmoscopy
  - Good magnification
  - No stereo
- Indirect ophthalmoscopy
  - Poor magnification and detail
- Optic disc photography
  - Great for documentation and monitoring for progression
  - Always taken at baseline, and usually every 2 years afterwards

What to look for?

- Disc: size and shape
- Neuroretinal rim: size, shape, color, localized defects (notching)
- Cup: size and shape *in relation* to the optic disc size
  - 0.7 C/D in a 1.8mm nerve – probably NOT ok
  - 0.7 C/D in a 2.7mm nerve – probable NOT glaucoma
- Optic disc hemorrhage: presence and location
- Nerve fiber layer defect
- Peripapillary atrophy
- Retinal arterial attenuation

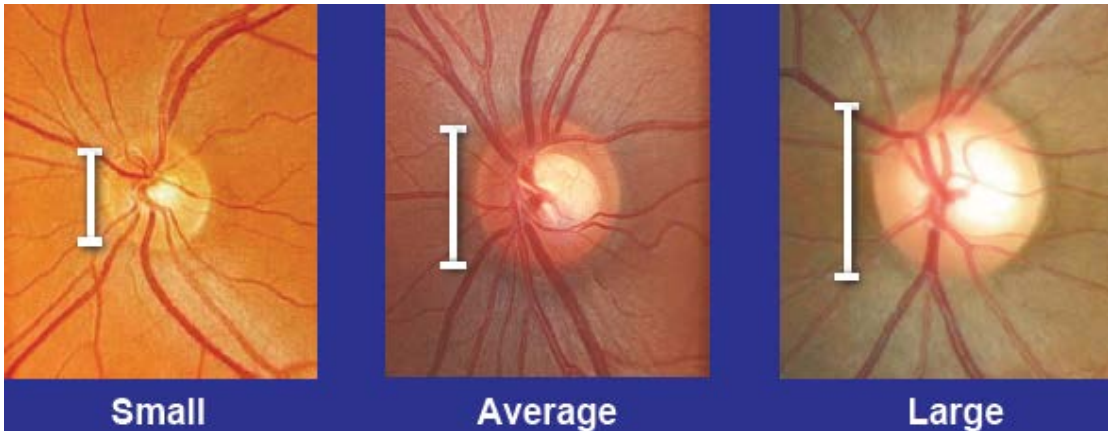
Optic disc size

- Critical in distinguishing between physiologic and pathologic cupping
- Scleral foramen/canal: 1-3mm
  - Large foramen = large disc = large cup
  - Small foramen = small disc = small cup



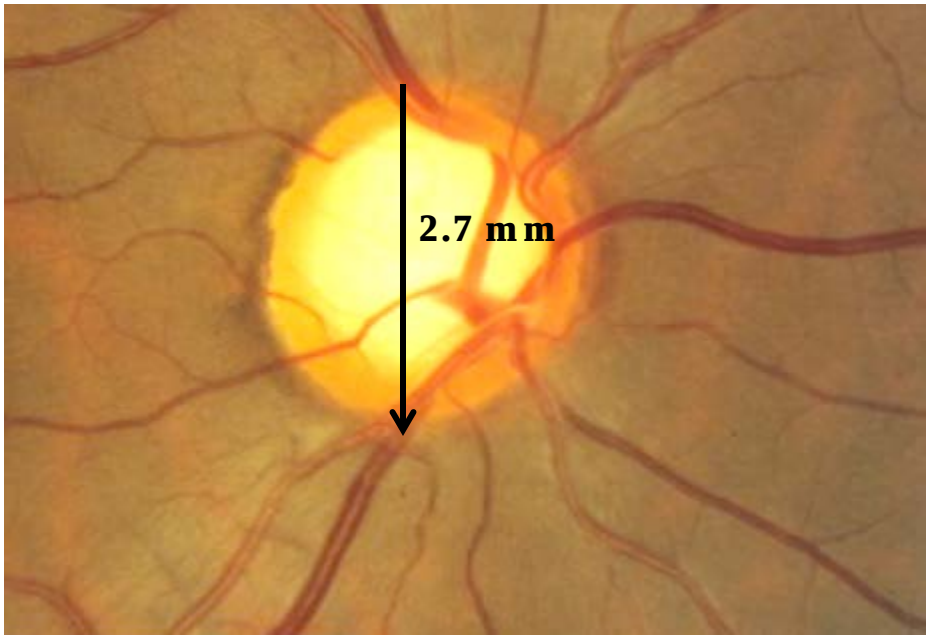
Optic disc size

- Measurement of vertical disc diameter
  - Length of vertical beam of slit lamp light
  - Multiplied by correction factor of condensing lens
    - Volk 60D: x 1.0
    - Volk 78D: x 1.1
    - Vold 90D: x 1.3



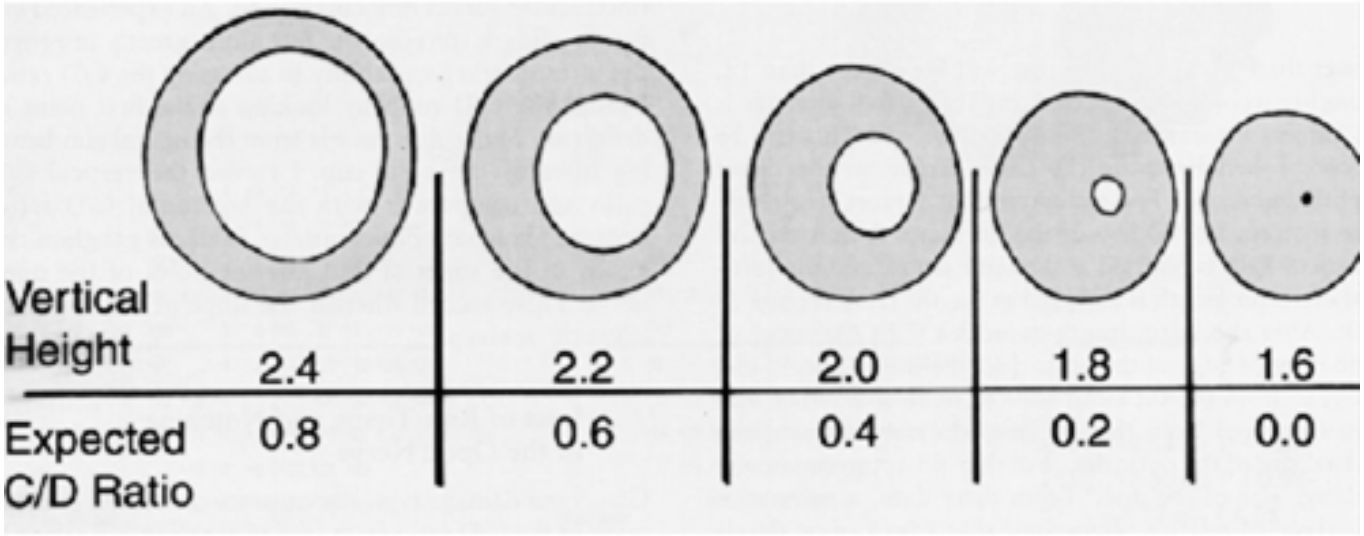
Optic disc size

- Average vertical diameter: 1.8-2.0mm
- Small optic nerve vertical diameter: ≤1.5 mm
- Large optic nerve vertical diameter: >2.2mm

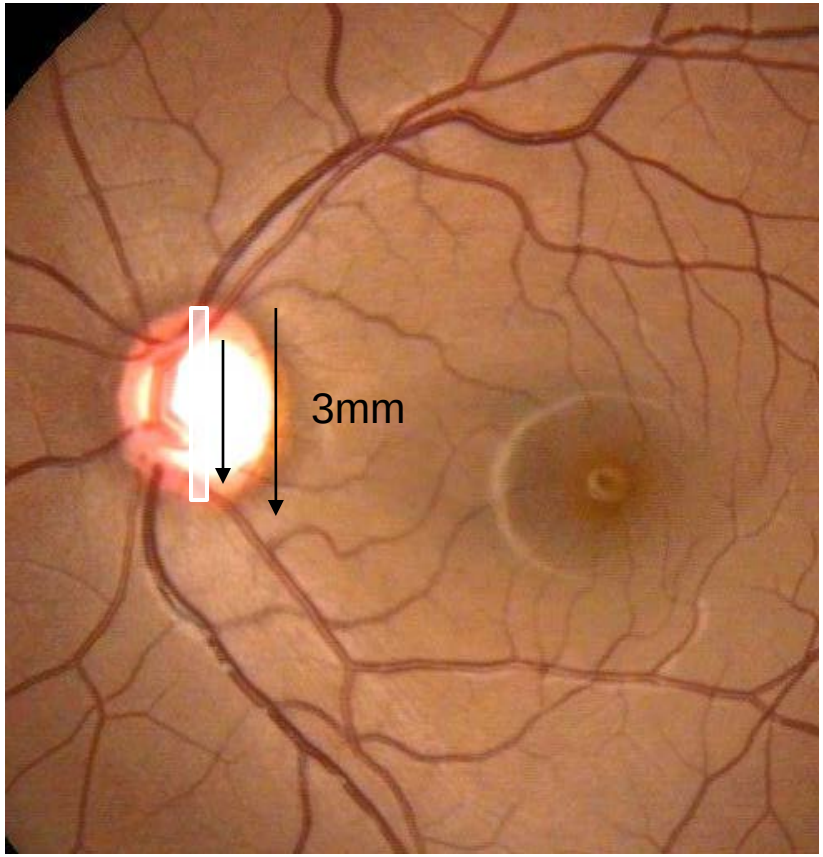


Disc vs. cup size

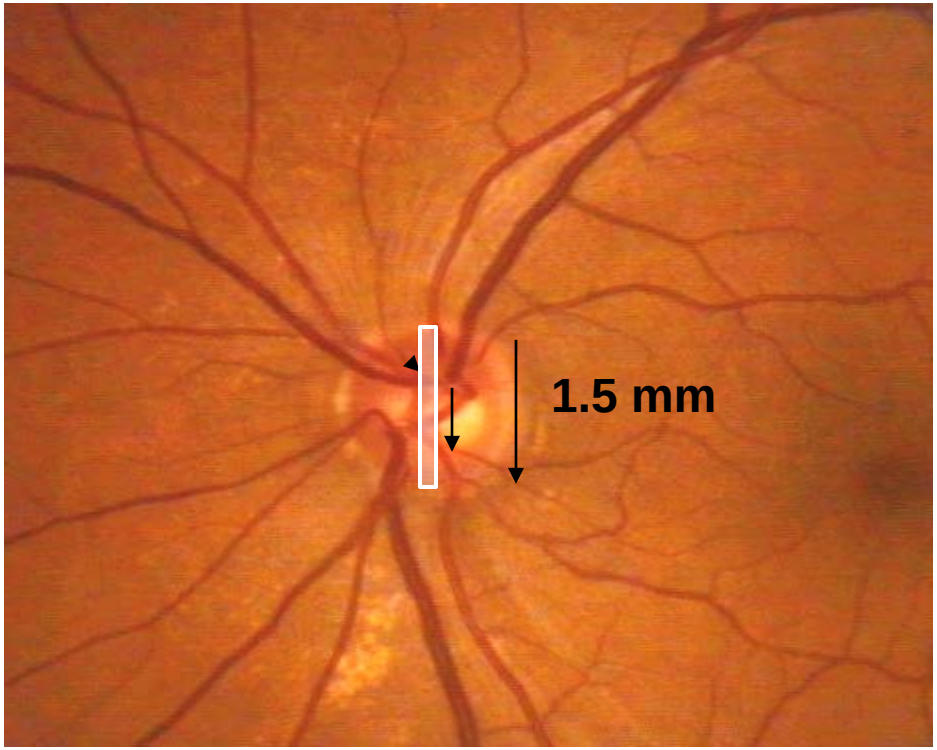
- Larger discs = larger cups
  - Due to the size of the scleral canal
- Always determine the size of the disc



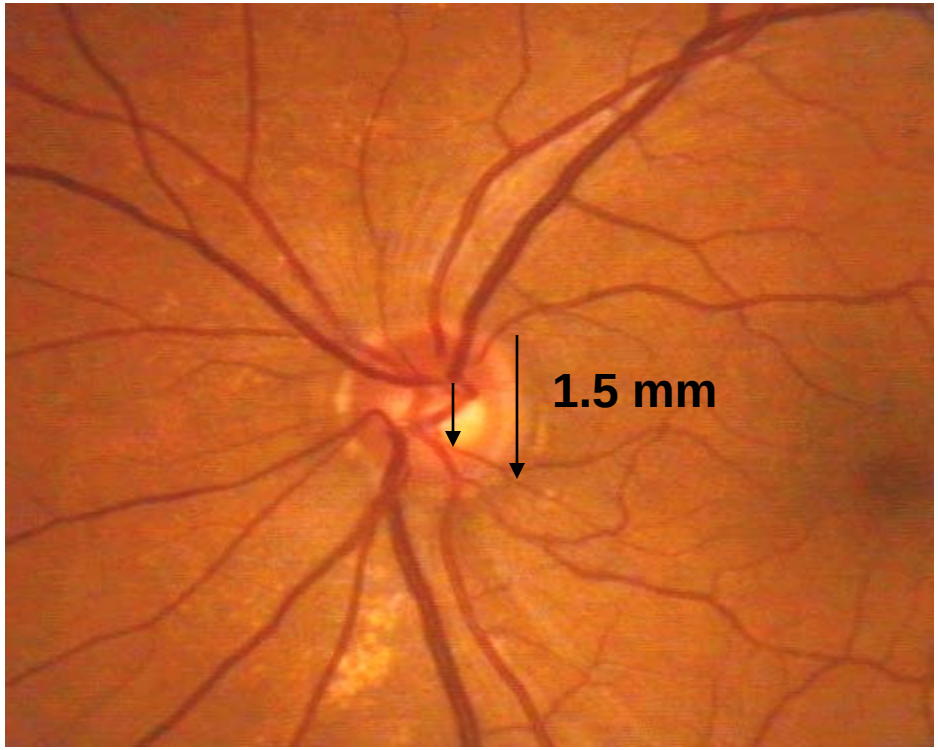
Large disc = large cup

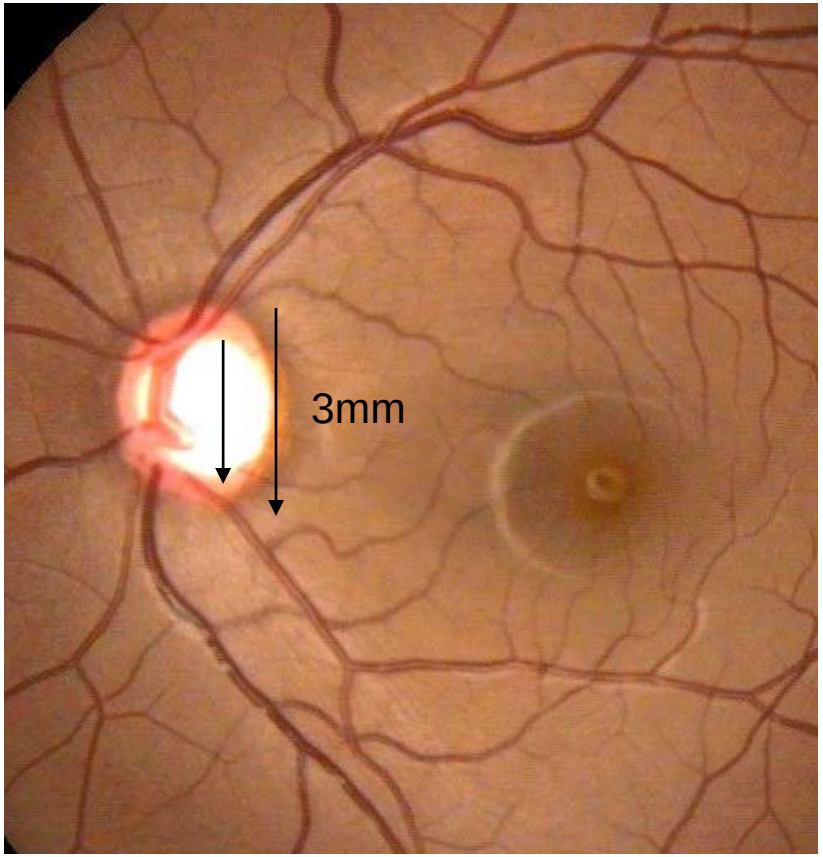


Small disc = small cup



Early and moderate glaucomatous damage in small discs may be missed due to initial low C/D ratios





C/D ratio

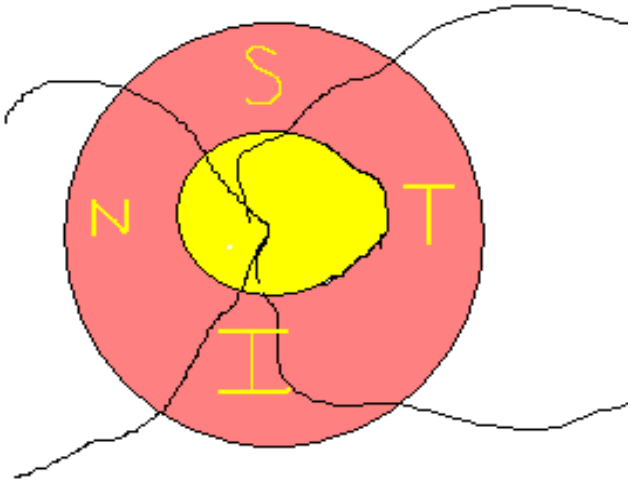
- Optic disc elongation
  - Vertically oval optic disc
  - Horizontally oval optic cup
- In normal eyes: horizontal C/D ratio > vertical C/D ratio
- In glaucomatous eyes: vertical C/D ratio > horizontal C/D ratio
- Documentation
  - Always include horizontal and vertical CD ratio
  - Stereophotographs of the ONH always beneficial

Neuroretinal rim

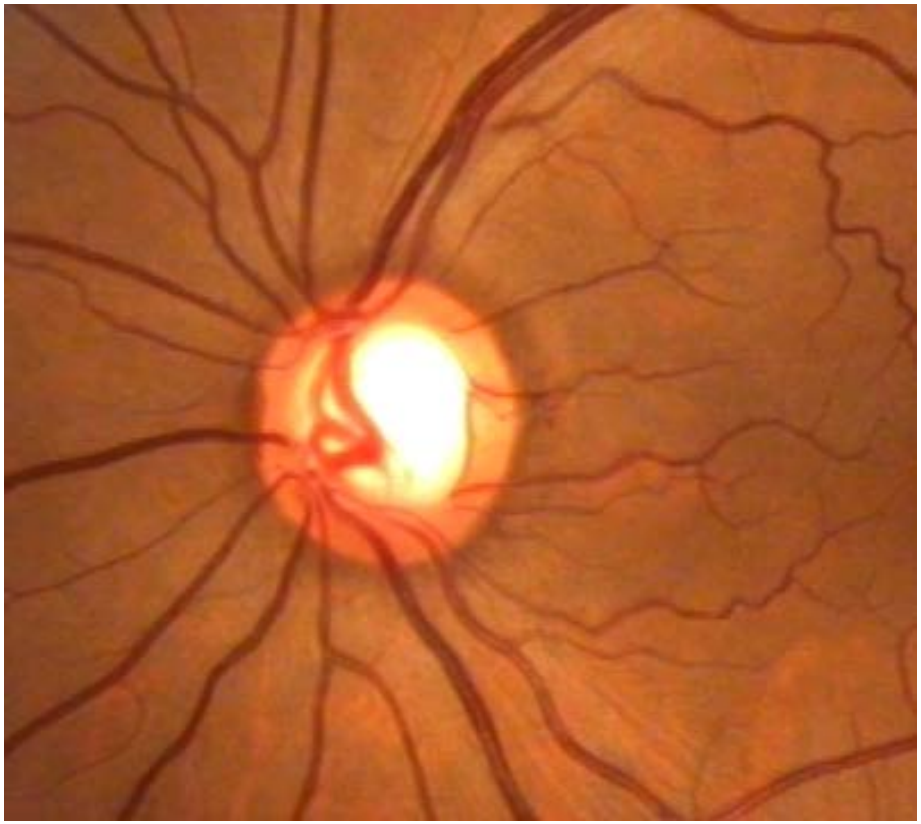
- Reflects selective loss of tissue
- It is the primary location of pathologic changes
- C/D ratio is often a poor indicator of early glaucoma
- Pay attention to the width and the health of the neuroretinal rim
- Look at the donut, not at the hole!

The neuroretinal rim

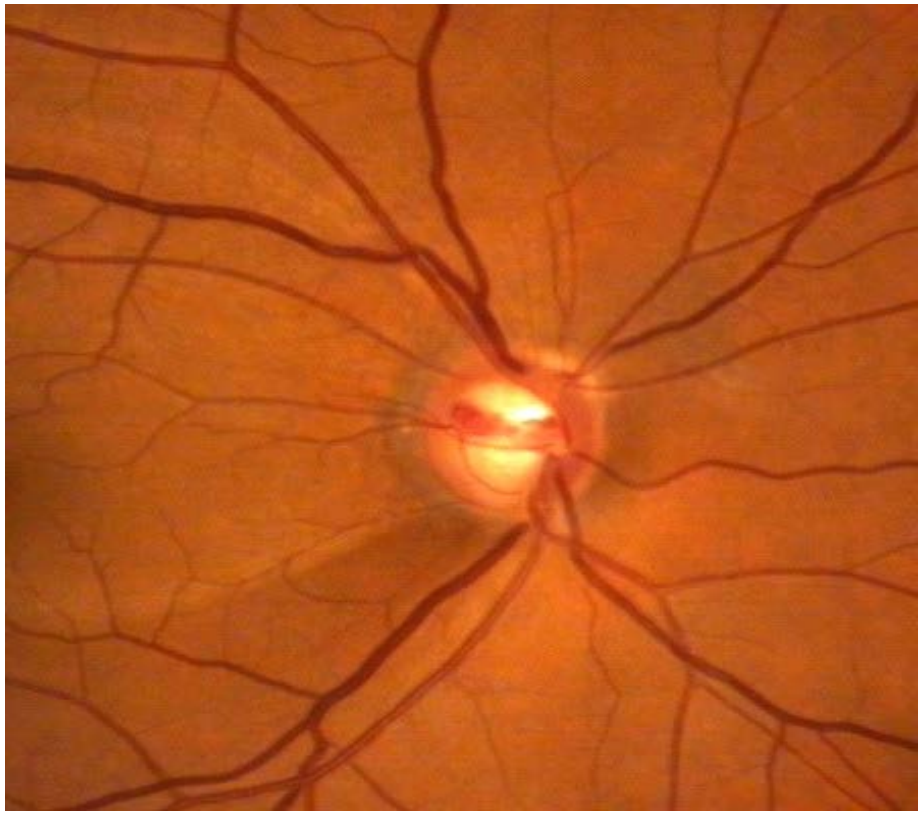
- Size
- Shape
- The ISNT rule
- Color
  - Glaucoma: cupping WITHOUT pallor

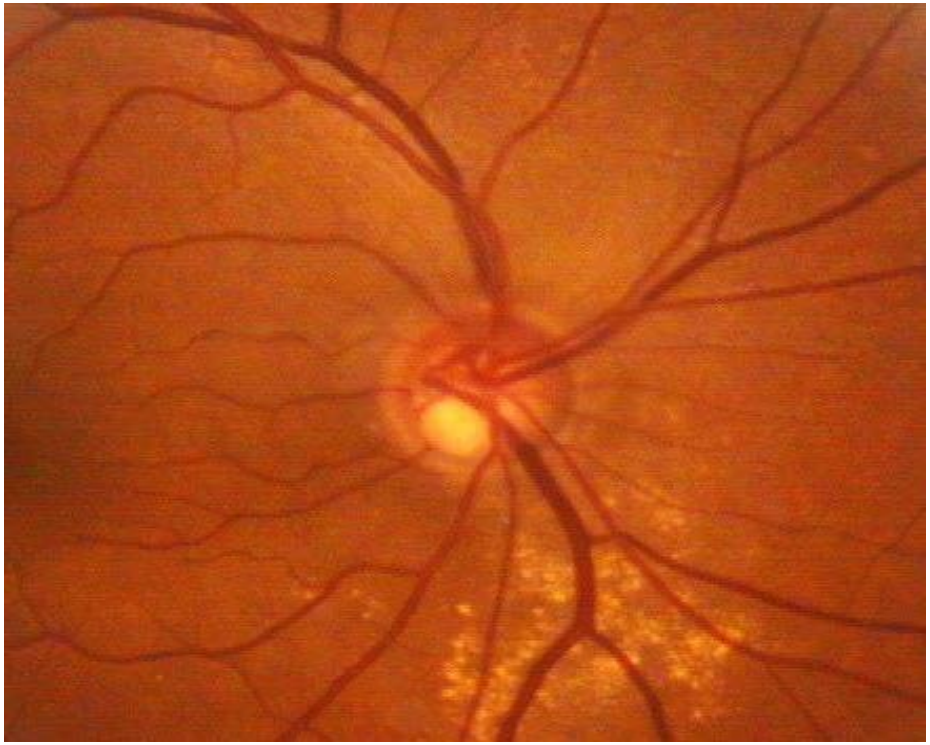


The ISNT rule



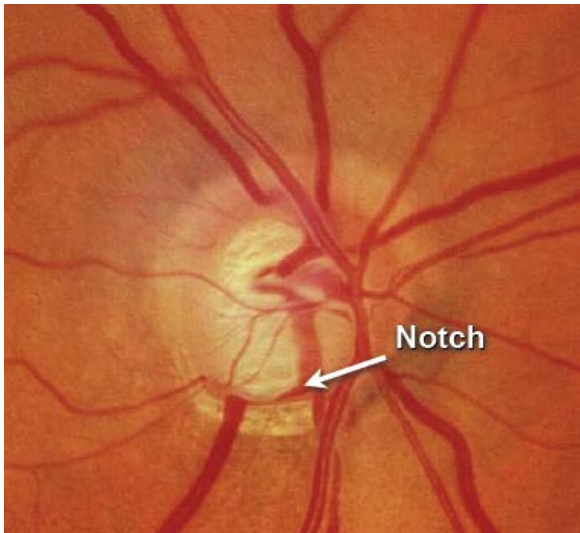
The ISNT rule





The neuroretinal rim

- Look for
  - Thinning
  - Notching: localized defect in the neuroretinal rim
  - Pallor: suspect a different or additional optic neuropathy

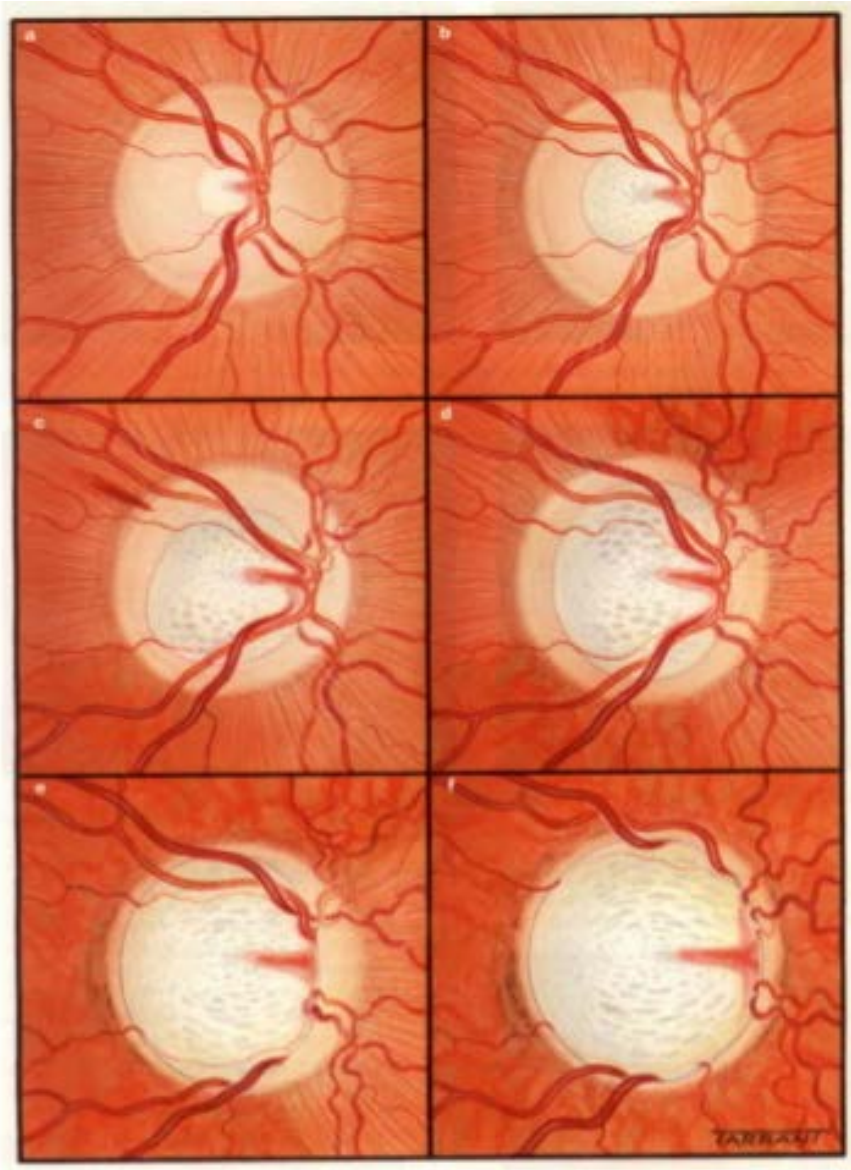


The neuroretinal rim

- Usual sequence of loss in glaucoma:
  - Inferotemporal/superotemporal
  - Temporal
  - Inferonasal/superonasal
- In non-glaucomatous optic nerve damage, the rim is not always affected, therefore its contour is maintained

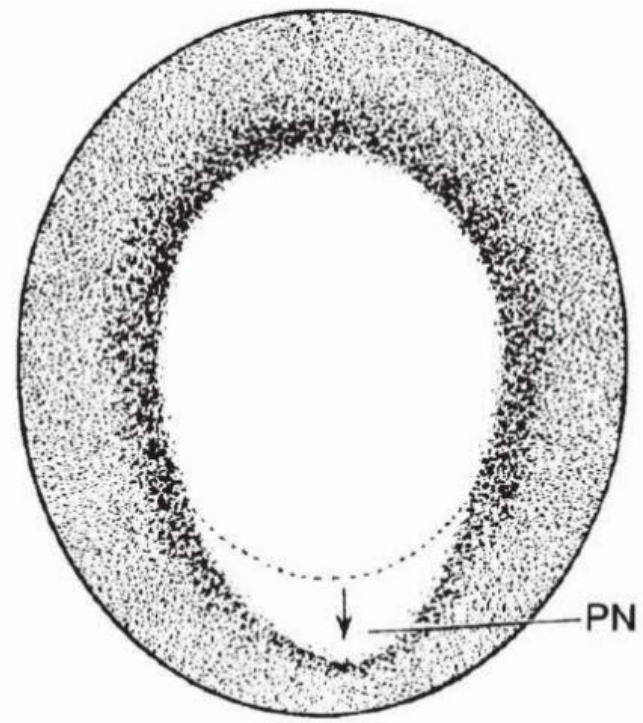
Patterns of cupping

- **Diffuse cupping**



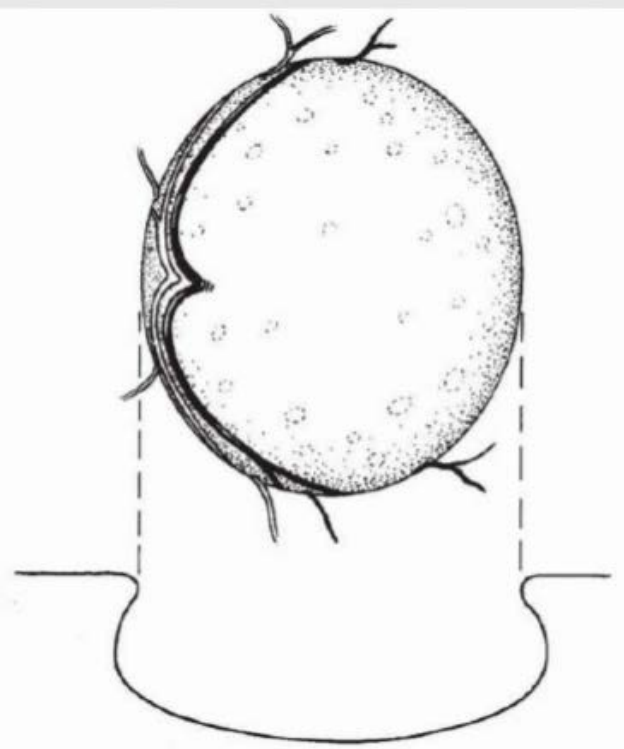
Patterns of cupping

- **Focal atrophy: notching**



Patterns of cupping

- **Bean-pot cupping**
  - Extreme posterior displacement of lamina cribrosa

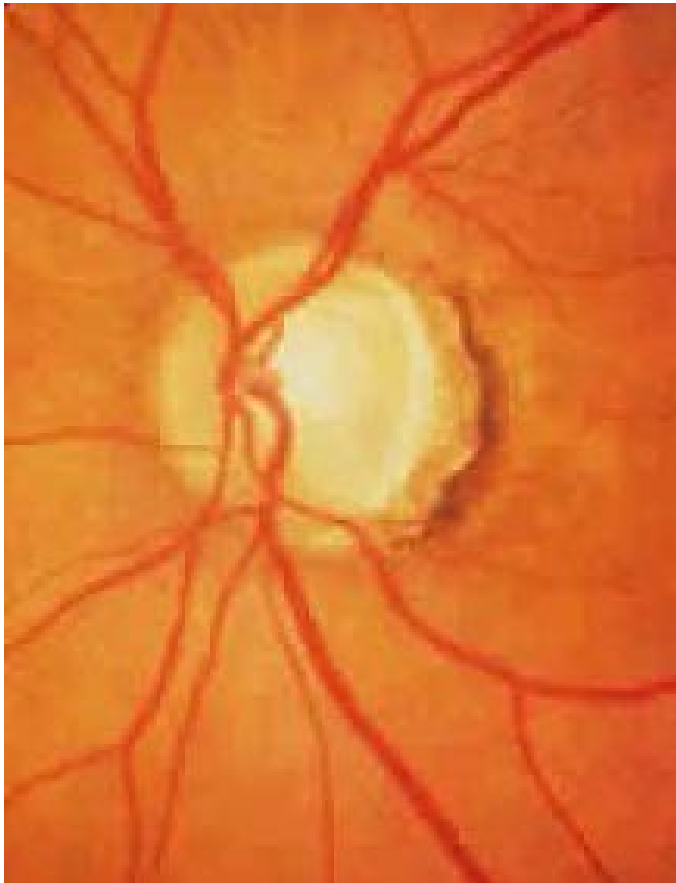


Peripapillary chorioretinal atrophy

- Irregular pigmentation around the optic nerve
- Nonspecific finding
  - Seen in normals
  - Should raise suspicion for POAG and NTG
- Associated with acquired damage to the optic nerves from glaucoma
- Clinical appearance
  - Moth-eaten appearance of the RPE temporal to ONH
  - Adjacent to area of neuroretinal rim thinning

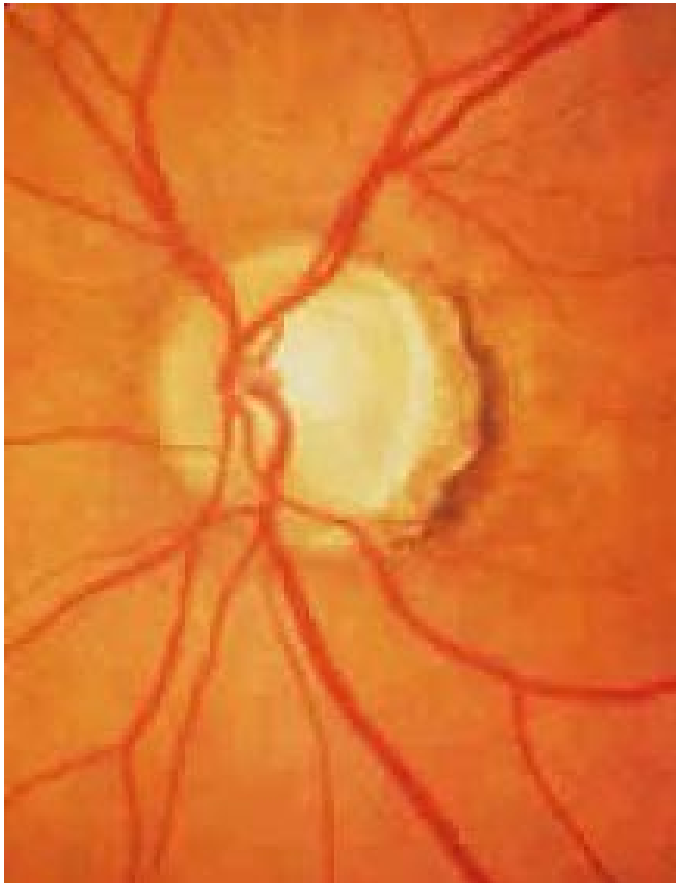
Peripapillary atropy

- Zone Alpha
  - Hypo and hyper pigmented areas due to RPE irregularity
  - Nasally bounded by zone beta
  - Temporally bounded by normal retina
  - Present in normal eyes
  - Present in glaucomatous eyes



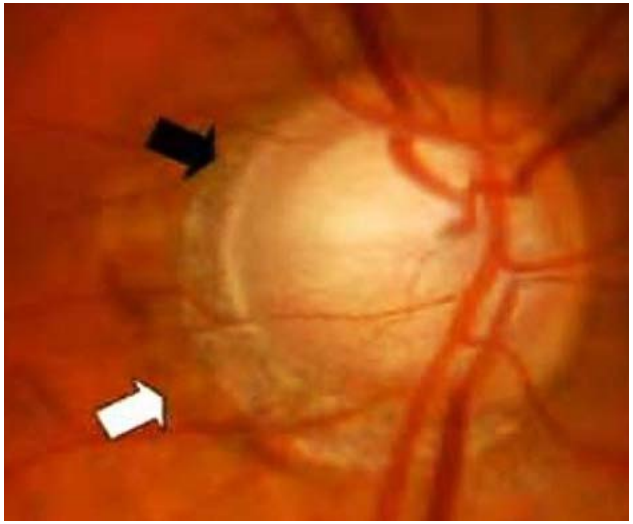
Peripapillary atropy

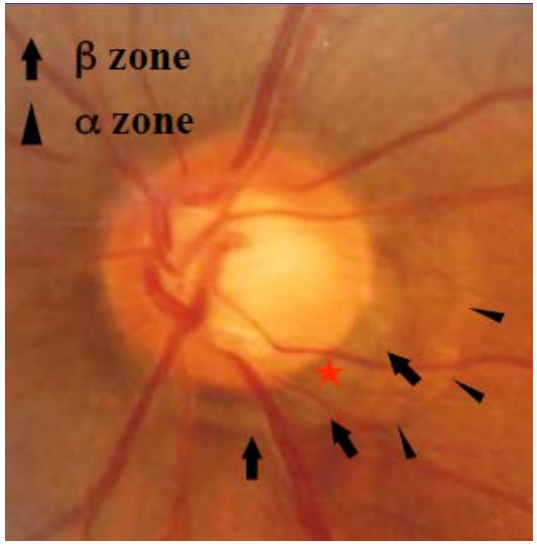
- Zone Beta
  - Atrophy of the RPE and choriocapillaris
  - May be due to poor perfusion to the peripapillary area
  - Large choroidal vessels become visible
  - More common in glaucomatous eyes

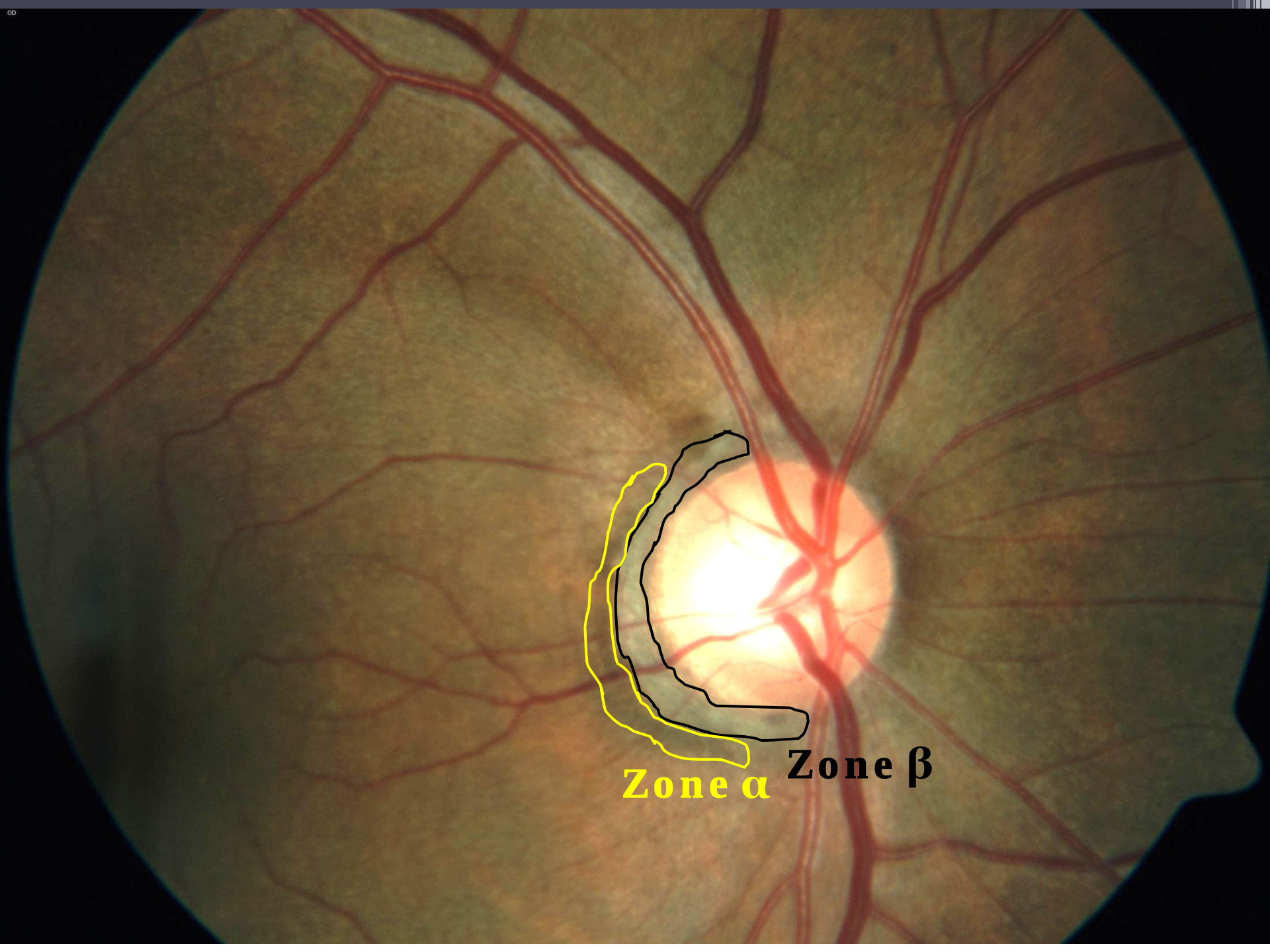


Peripapillary atrophy

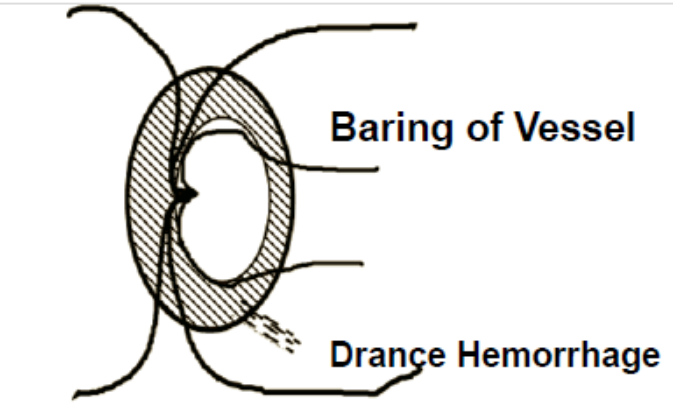
- Helps differentiate between glaucomatous and non-glaucomatous optic nerve damage
  - Beta zone larger and more frequent in glaucoma
  - Nasal PPA more frequent in glaucoma
- Width of beta zone inversely correlated with adjacent rim width
  - Larger beta zone → thinner neuroretinal rim
- Progression of beta zone associated with progression of glaucoma






Zone α
Zone β

Vascular changes



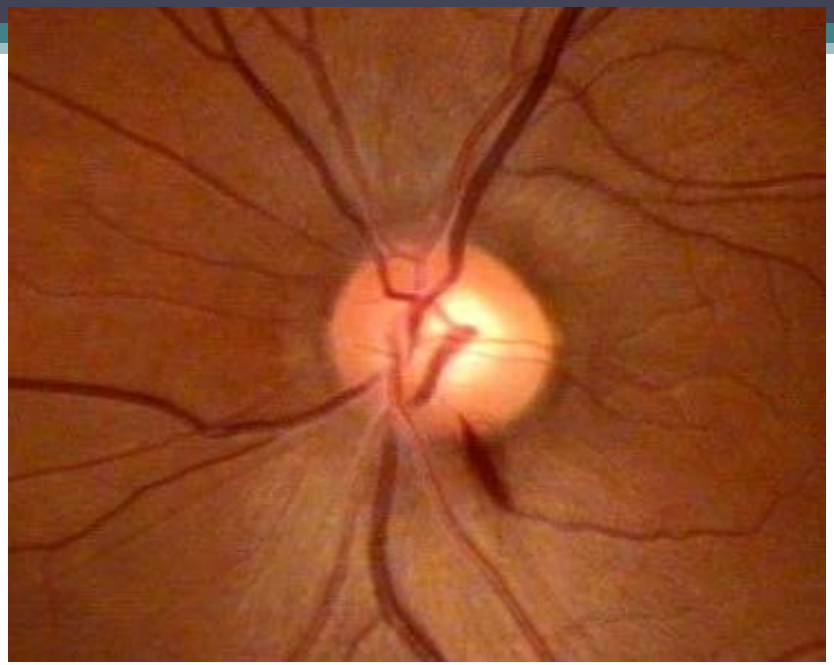
- Optic disc hemorrhages
- Baring of curcumlinear vessel
- Bayonetting of vessels
  - Advanced cupping causes vessels to emerge from floor of the cup, disappear as they ascend up the excavated wall of the cup, and emerge again at the disc margin
- Nasalization of vessels: major vessels show nasal shift
- Optic nerve shunts/collaterals
- Retinal artery attenuation

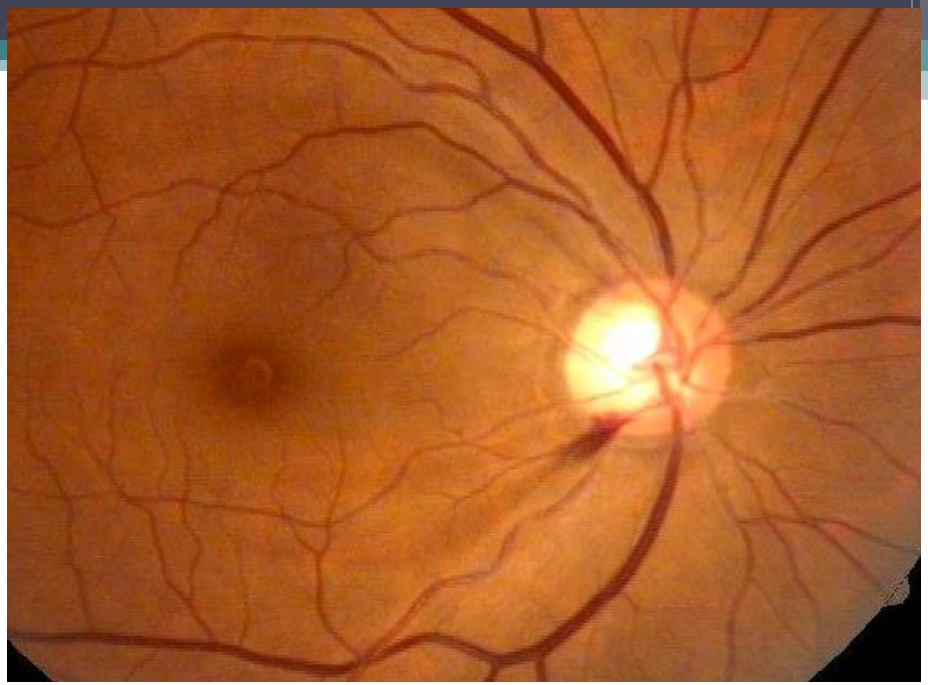
Optic disc hemorrhage

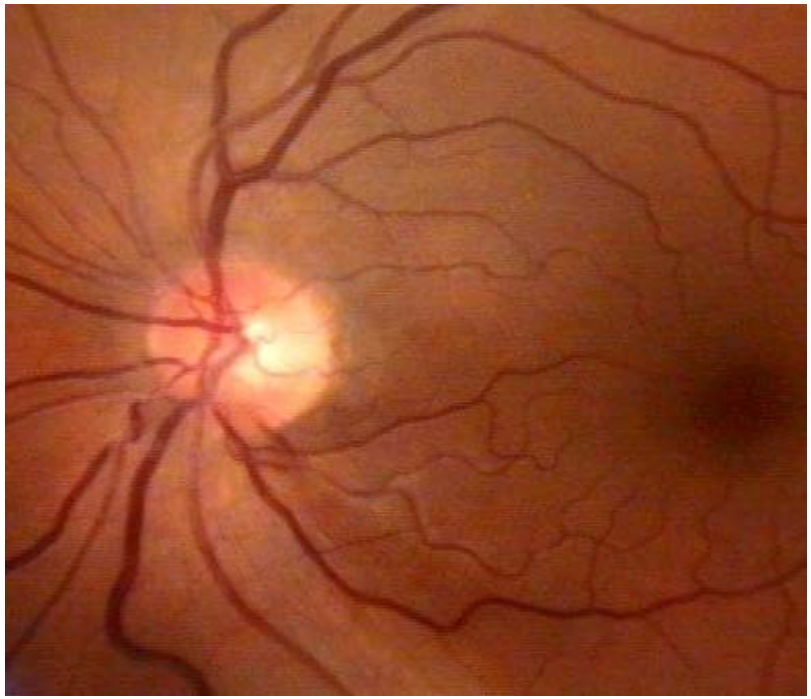
- Aka drance hemorrhage
- Splinter or flame shaped
- Located on the disc margin
- Hallmark of glaucomatous optic nerve damage
  - 4-10% of eyes with glaucoma
- Found in early and moderate stages, rare in advance stages
- Usually located on IT and ST disc margins

Optic disc hemorrhage

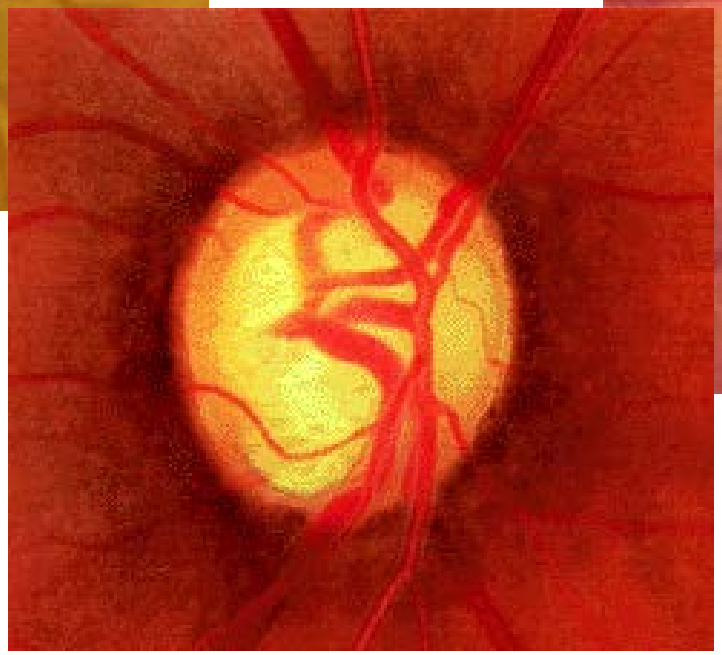
- Can resolve within 6-10 weeks of onset
  - Can take anywhere between 2-35 weeks
- Associated with localized RNFL defects and rim notching
- Suggests progression
  - Appearance may precede RNFL loss, notching, and VF defect
- More common in NTG
- Can be seen in PVD, BRVO, HTN retinopathy, and NAION



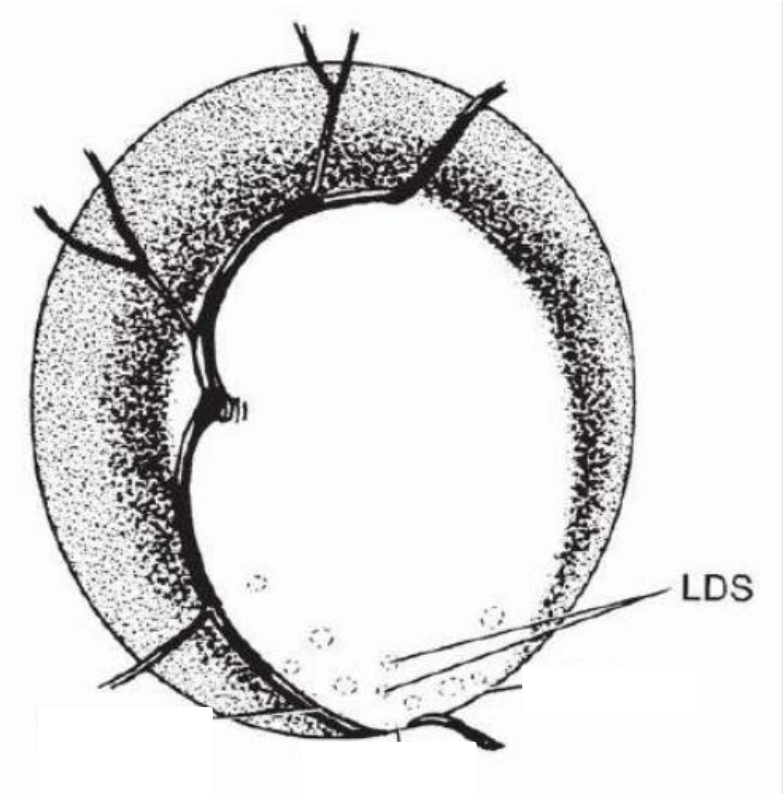


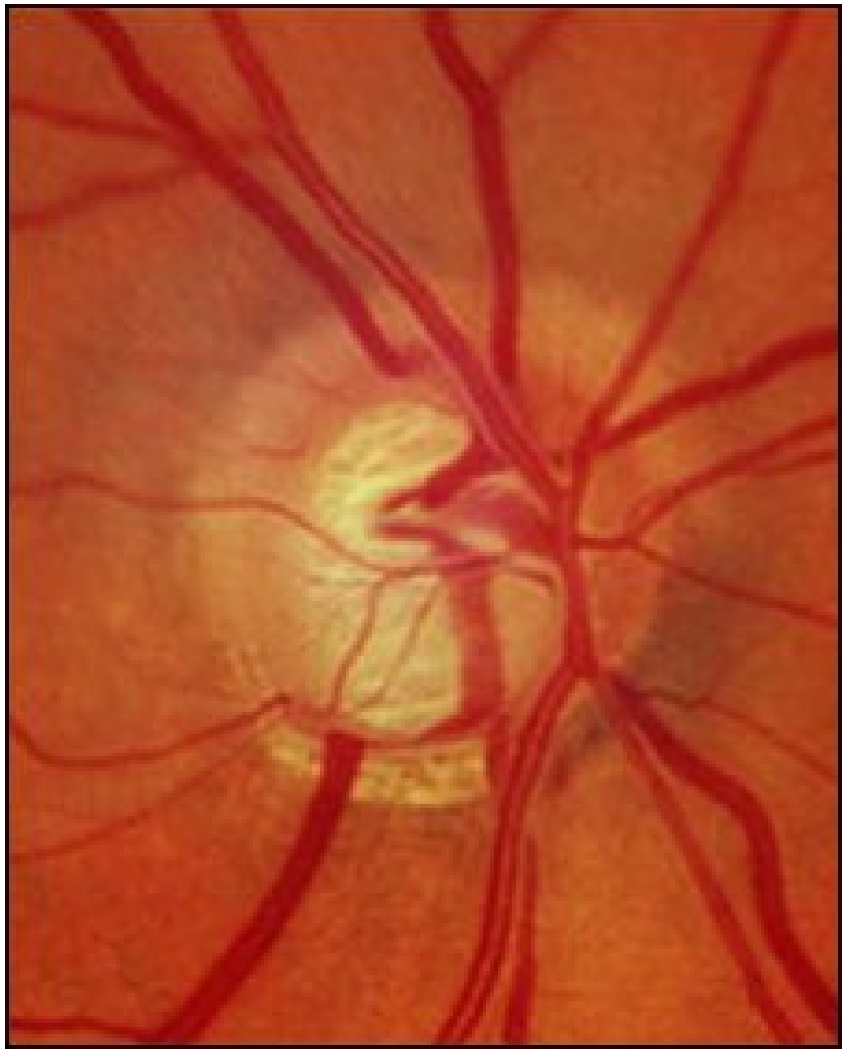


Baring of vessels

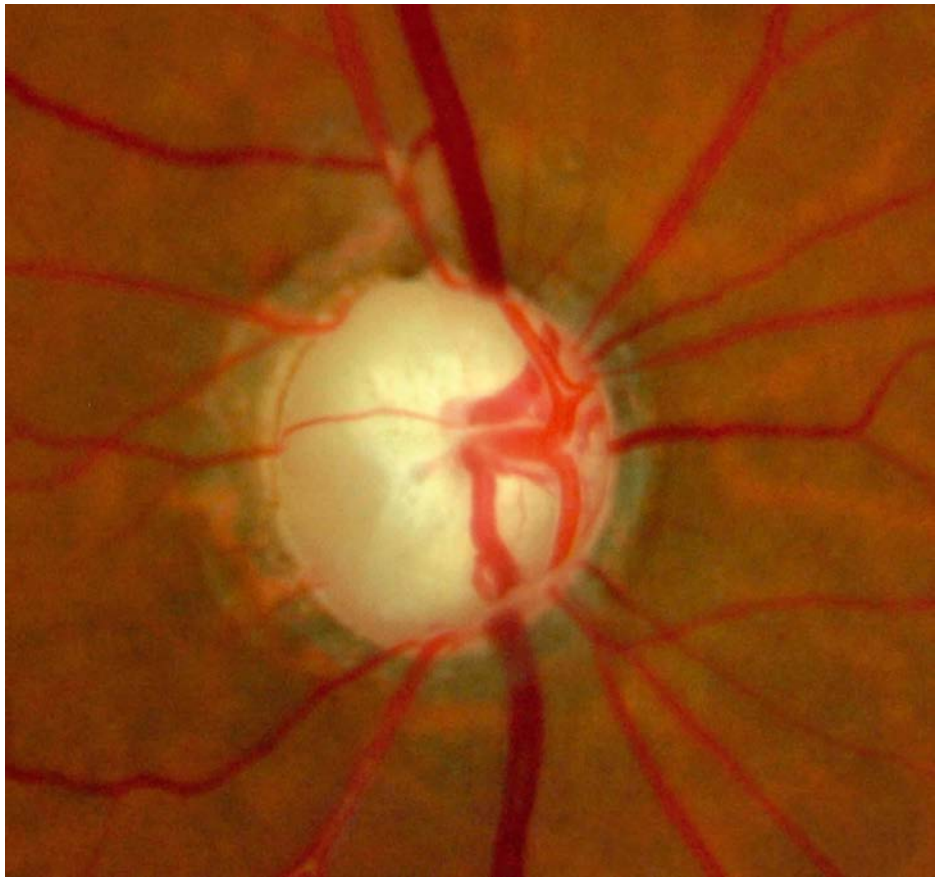


Bayonetting of vessels





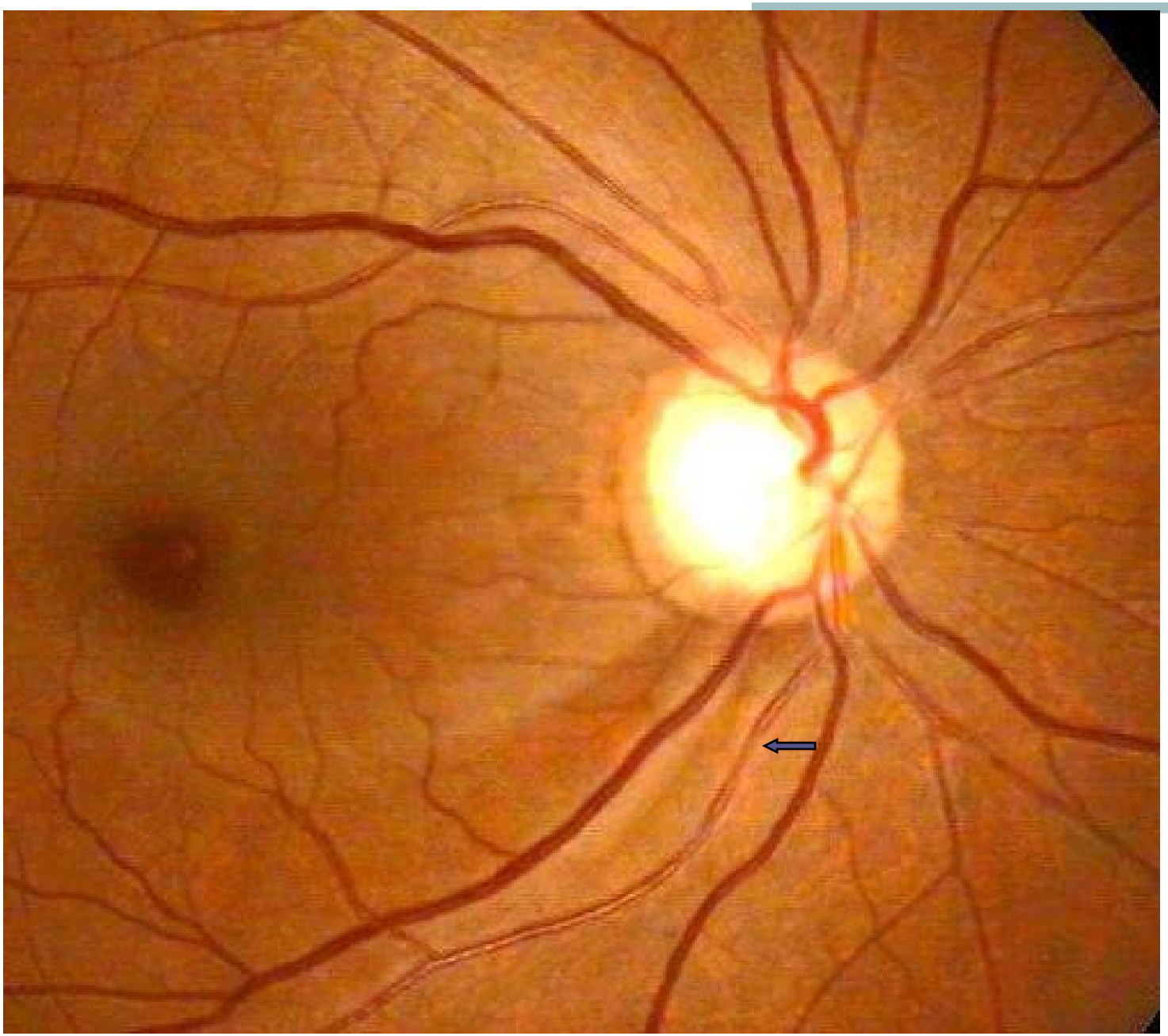
Nasalization of vessels

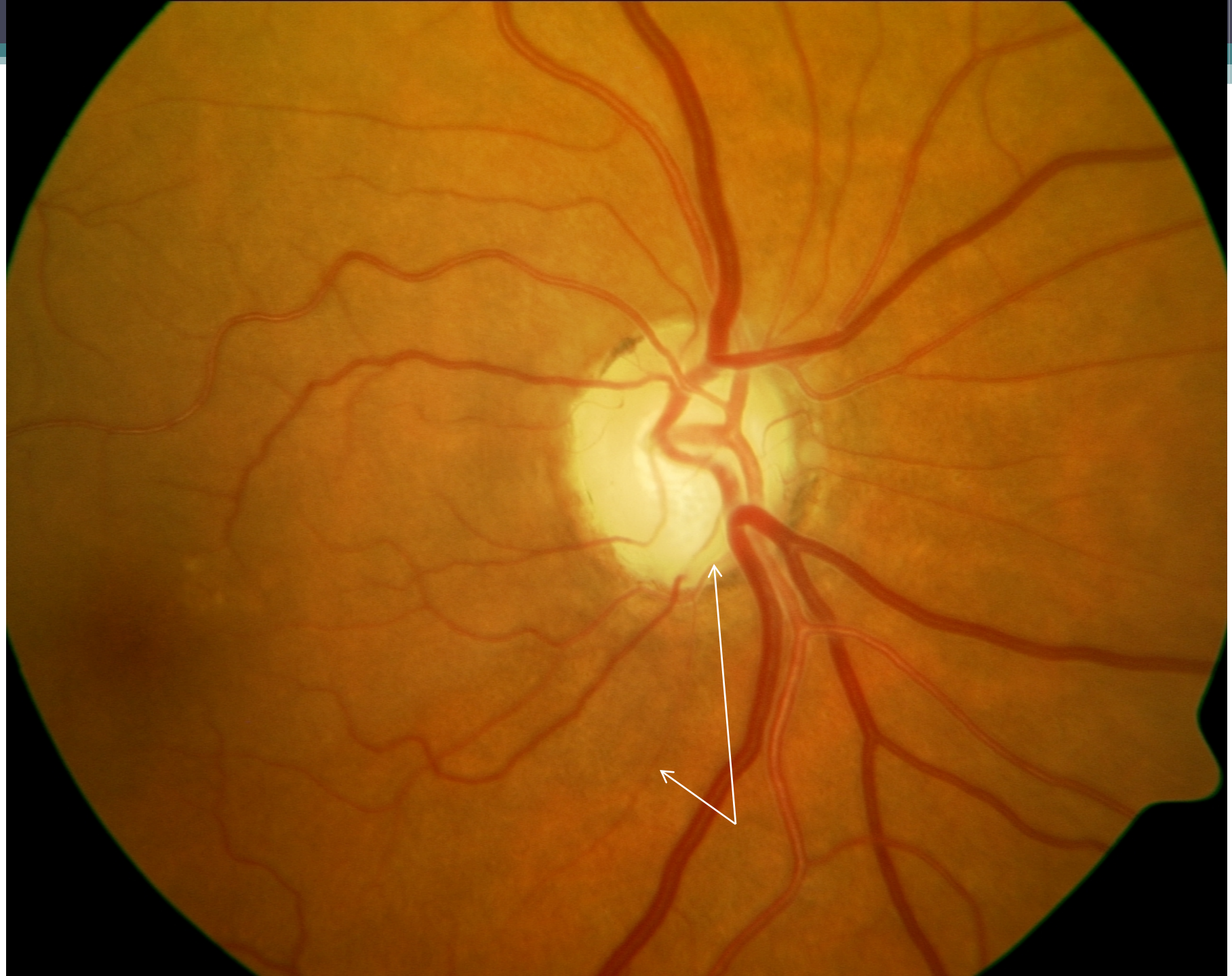


Optic nerve shunts/collaterals

Retinal artery attenuation

- Diffuse narrowing
  - Decreasing neuroretinal rim
  - Increased RNFL loss
  - Infreased VF defects
- Focal attenuation
  - More common in NTG
  - Degree of narrowing increases with amount of damage





Retinal nerve fiber layer (RNFL)

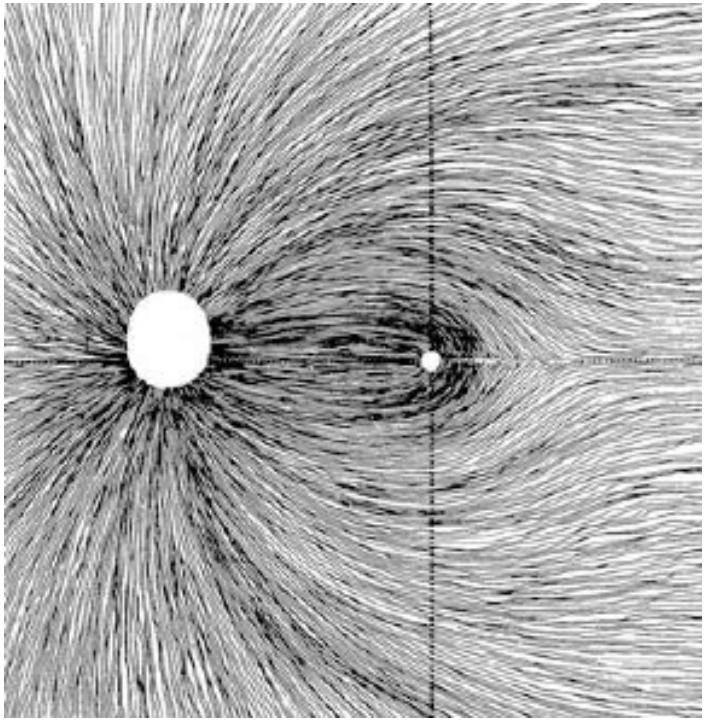
- RNFL: retinal ganglion cell axons covered by astrocytes and bundled by Muller cell processes
- Seen as bright fine striations fanning off the disc
- Best evaluated with red-free filter
- Can be difficult to appreciate in the blond fundus
- Most visible infero-temporally and supero-temporally
- Obscures details of underlying peripapillary retinal vascular walls

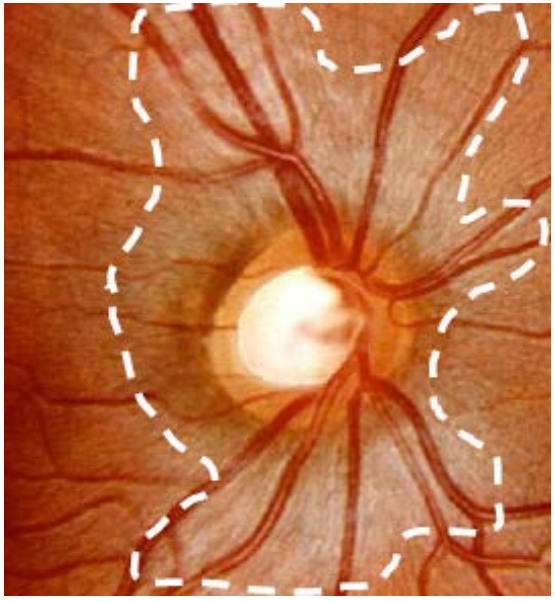
Clinical assessment of RNFL

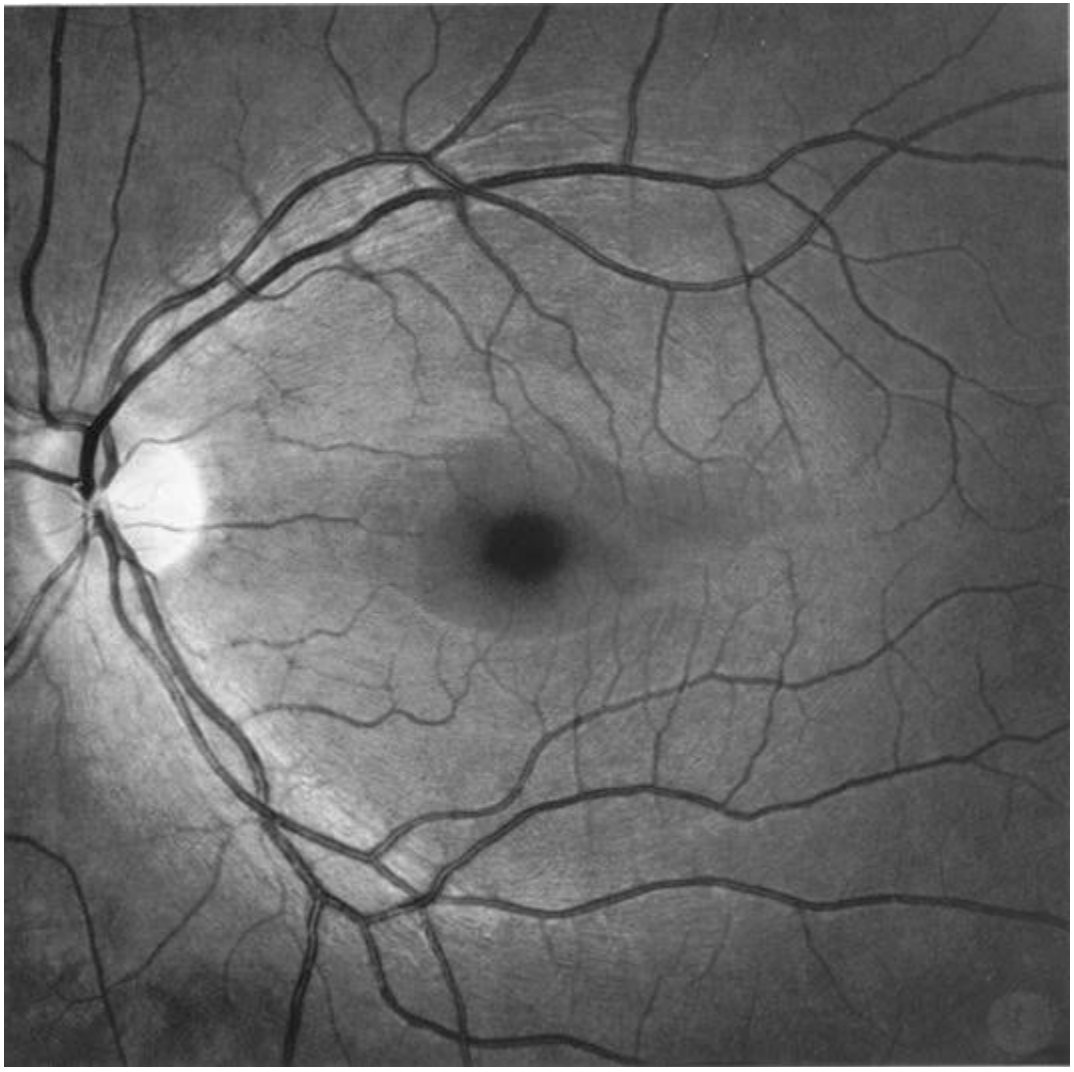
- Requires
  - Bright light
  - Red-free filter
    - Green light produced by filter is absorbed by the RPE and choroid, creating a dark background
    - The RNFL reflects the green light and is contrasted against the dark background

Normal RNFL

- Bright, linear, striated appearance
- Coarse texture
- Casts white haze over underlying retinal structures and obscures smaller blood vessels
- Normal pattern: bright-dim-bright
  - Pattern should be symmetric between S/I bundles and between the two eyes
- Brightness depends on
  - Integrity of RNFL bundles
  - Amount of pigmentation in RPE and choroid – blonde fundi, dull RNFL
  - Media clarity







RNFL defects in glaucoma

- Selective damage to superior and inferior arcuate bundles
- Relative sparing of papillomacular and nasal bundles
- Defects appear as darker zones in areas of expected brightness
- Retinal vessels appear redder and darker
- Small vessels become more visible

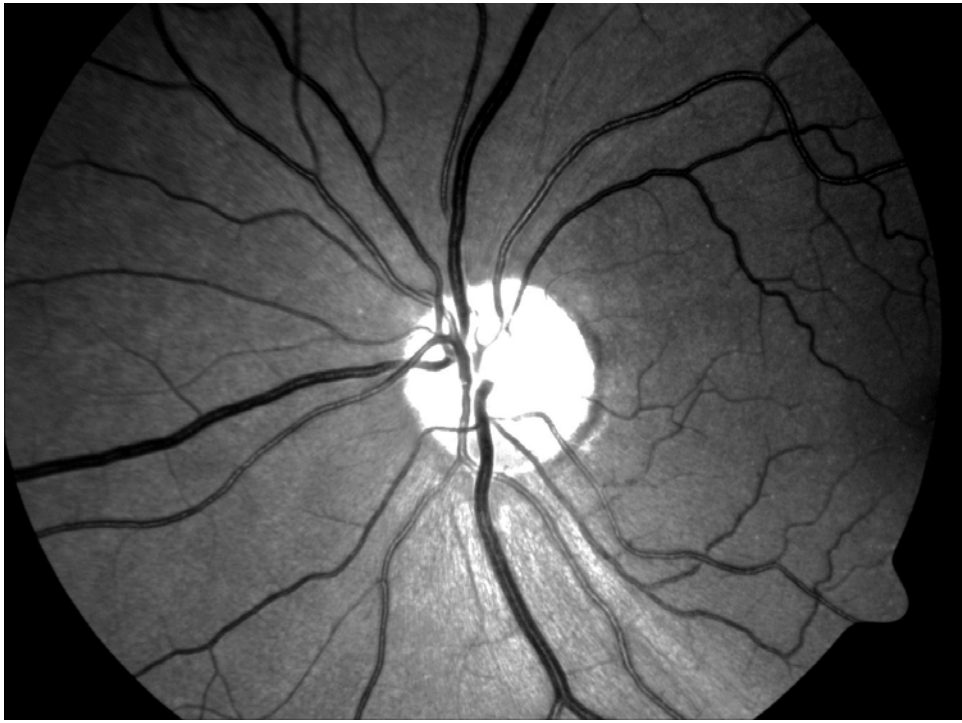
RNFL defects

- Diffuse
  - Most common and most difficult to detect
  - Compare S/I and R/L striations: raked appearance and loss of brightness
  - Peripapillary vessels appear bare
  - Underlying choroidal vessels more clearly visible

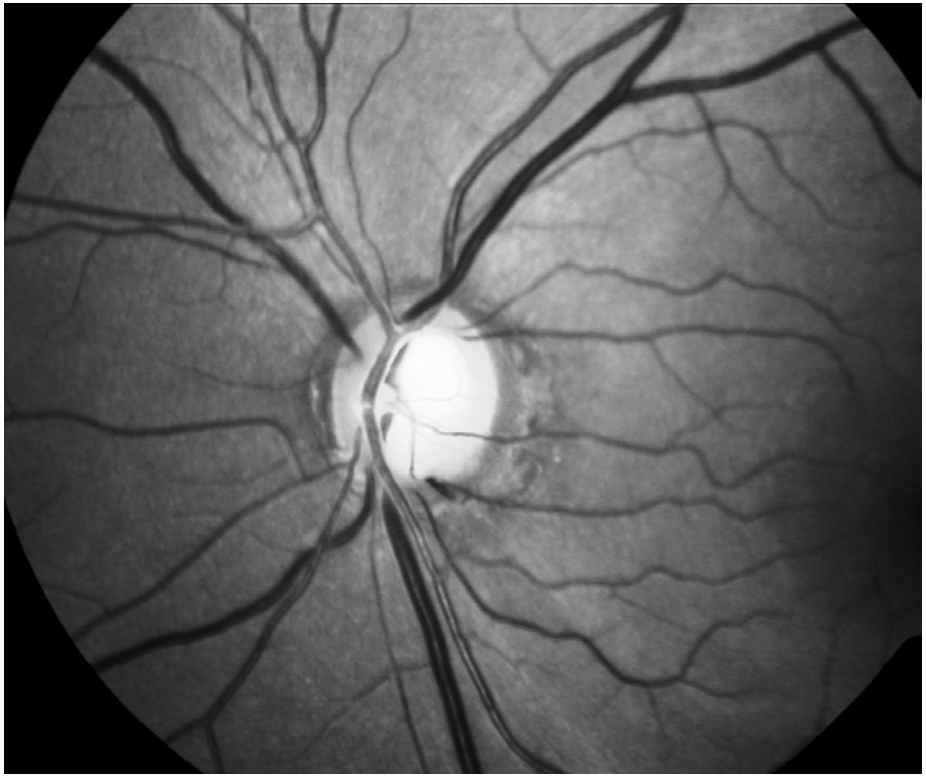
RNFL defects: diffuse loss

- Mild (D1)
  - Striations are less bright and less coarse
  - Medium size vessels apparent
  - Small vessels still obscured
- Moderate (D2)
  - Striations even less prominent
  - Medium and small vessels clear
- Severe (D3)
  - Few striations visible
  - Deep retinal layers have grainy appearance
  - Pseudosheathing of blood vessels: collagen walls become more visible

RNFL: diffuse loss



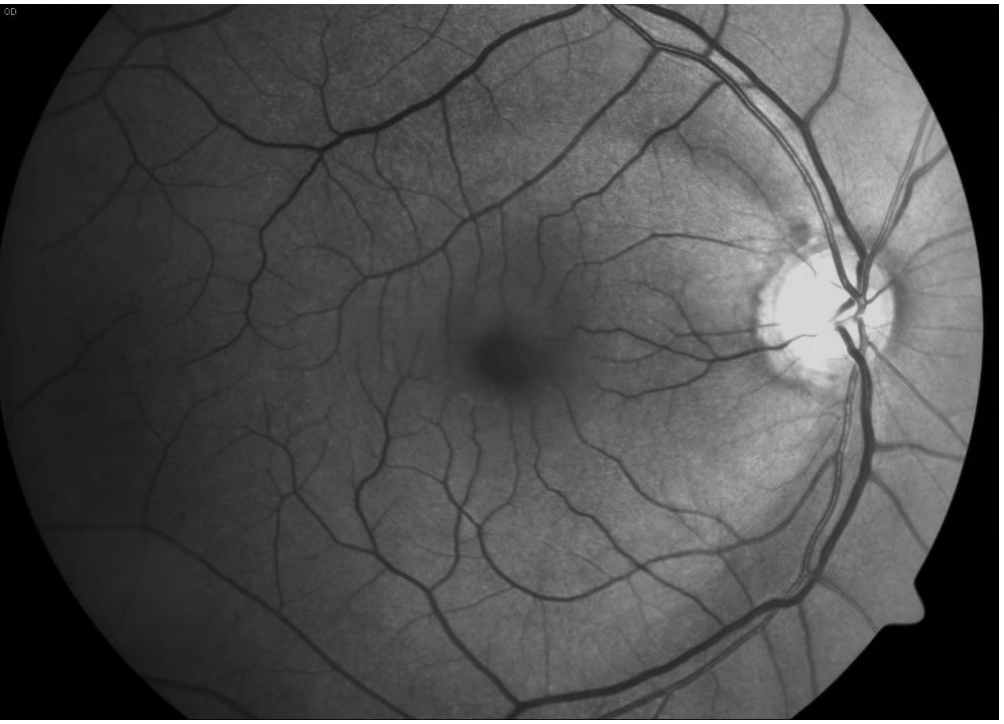
RNFL: diffuse loss

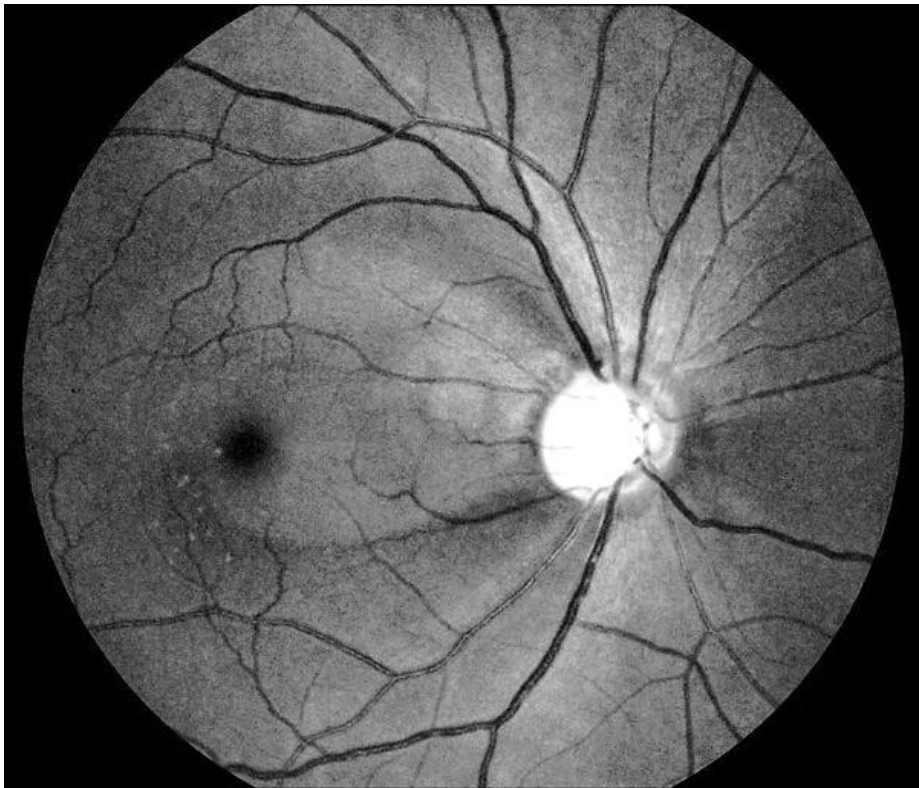


RNFL defects: focal loss

- Slit or wedge
  - Easiest to identify
  - Less common
  - Usually associated with notch at disc or current/prior drance hemorrhage

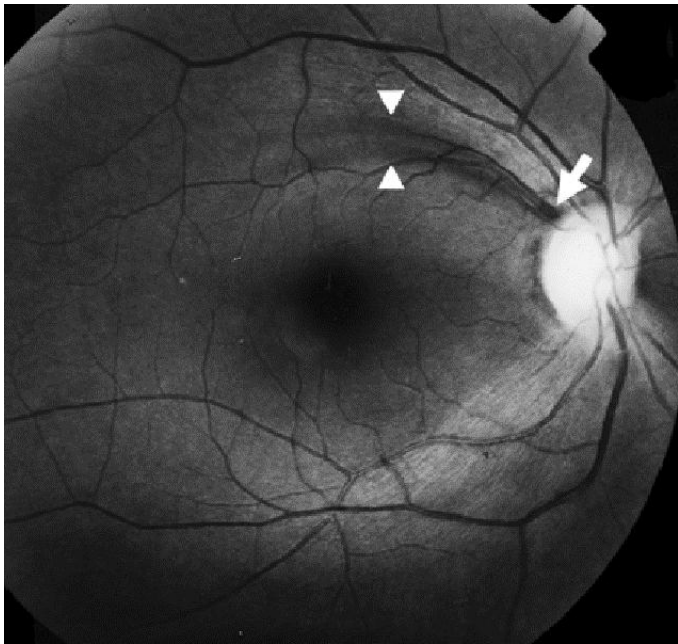
RNFL: focal loss





RNFL defects: focal loss

- Slit:
  - Larger than an arteriole in width
  - Travels back to the ONH
- Wedge:
  - Expanding focal damage
  - Associated with notching and arcuate VF defect



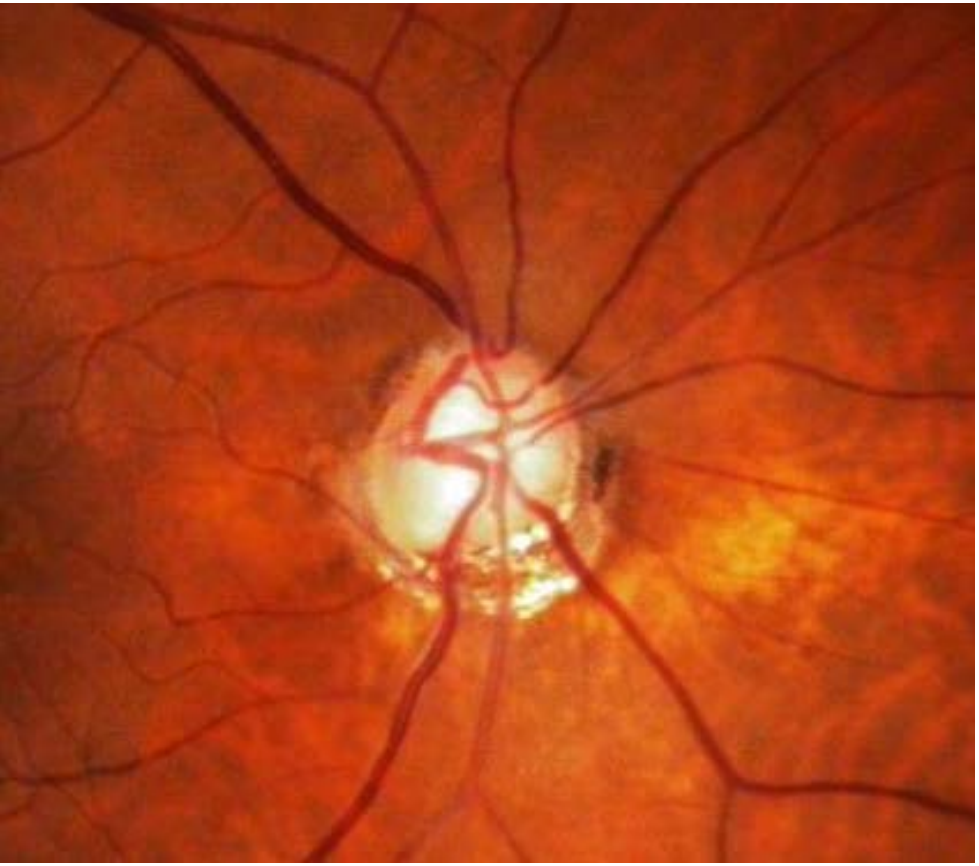
Take-home points

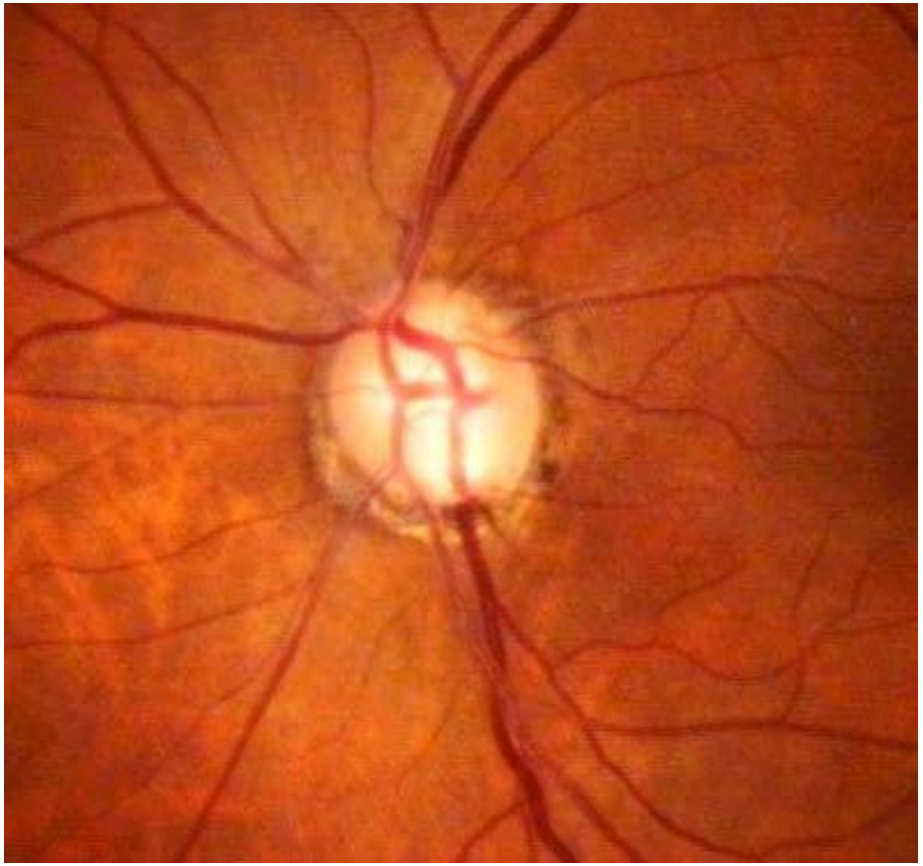
- C/D ratio is NOT the only factor to consider when evaluating the ONH
- You MUST give due diligence to the neuroretinal rim
  - Focal defects
  - Generalized thinning
- You MUST evaluate any asymmetry in the superior and inferior poles of the same eye
- You MUST evaluate any asymmetry between the two eyes
- Always remember, glaucoma is cupping WITHOUT pallor
- Use imaging technologies and perimetry to evaluate suspicious nerves and high-risk patients

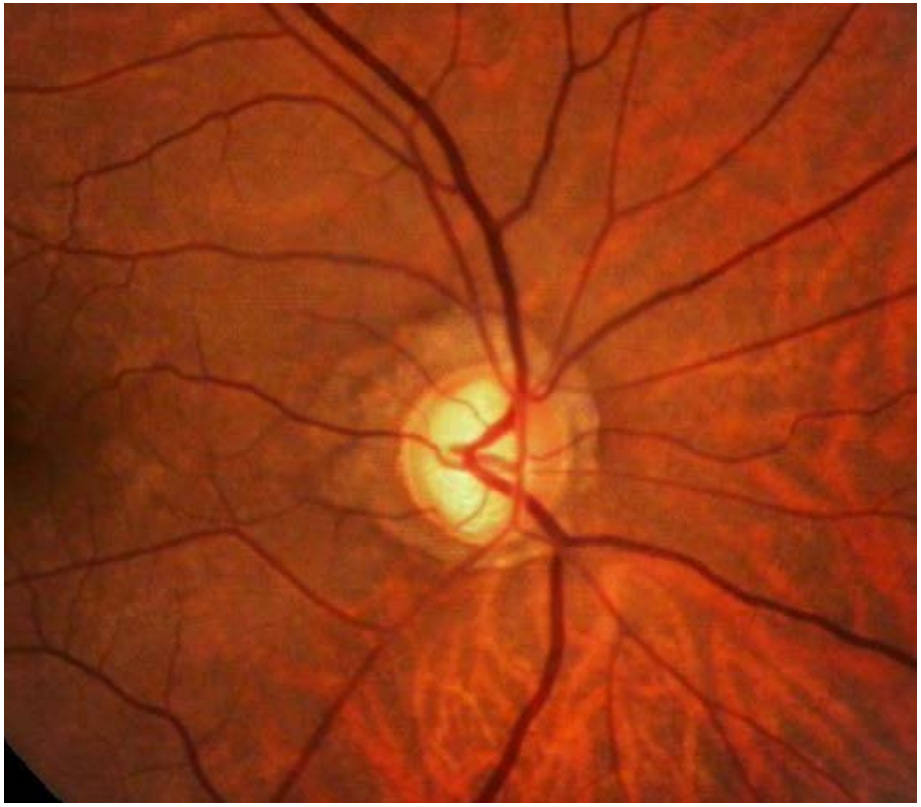
Optic nerve evaluation checklist

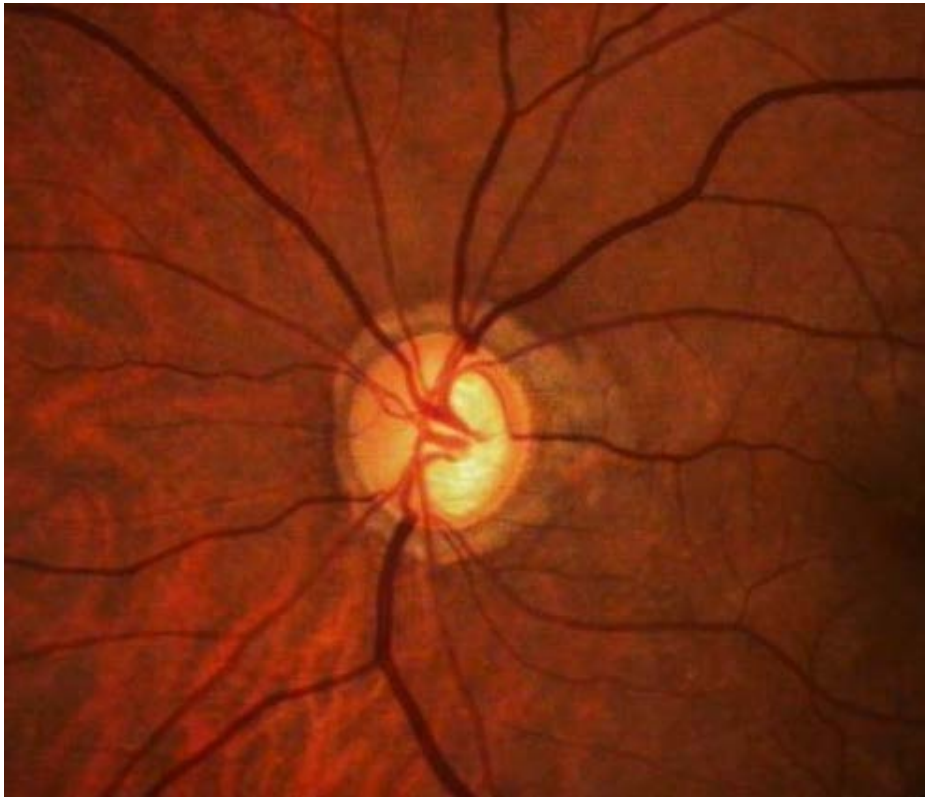
- Measure size and shape of the ONH
- Evaluate size and shape of the optic cup
- Determine the vertical and horizontal C/D ratio
- Compare the expected C/D ratio based on vertical disc diameter
- Neuroretinal rim integrity/thinning/notching/pallor
  - Superior vs inferior
  - OD vs OS
- Vascular changes: disc hemorrhages, nasalization of vessels, arteriole narrowing, optociliary shunt vessels, baring of vessels
- Peripapillary atrophy
- RNFL defects: diffuse/focal

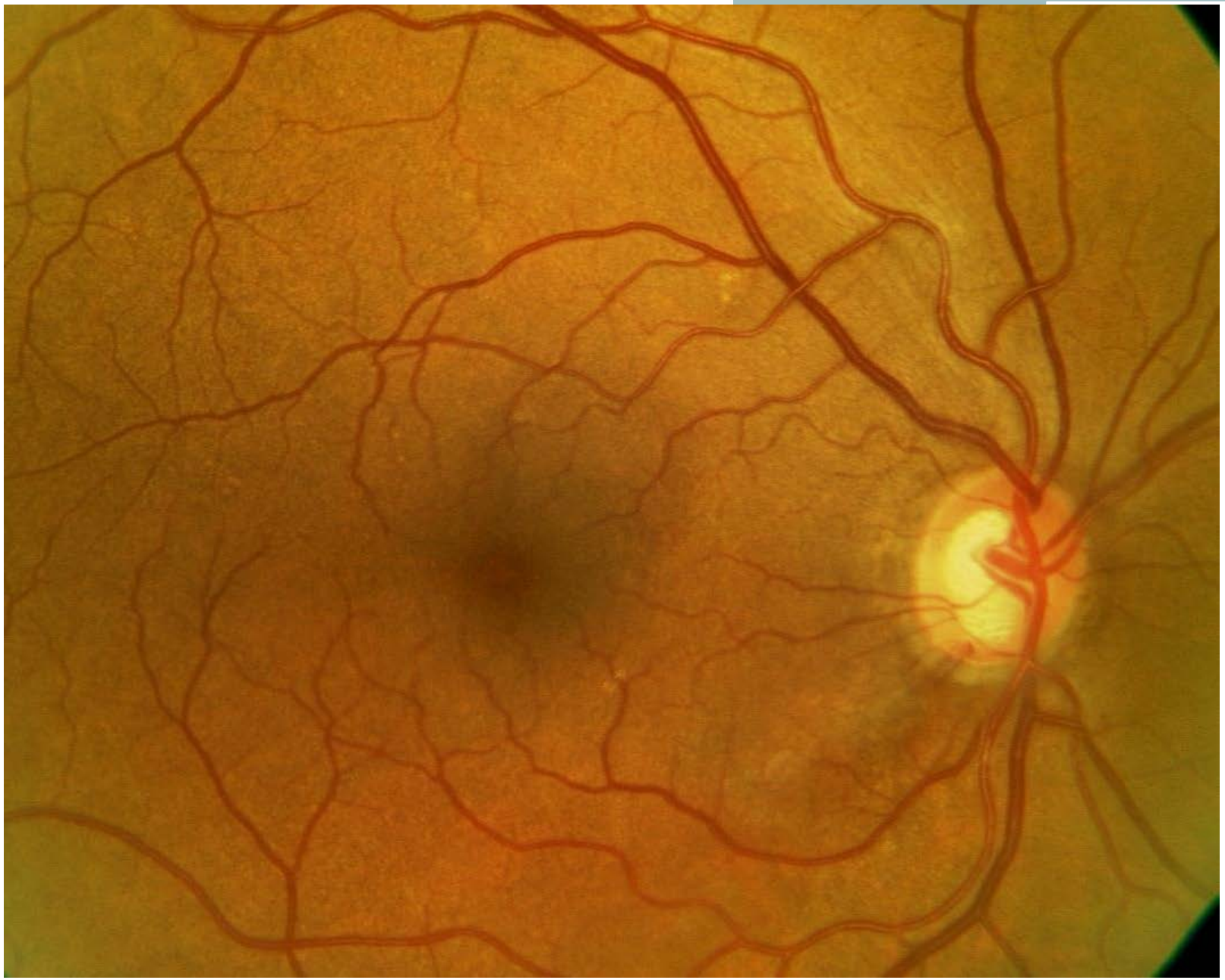
Let us look at some nerves!



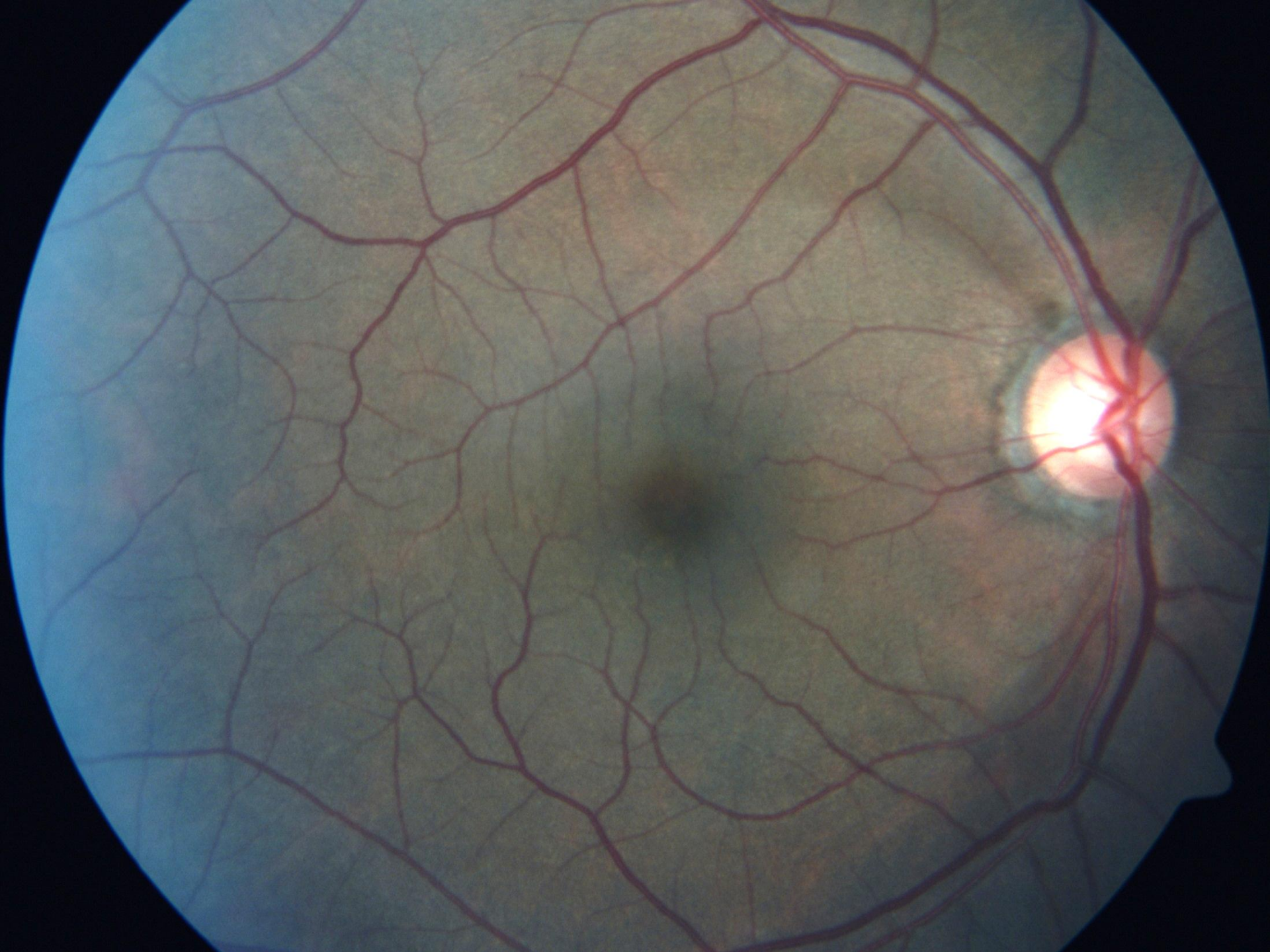




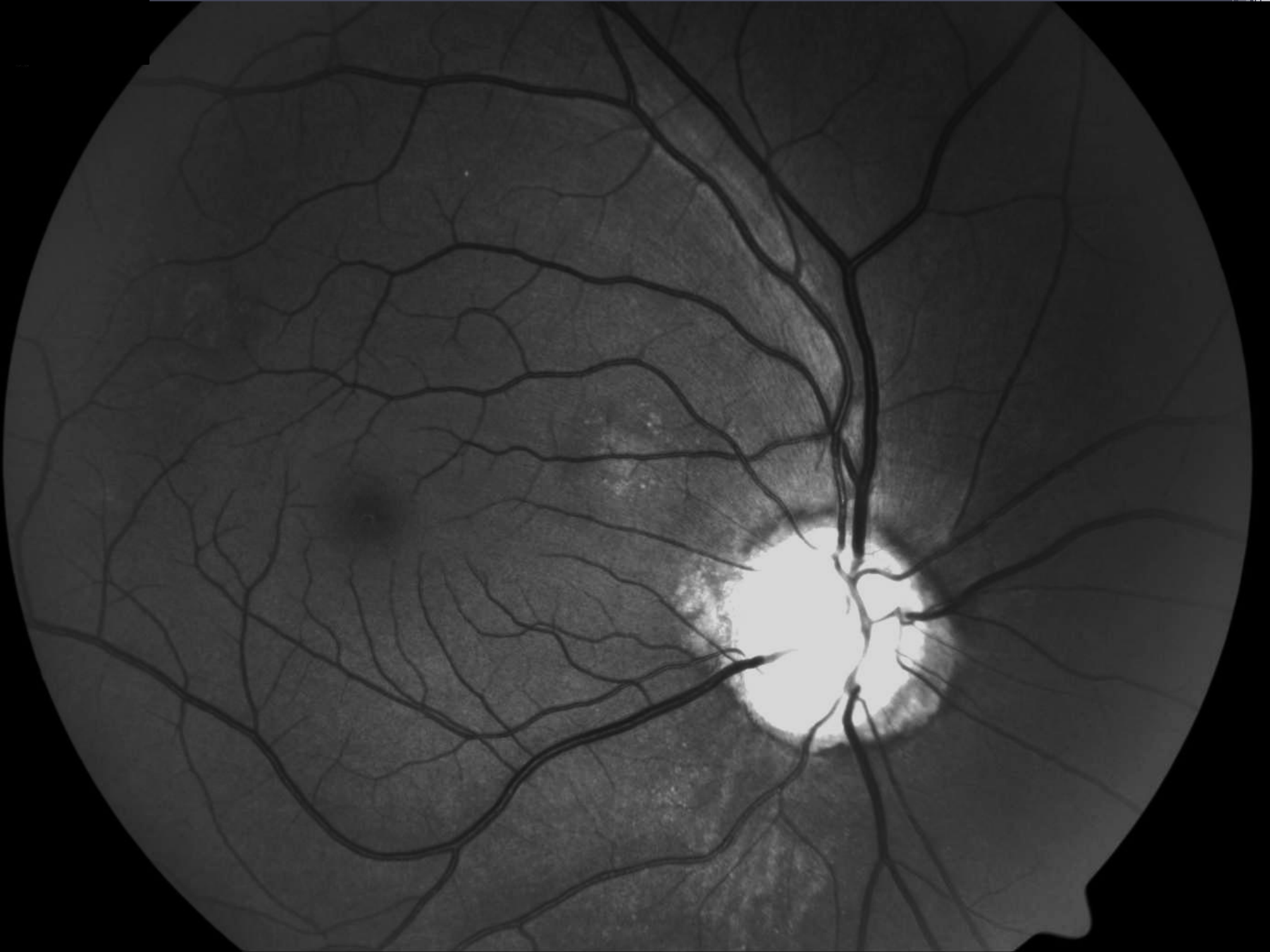





OD




OD



Thank you!