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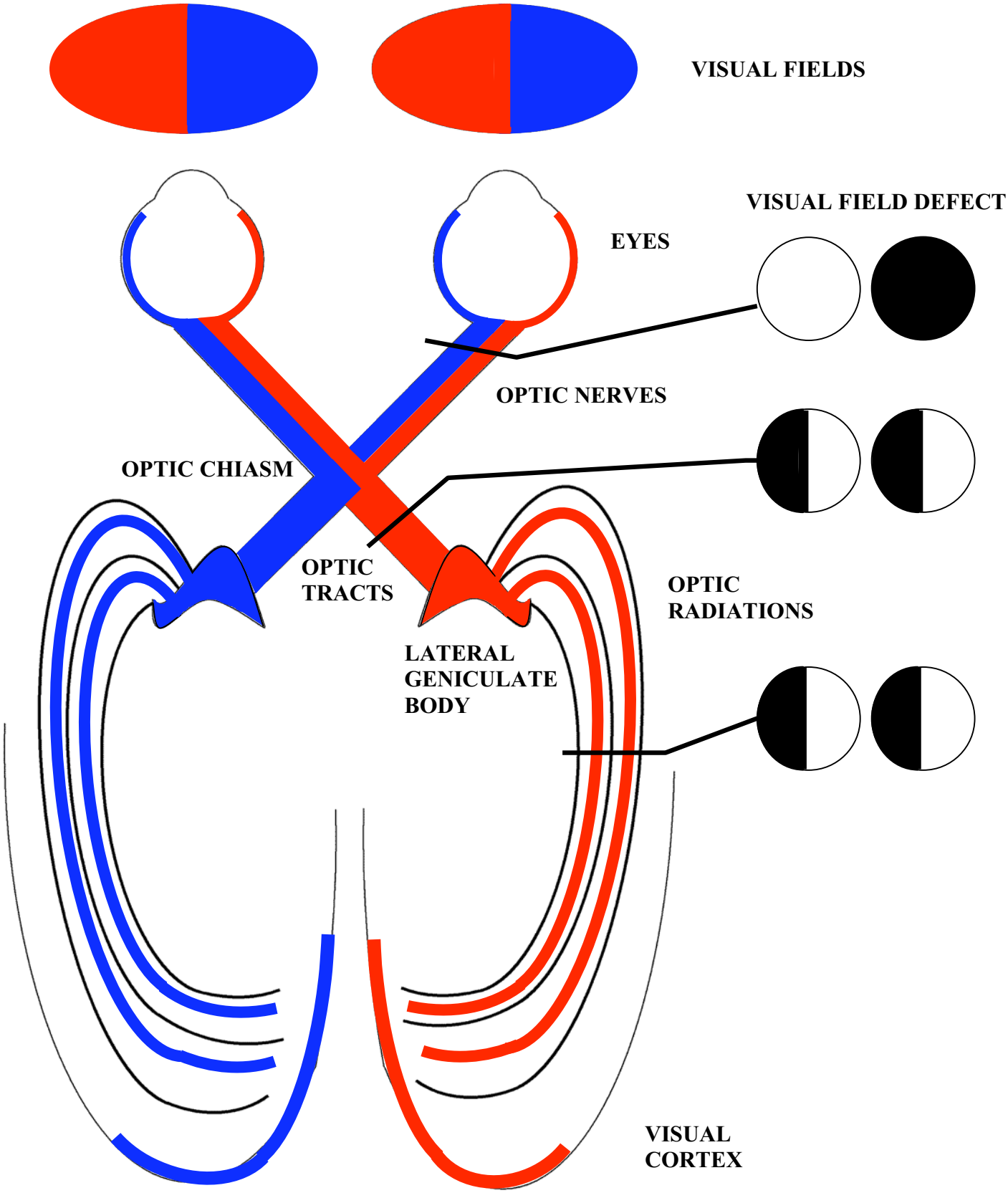


Figure 1. Visual pathways and visual field defects resulting from injury to the pathways

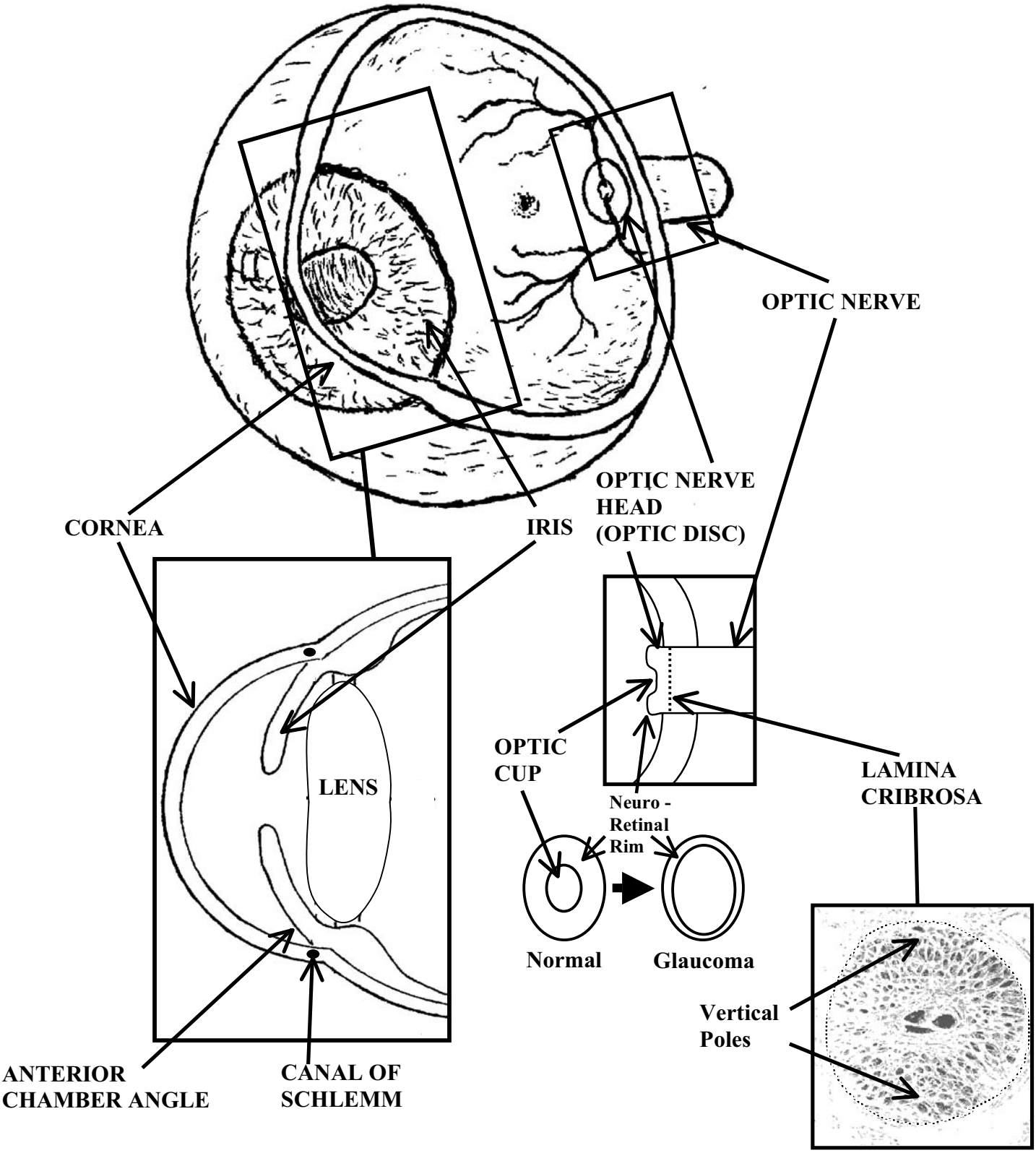


Figure 2. Schematic representation of the anatomy of the eye

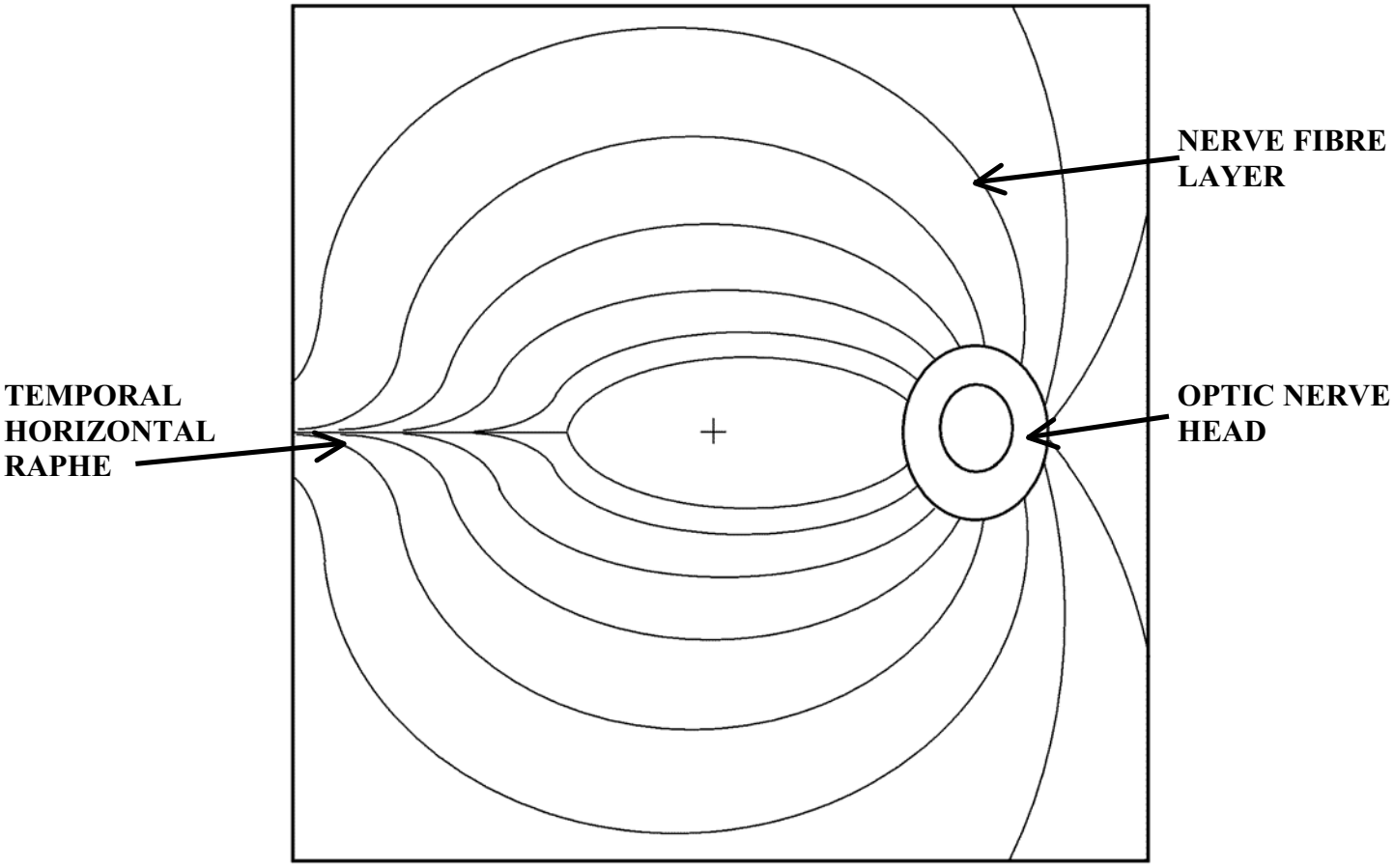


Figure 3. Schematic representation of the nerve fibre layer

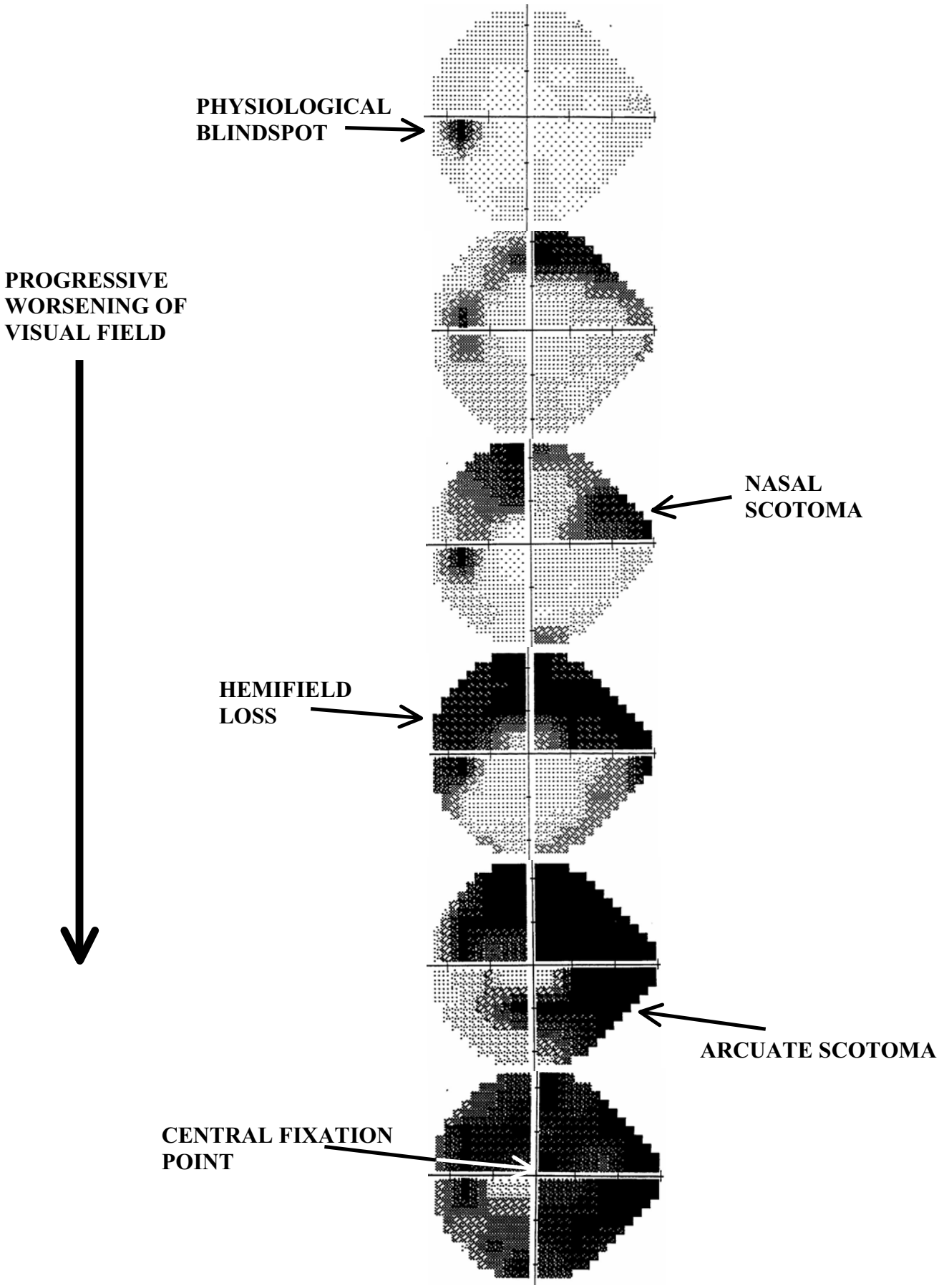


Figure 4. Grey-scale of the left visual field showing progressive loss from glaucoma

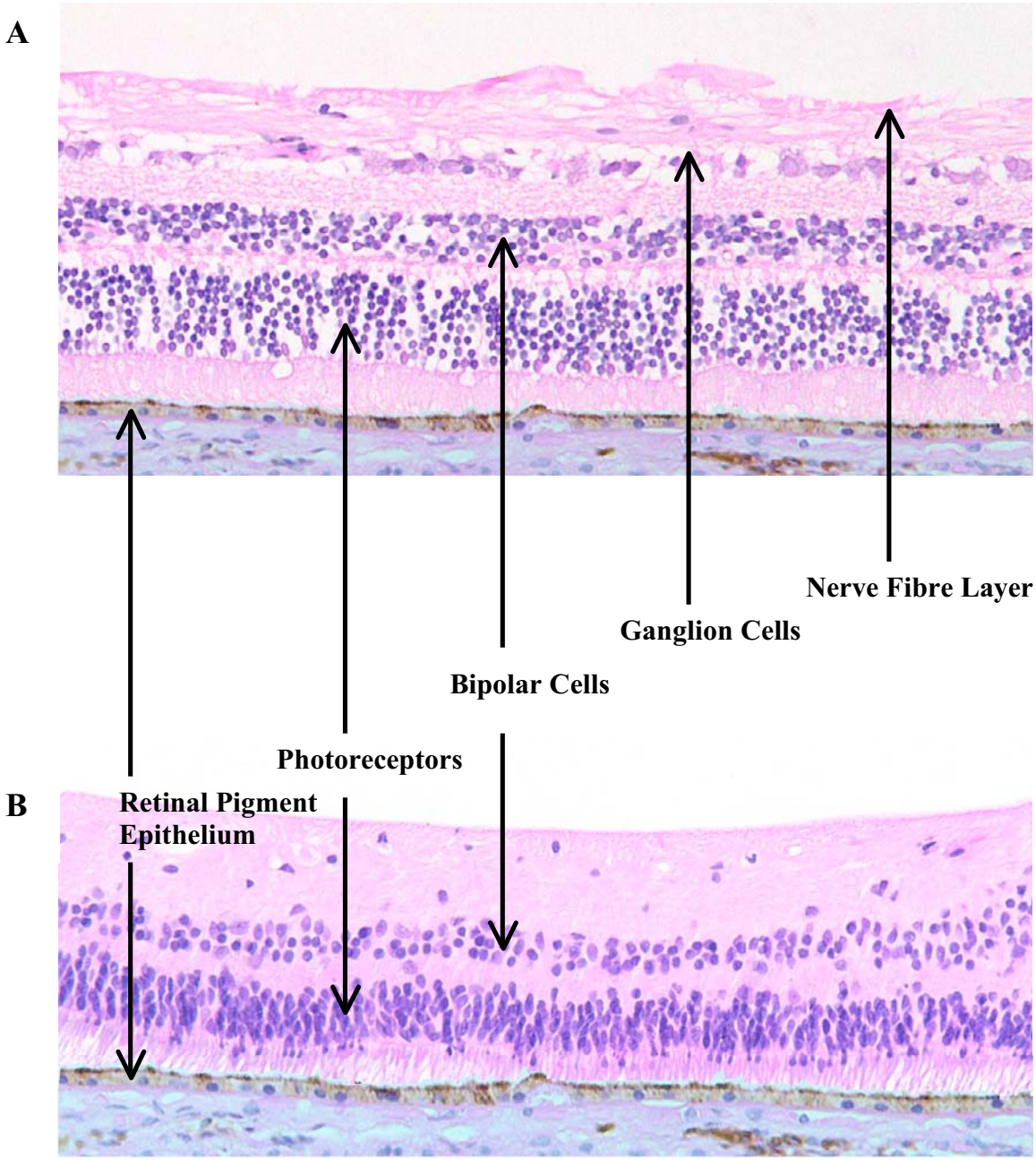


Figure 5. Micrograph of retina in (A) Healthy patient and (B) Glaucoma patient

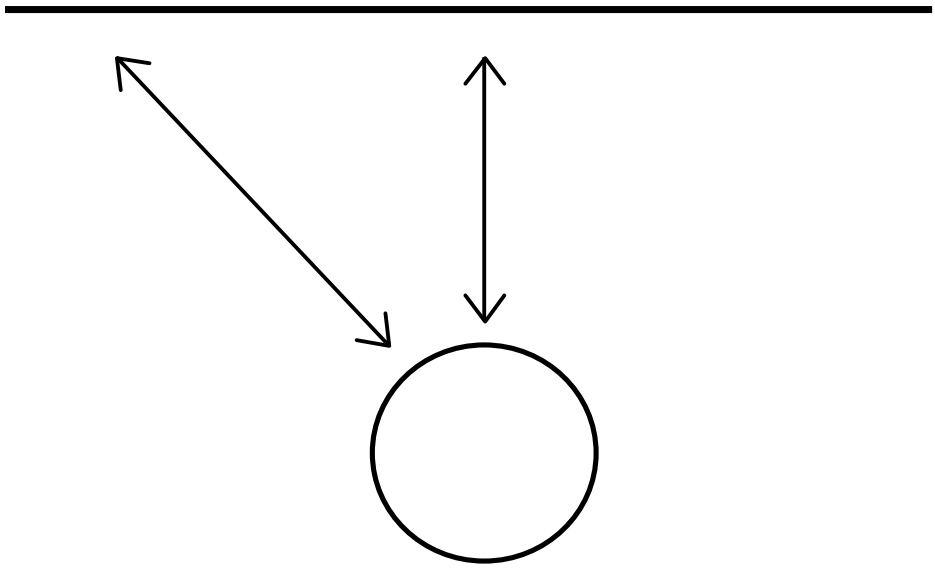


Figure 6. Schematic representation of visual field testing with a flat screen (campimetry)

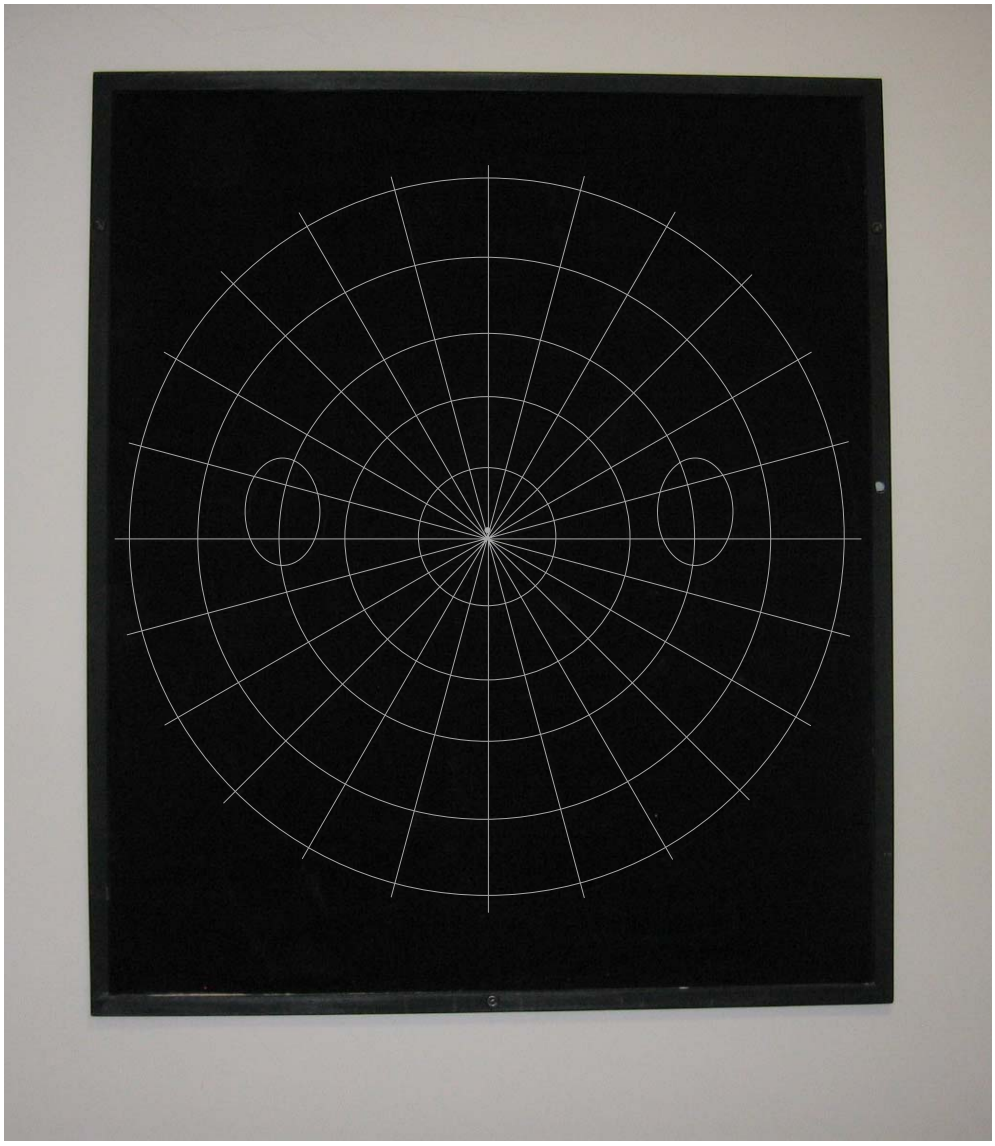


Figure 7. Bjerrum screen

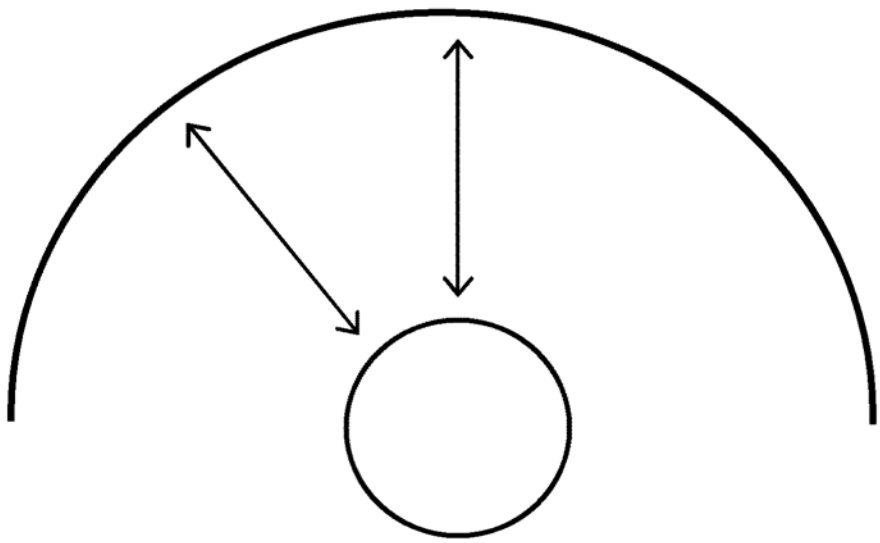


Figure 8. . Schematic representation of visual field testing with a curved screen (perimetry)

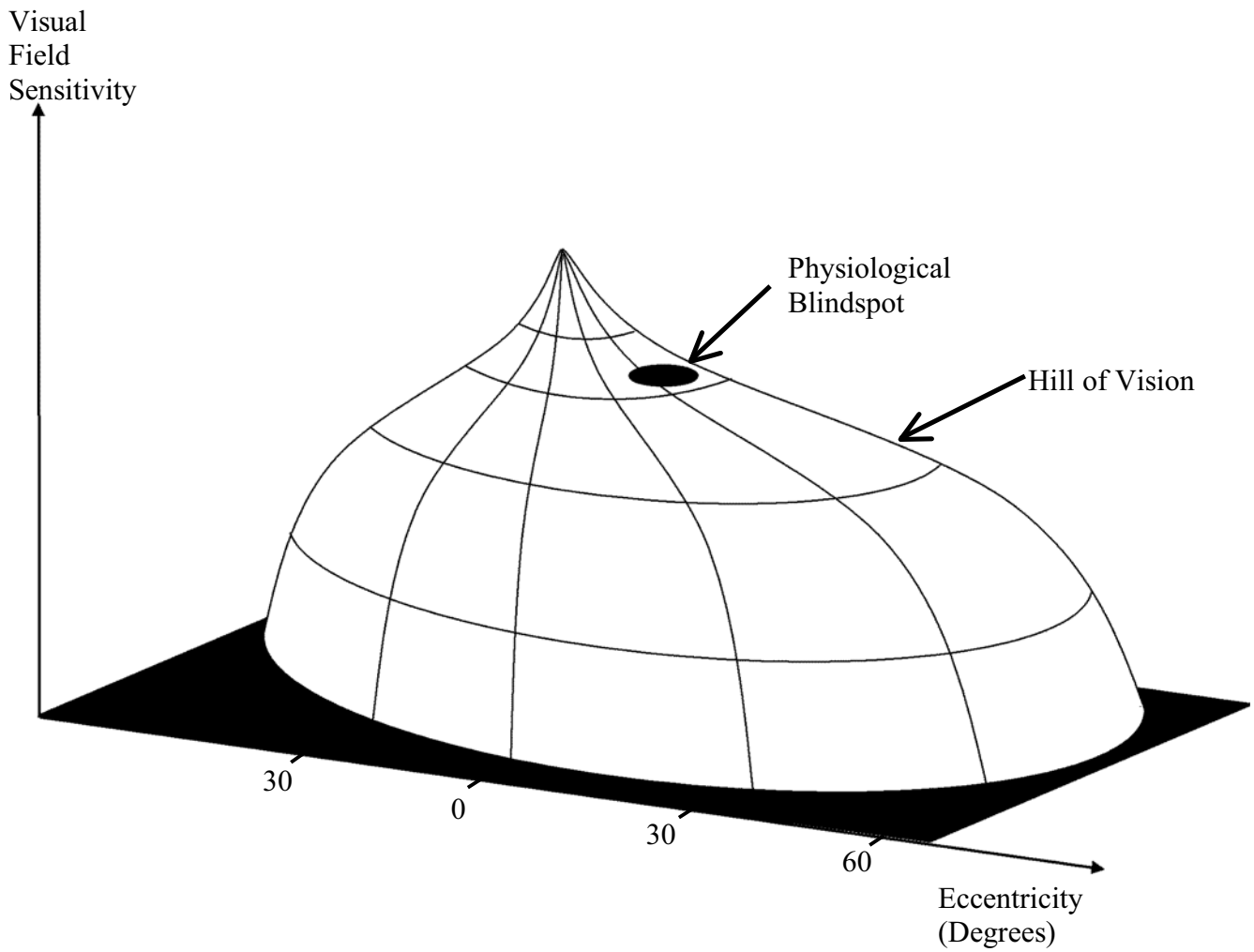


Figure 9. The 'Island of Traquair'

Figure 10 The Goldman Perimeter

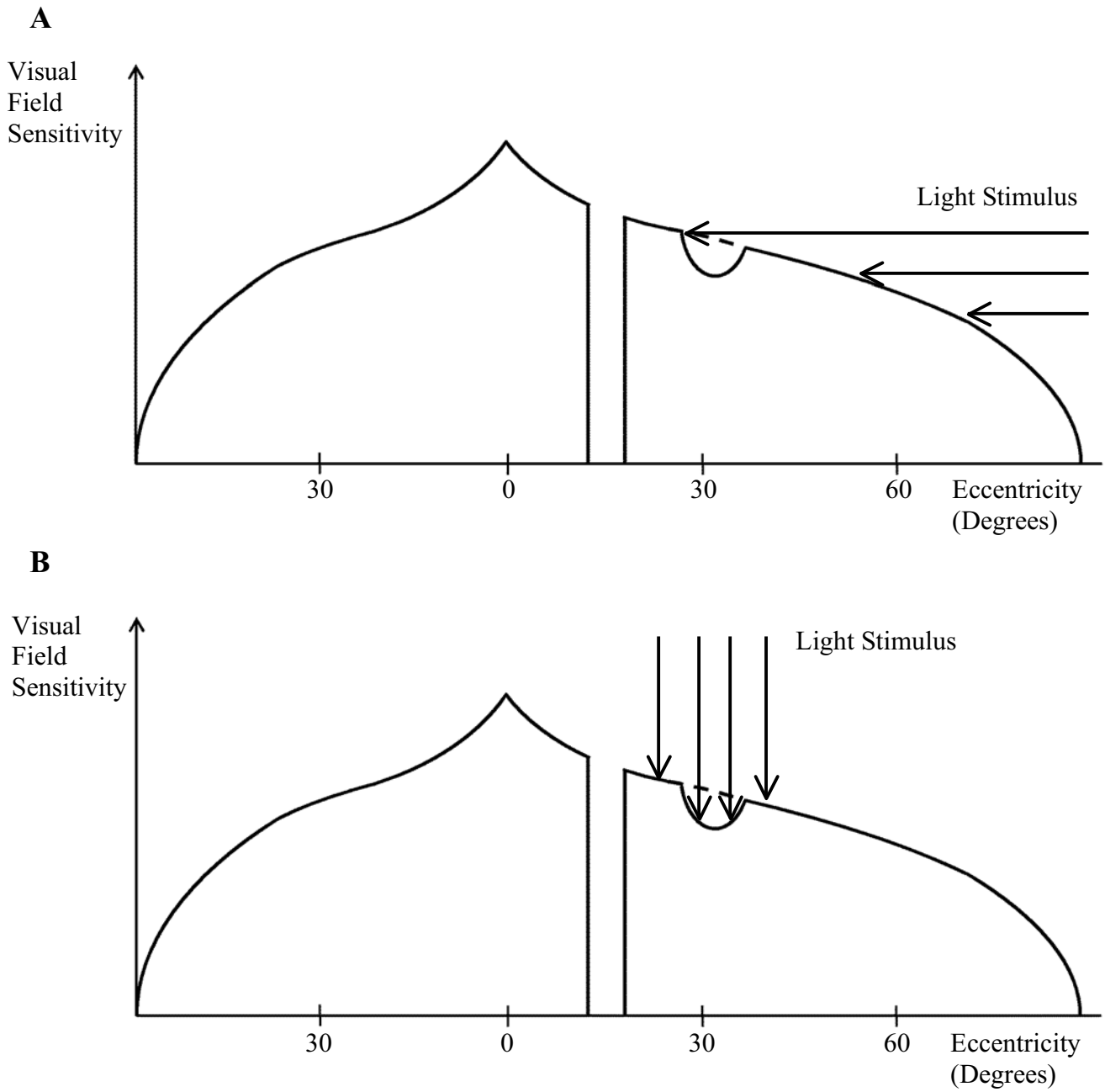


Figure 11 Mapping a small visual field scotoma using (A) kinetic and (B) static perimetry

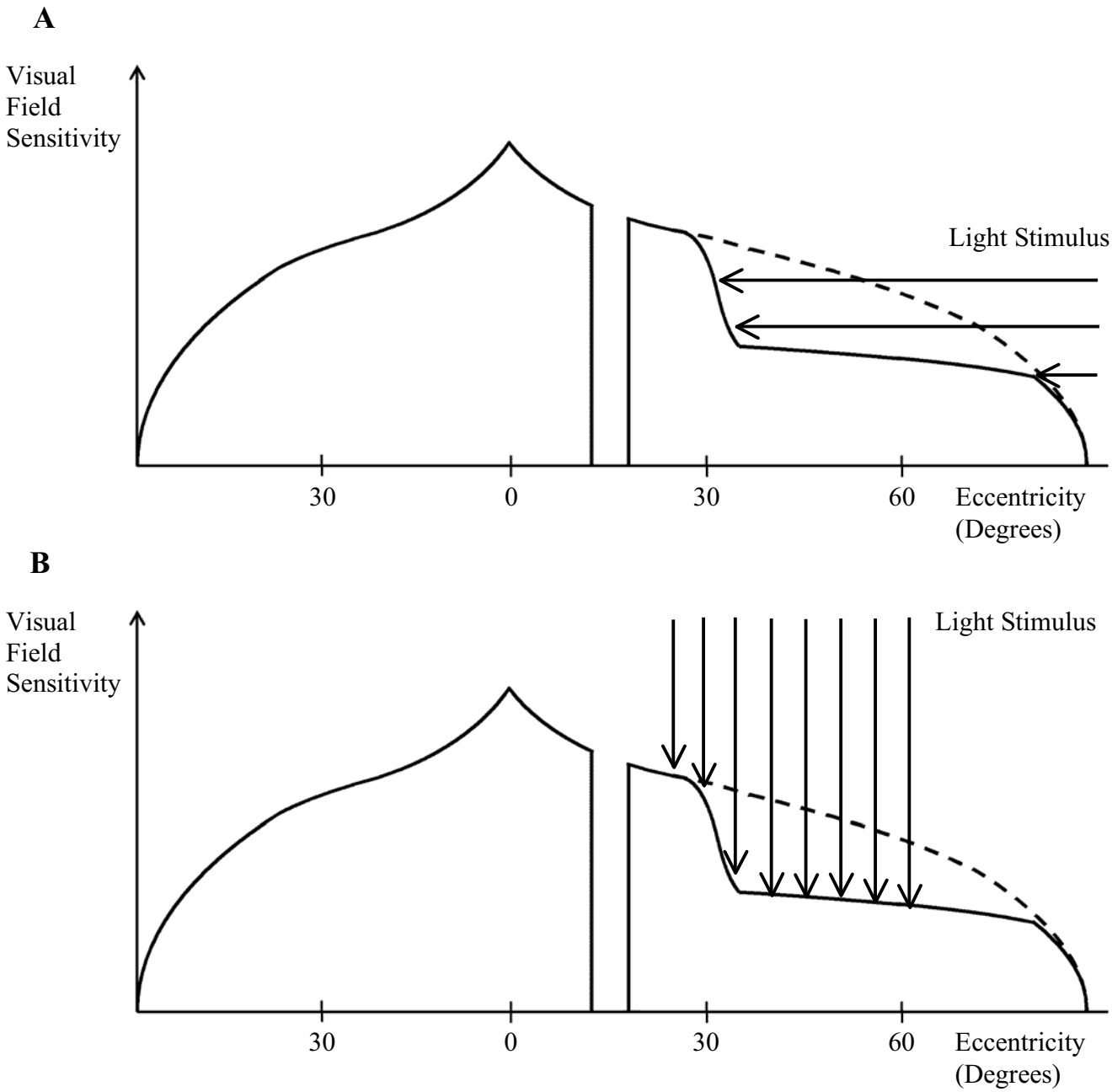


Figure 12 Mapping a steep scotoma using (A) kinetic and (B) static perimetry

Figure 13. The Humphrey Field Analyzer

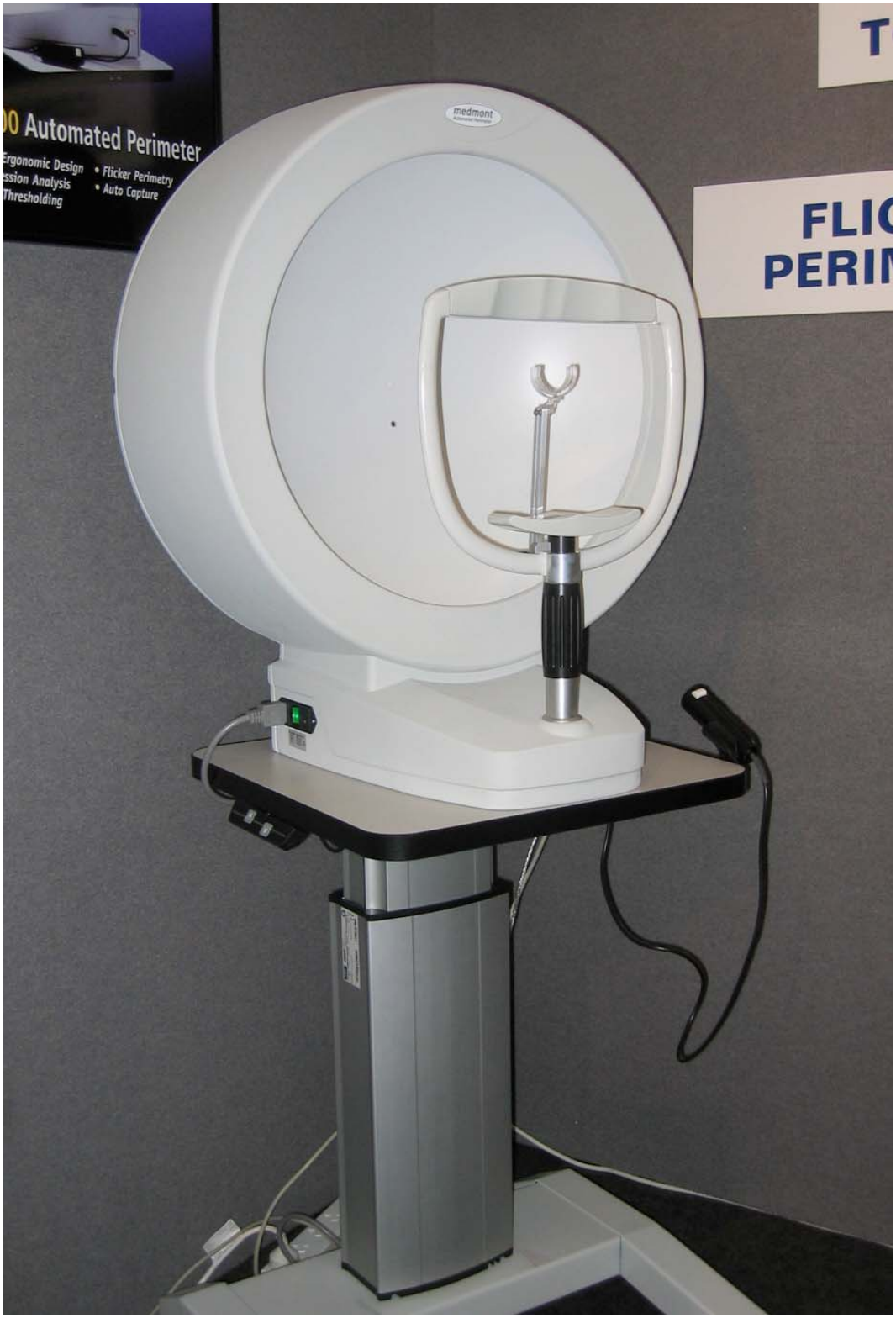


Figure 14. The Medmont perimeter

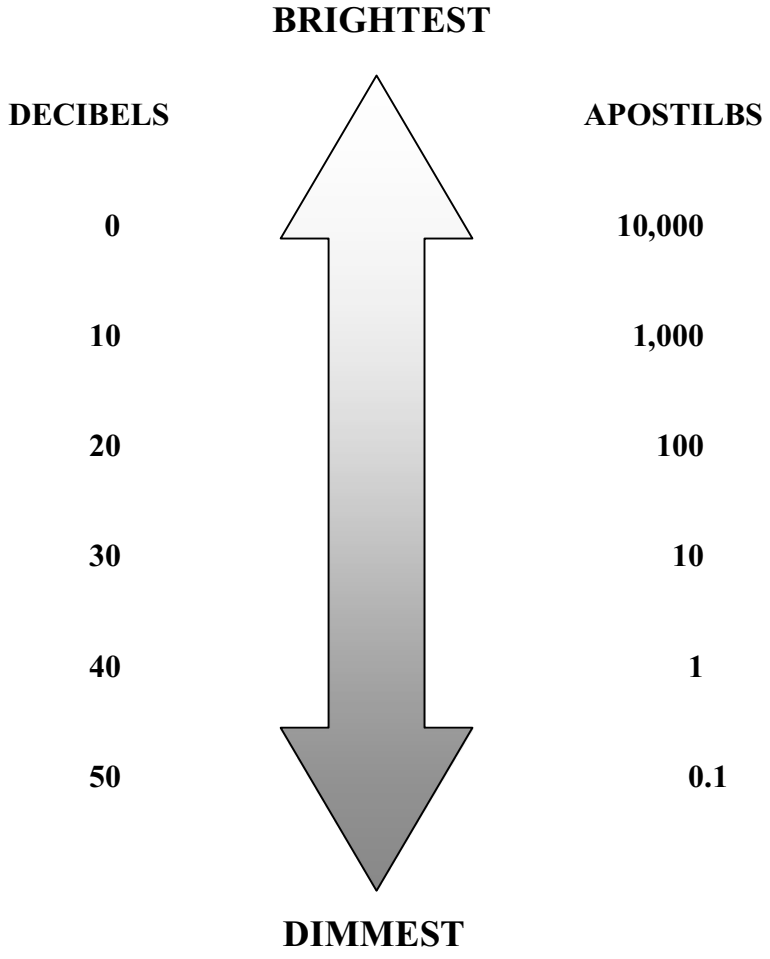


Figure 15. The relationship between stimulus brightness (Apostilbs) and visual field sensitivity (Decibels)

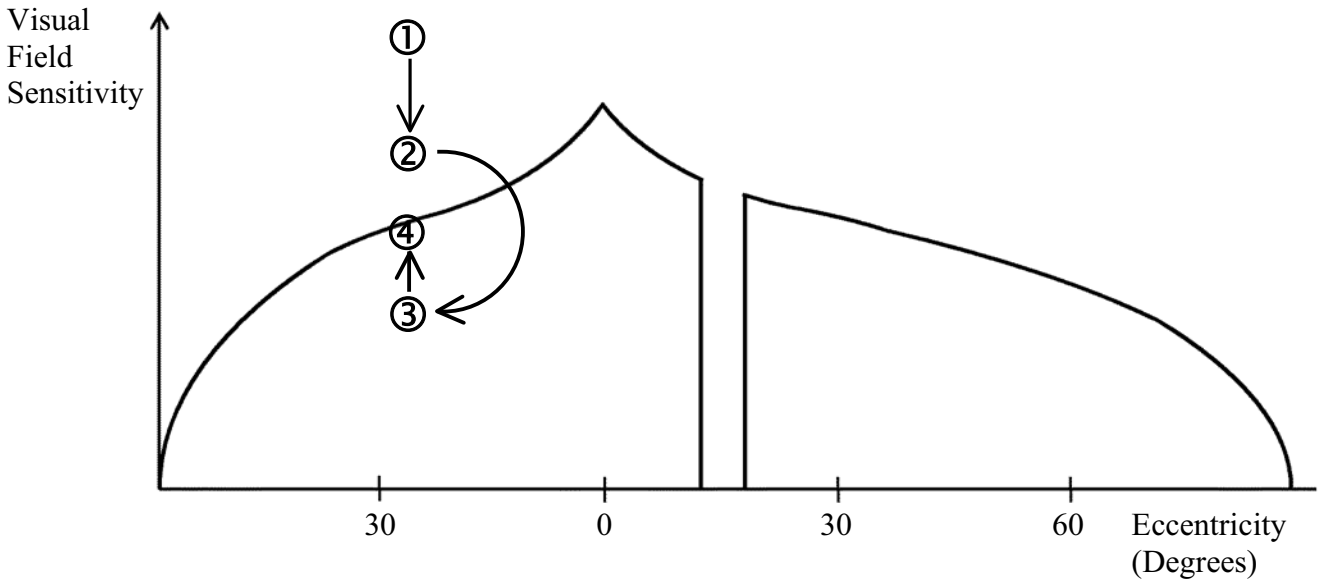


Figure 16. Schematic representation of the 'Stair-case' method used in static automated perimetry

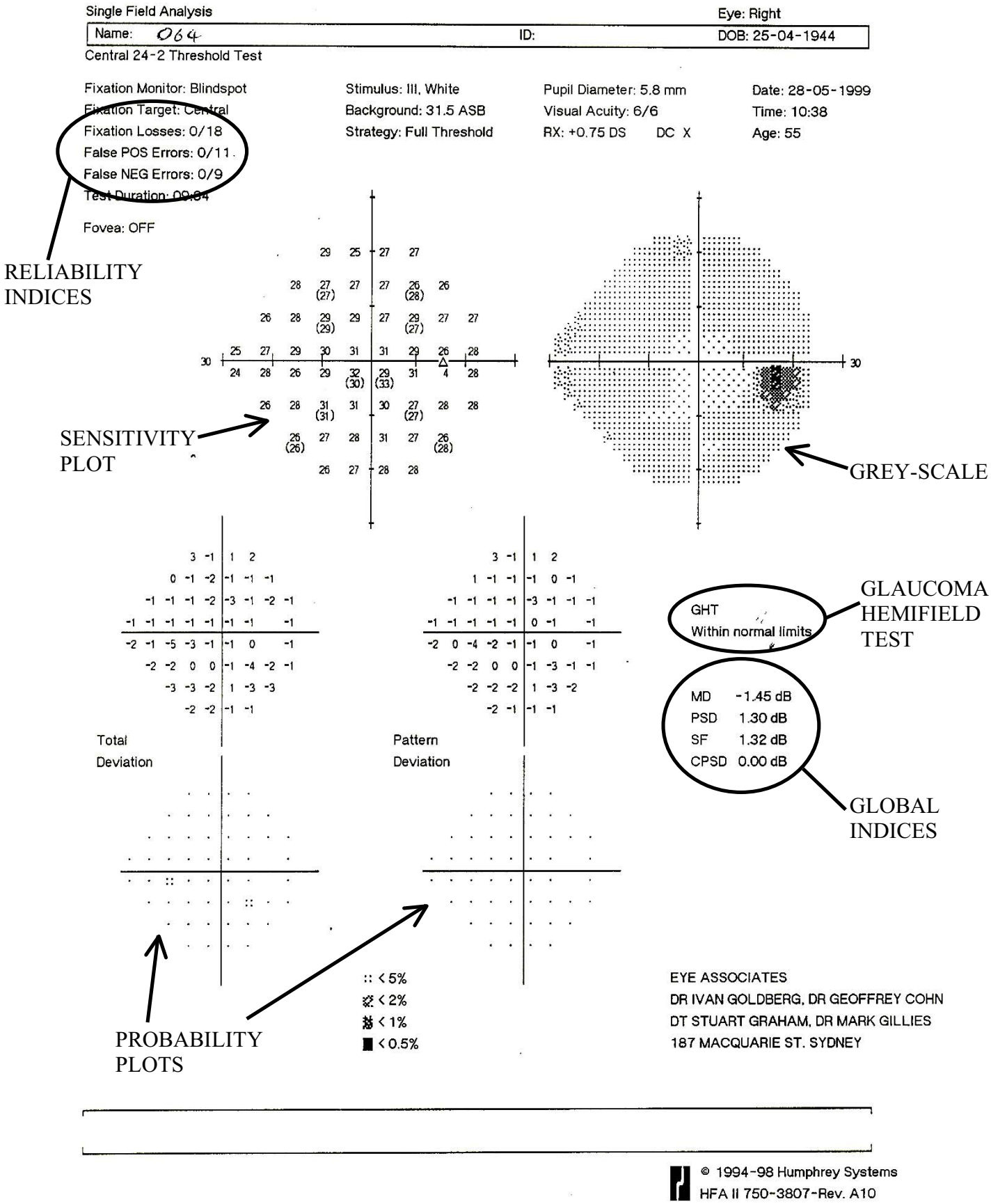
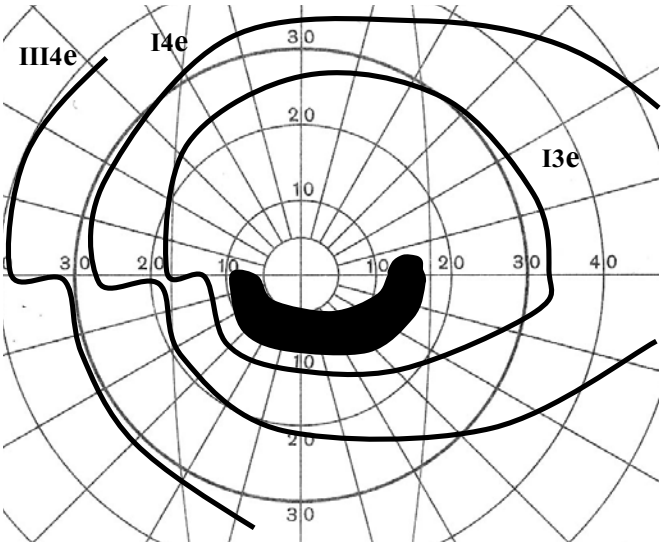


Figure 17. Print-out of the visual field from a right eye using a Humphrey Field Analyzer

A



B

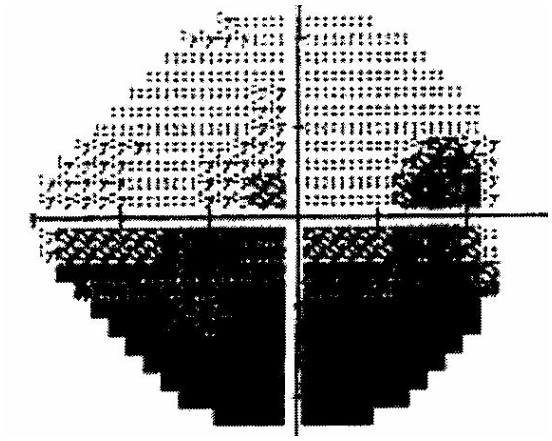


Figure 18. Visual field from the right eye using (A) manual kinetic perimetry and (B) automated static perimetry

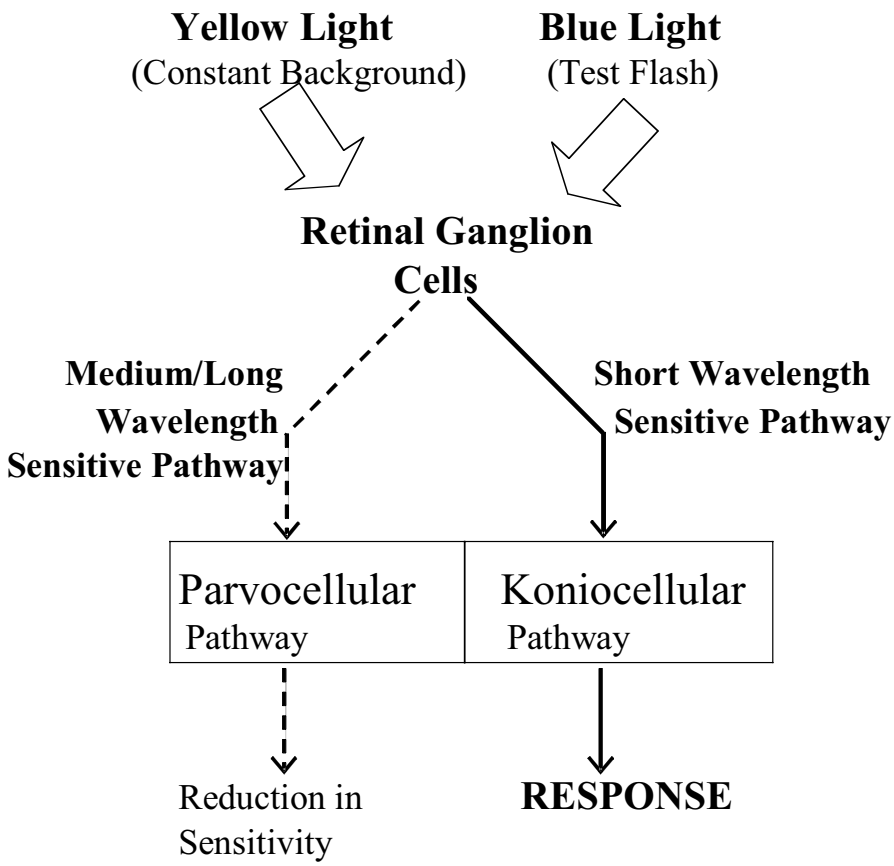


Figure 19. Schematic representation of the colour sensitive visual pathways

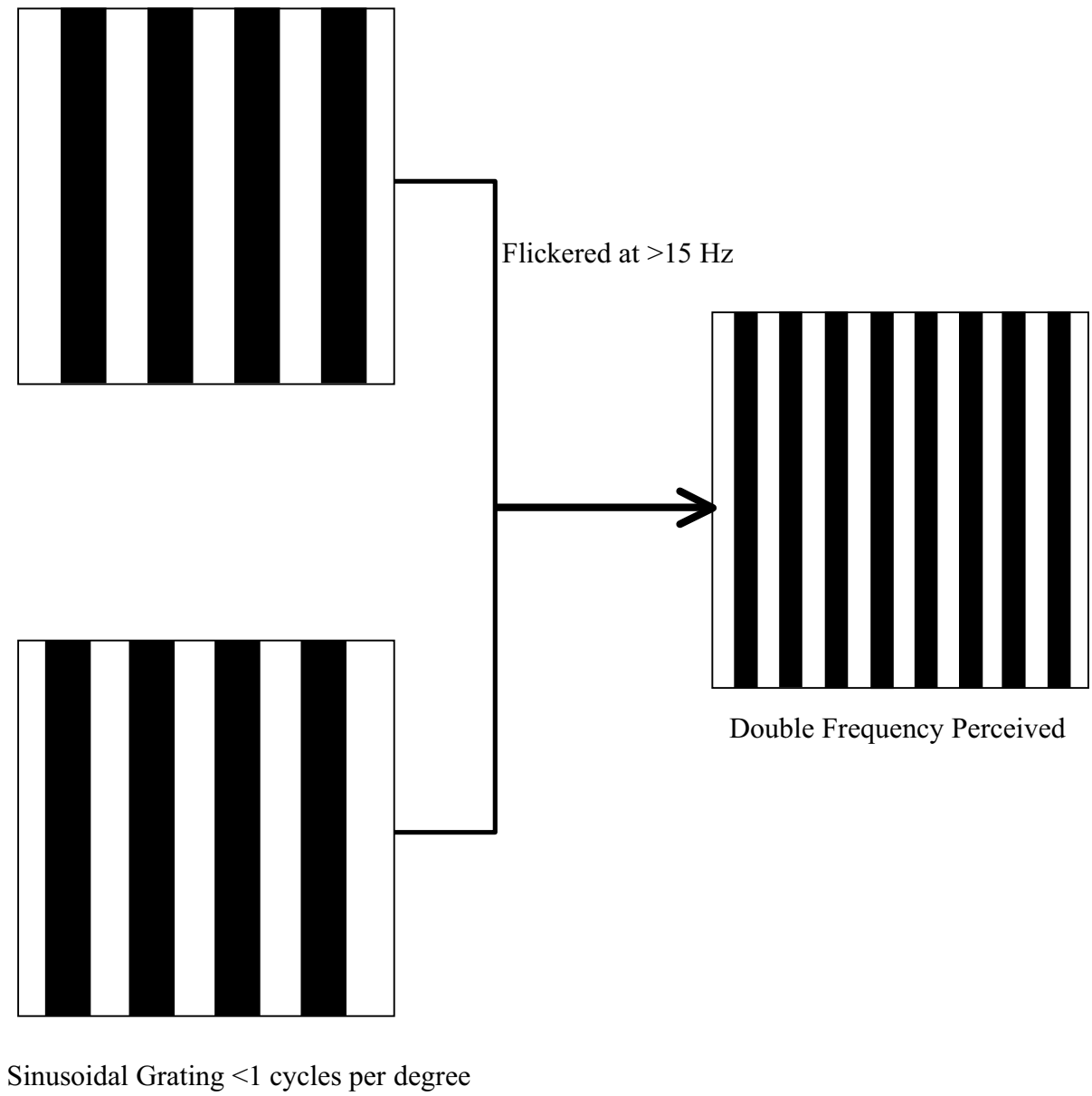


Figure 20. Schematic representation of the target used in frequency doubling perimetry

Figure 21. The Frequency Doubling Perimeter

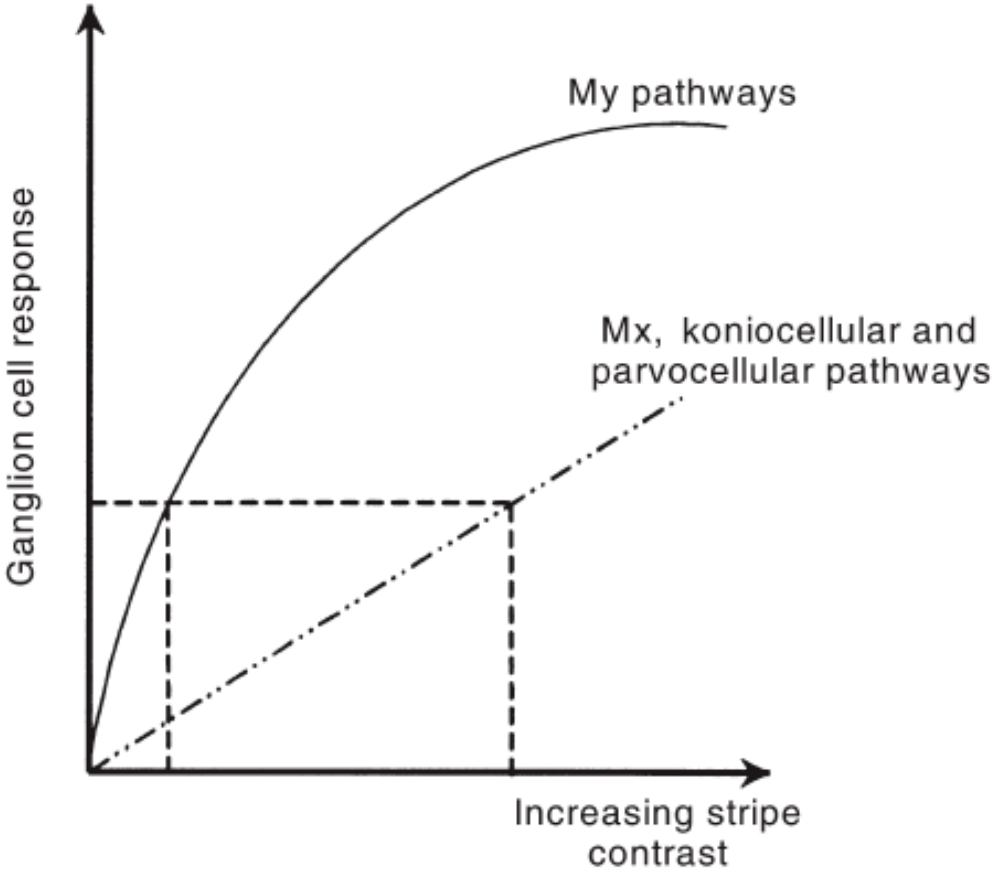


Figure 22. Relationship between change in target stripe contrast and My, Mx, Koniocellular and Parvocellular pathway responses (modified with permission from Prof. E Kaplan).[217] Shows the difference in target stripe contrast needed to achieve the same ganglion cell response.

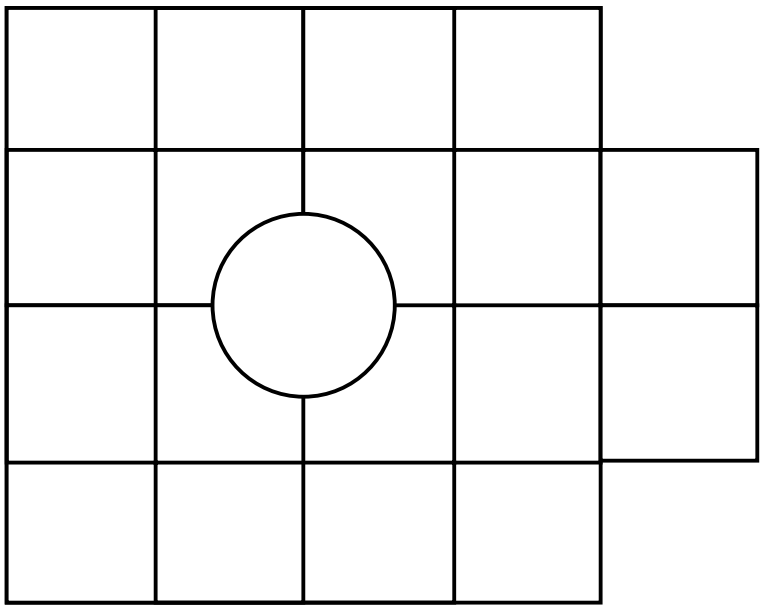


Figure 23. The testing pattern used by the frequency doubling perimeter to test the left eye

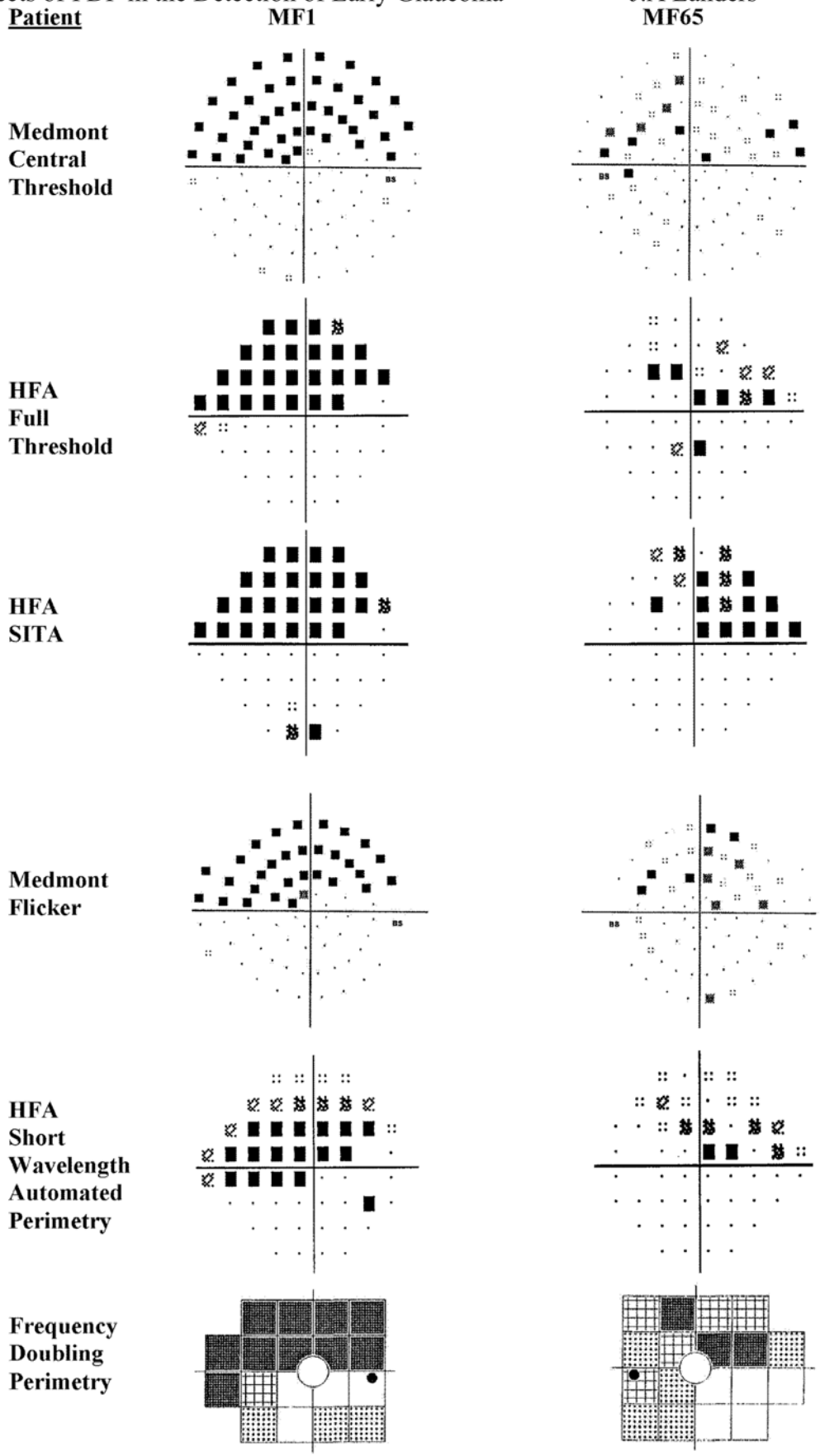


Figure 24. Pattern deviations from two patients (MF1, MF65).
Medmont probabilities: , < 6 dB; , < 12 dB; , <18 dB.
HFA probabilities: , P < 5%; , P < 2%; , P < 1%; , P < 0.5%.
FDP probabilities: , P < 5%; , P < 1%; , P < 0.5%

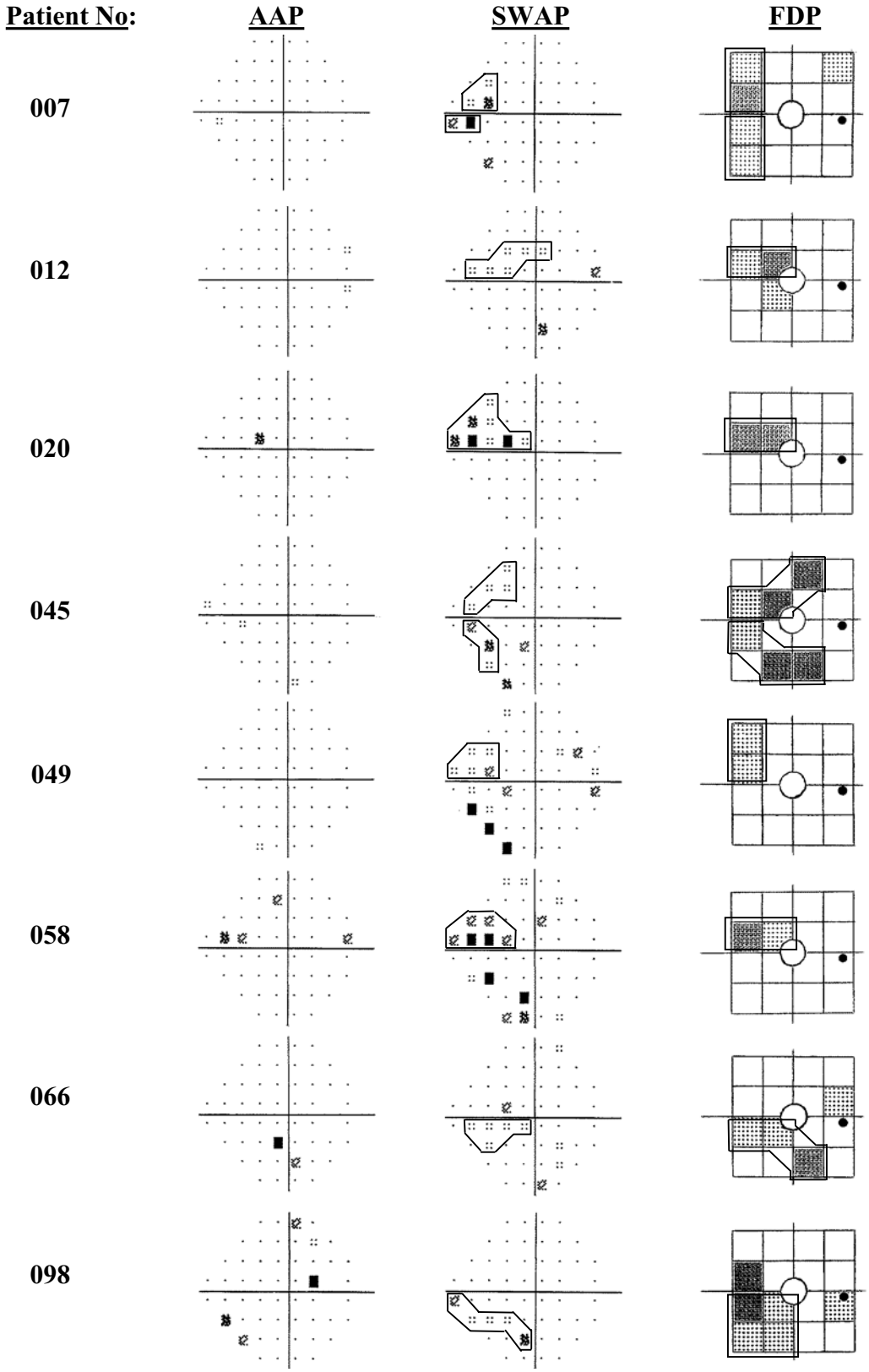


Figure 25. Pattern deviations from those patients both with short wavelength automated perimetry (SWAP) and frequency doubling perimetry (FDP) losses. Achromatic automated perimetry (AAP) and SWAP probabilities: ∷, P < 5%; ⁂, P < 2%; ▒, P <1%; ■, P < 0.5%.
FDP probabilities: ▦, P < 5%; ▩, P < 1%.
Areas of visual field loss are outlined.

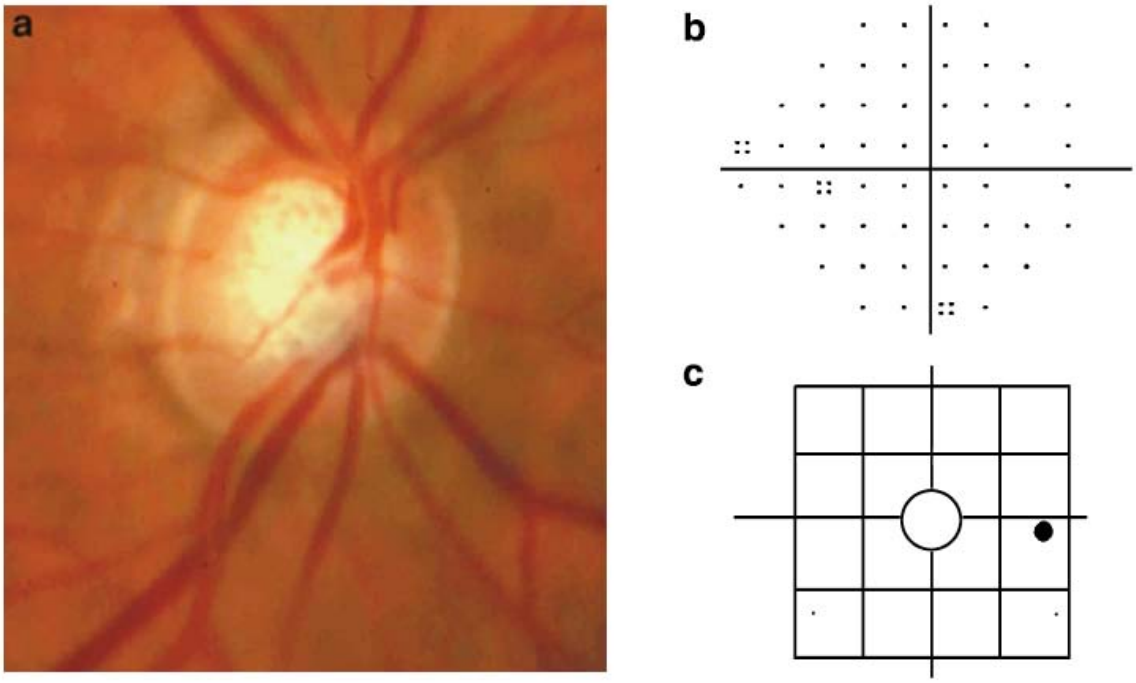


Figure 26. (a) Disc photograph; (b) short wavelength automated perimetry visual field; and (c) frequency doubling perimetry visual field from a false negative subject.

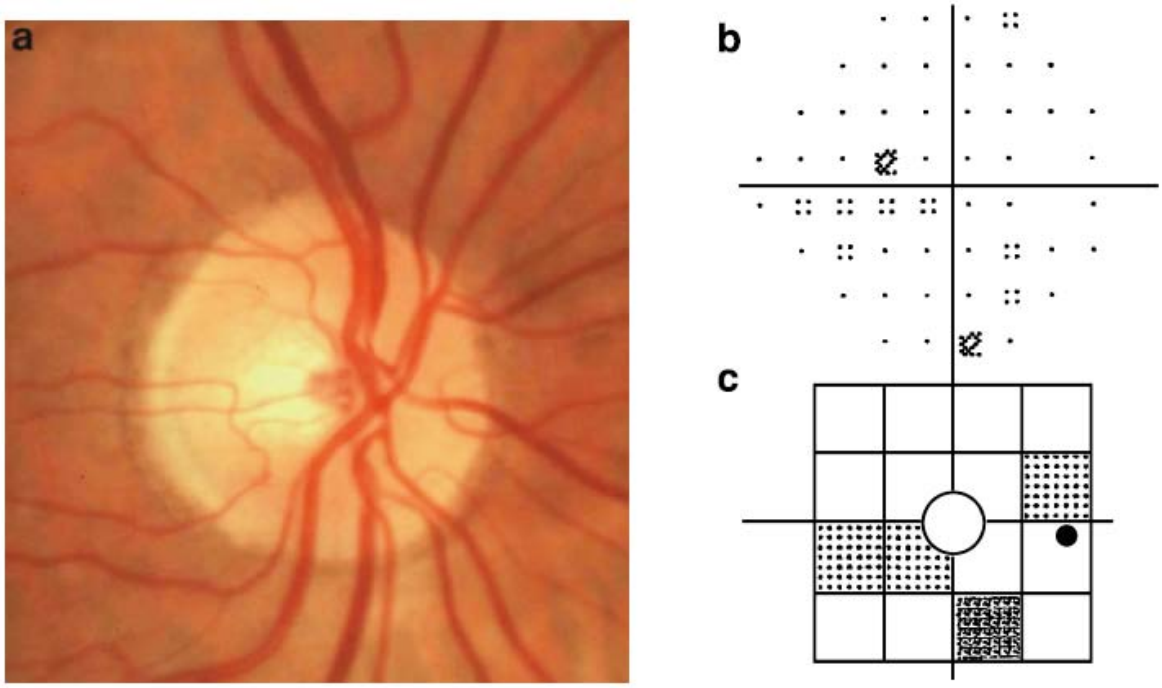


Figure 27. (a) Disc photograph; (b) short wavelength automated perimetry visual field; and (c) frequency doubling perimetry visual field from a false positive subject.

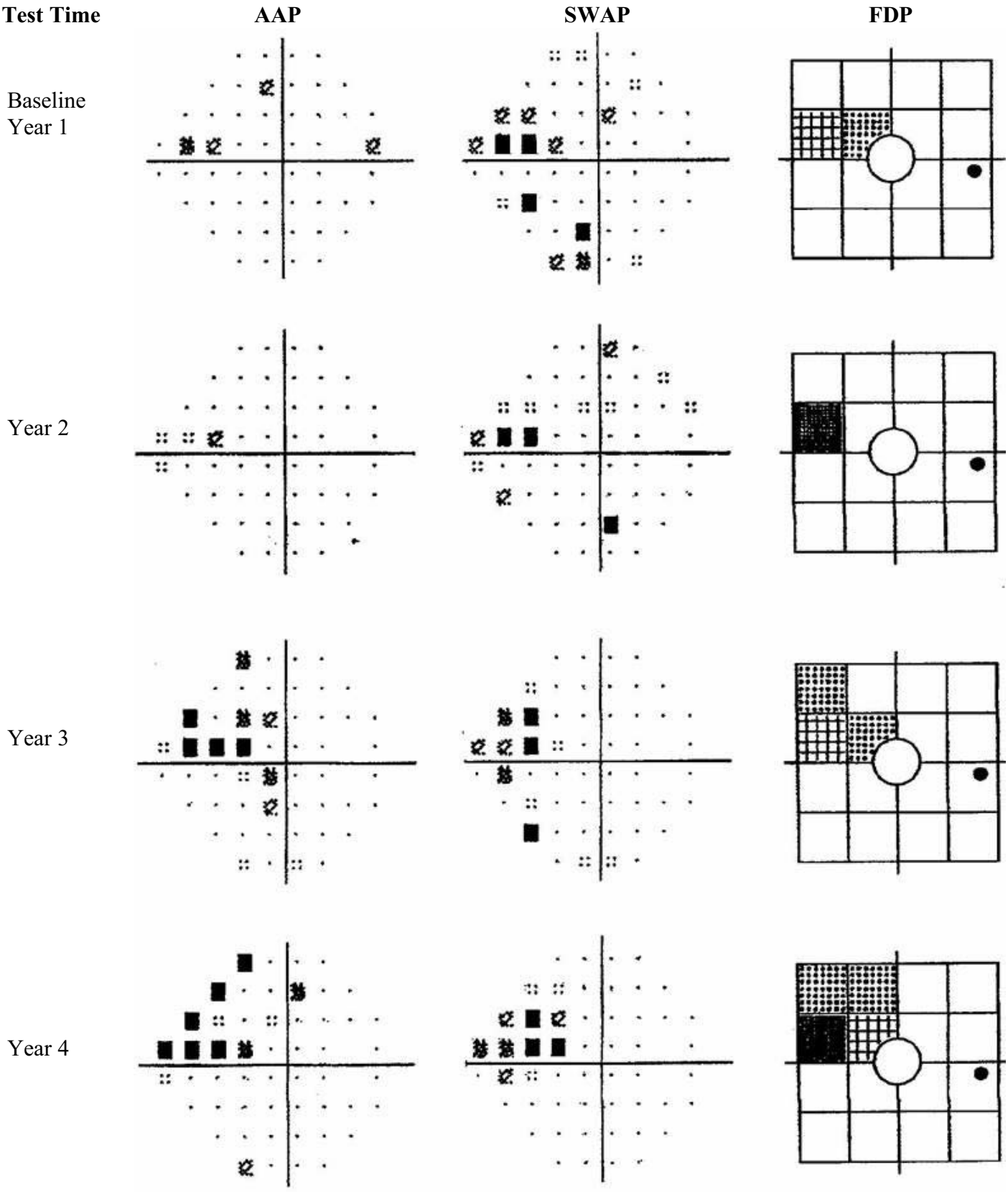


Figure 28. Pattern deviations from Patient **058** for Achromatic Automated Perimetry (AAP), Short Wavelength Automated Perimetry (SWAP) and Frequency Doubling Perimetry (FDP) over the four year study period.
HFA probabilities: , P < 5%; , P < 2%; , P < 1%; , P < 0.5%.
FDP probabilities: , P < 5%; , P < 1%; , P < 0.5%

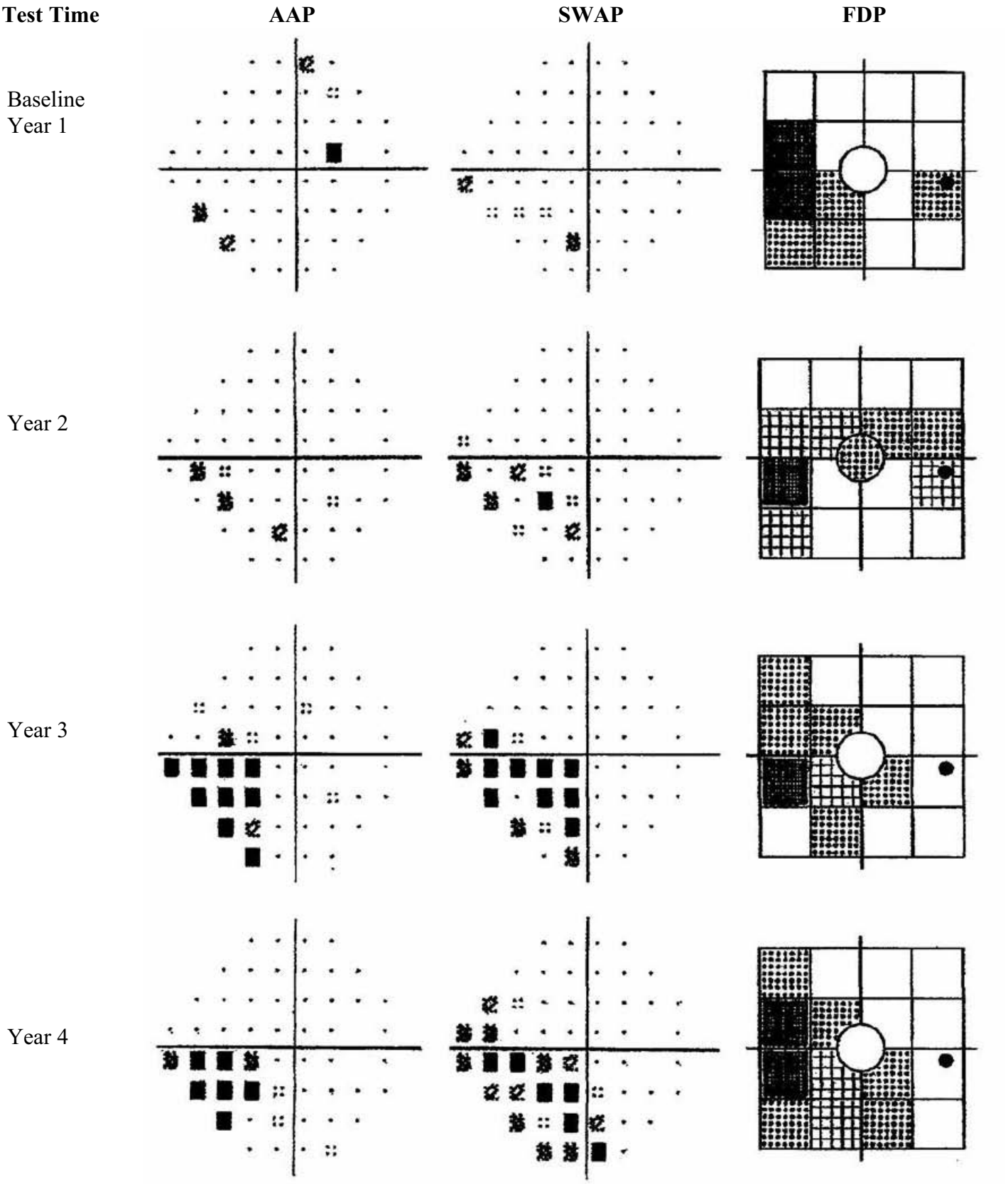


Figure 29. Pattern deviations from Patient **098** for Achromatic Automated Perimetry (AAP), Short Wavelength Automated Perimetry (SWAP) and Frequency Doubling Perimetry (FDP) over the four year study period.
HFA probabilities: , P < 5%; , P < 2%; , P < 1%; , P < 0.5%.
FDP probabilities: , P < 5%; , P < 1%; , P < 0.5%

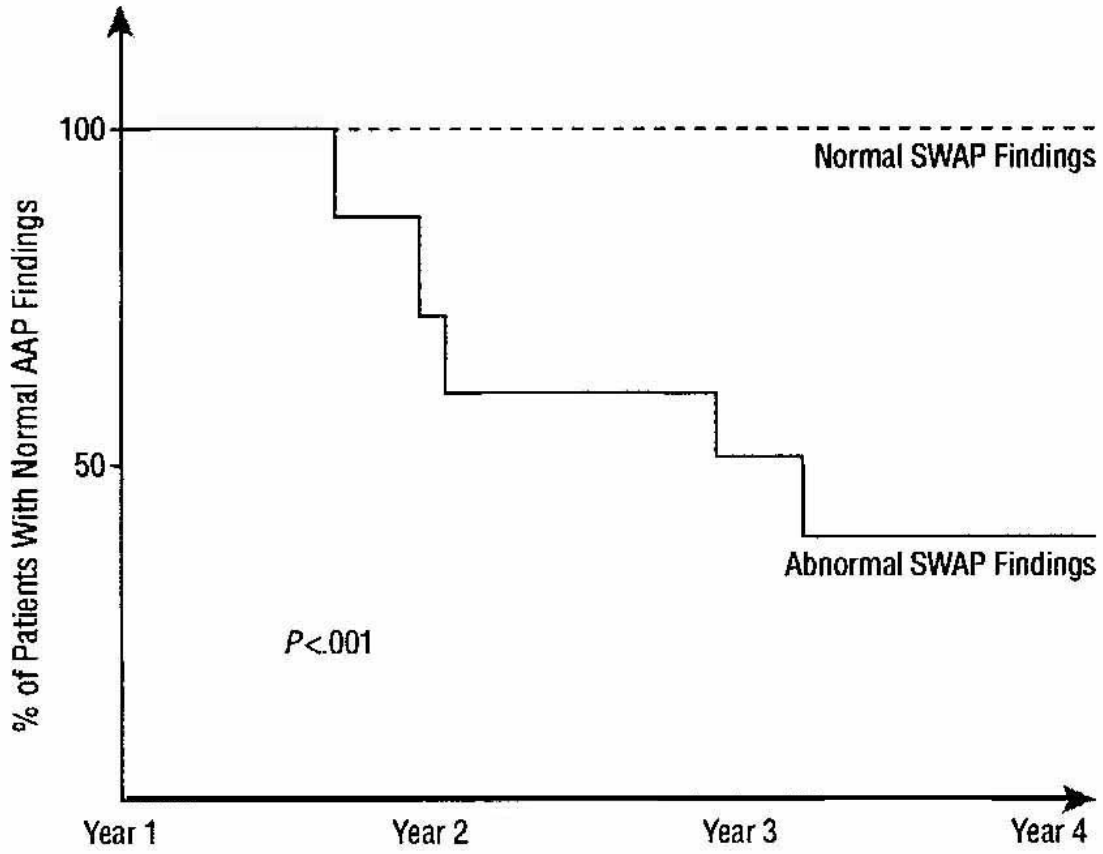


Figure 30. Survival curve of patients with normal SWAP and abnormal SWAP, using the development of an AAP abnormality as end point.

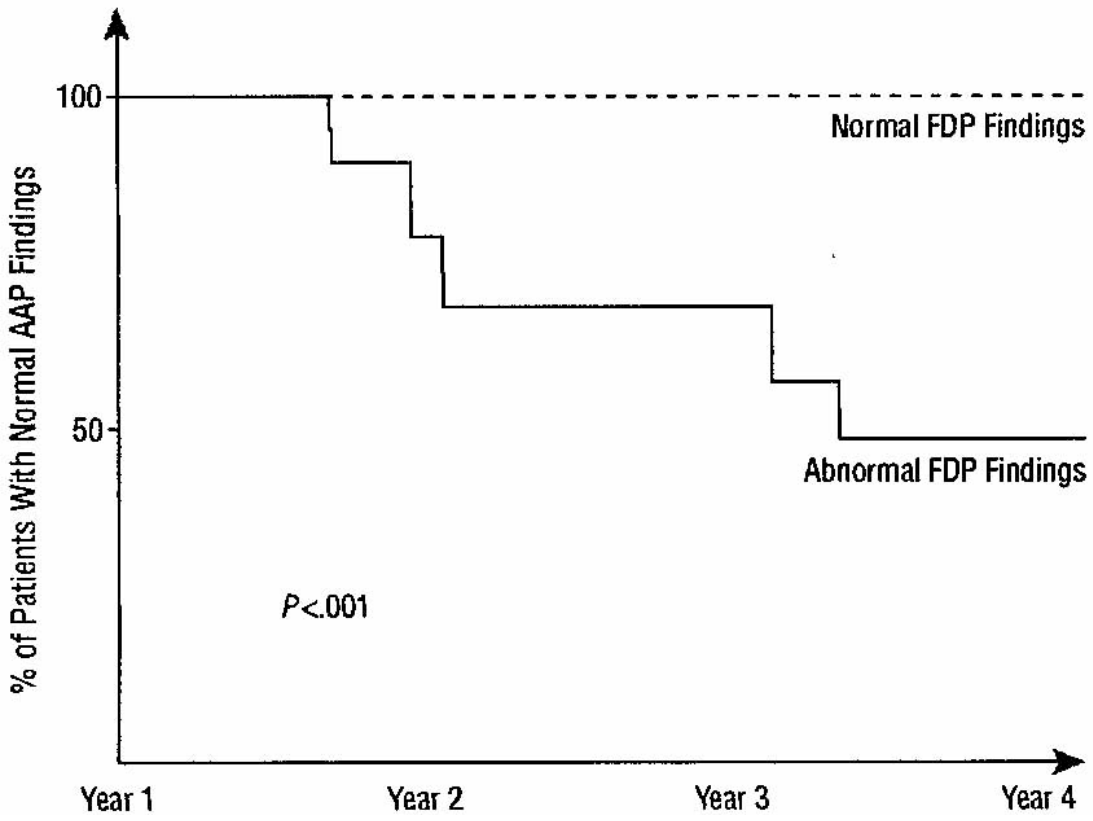


Figure 31. Survival curve patients with normal FDP and abnormal FDP, using the development of an AAP abnormality as end point.

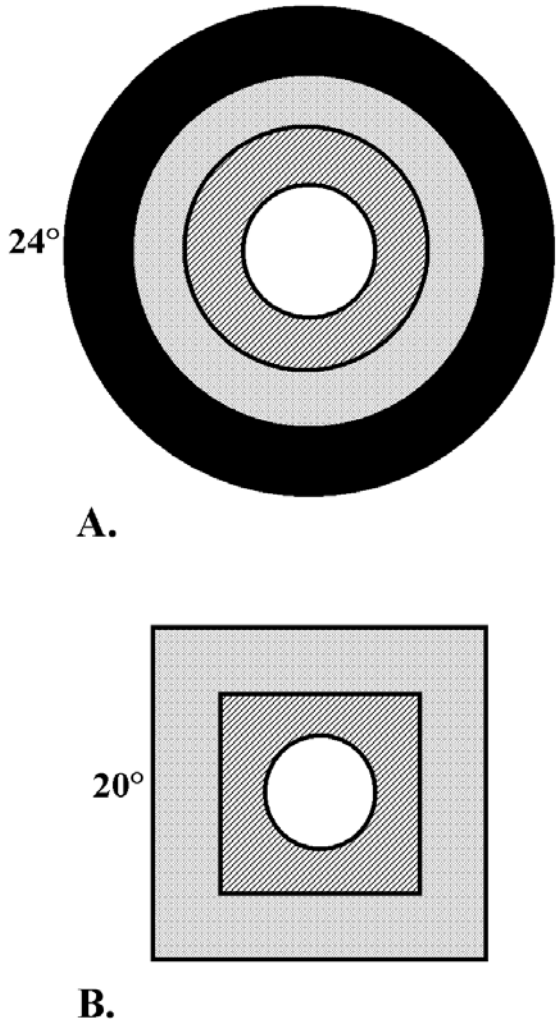


Figure 32. The position of visual fields zones for: **A.** Humphrey Field Analyzer for AAP and SWAP and **B.** Frequency Doubling Perimeter.

(Zone 1 (10° eccentricity), Zone 2 (15° eccentricity),

Zone 3 (20° eccentricity), Zone 4 (24° eccentricity))

(Eccentricity of the visual field is indicated)

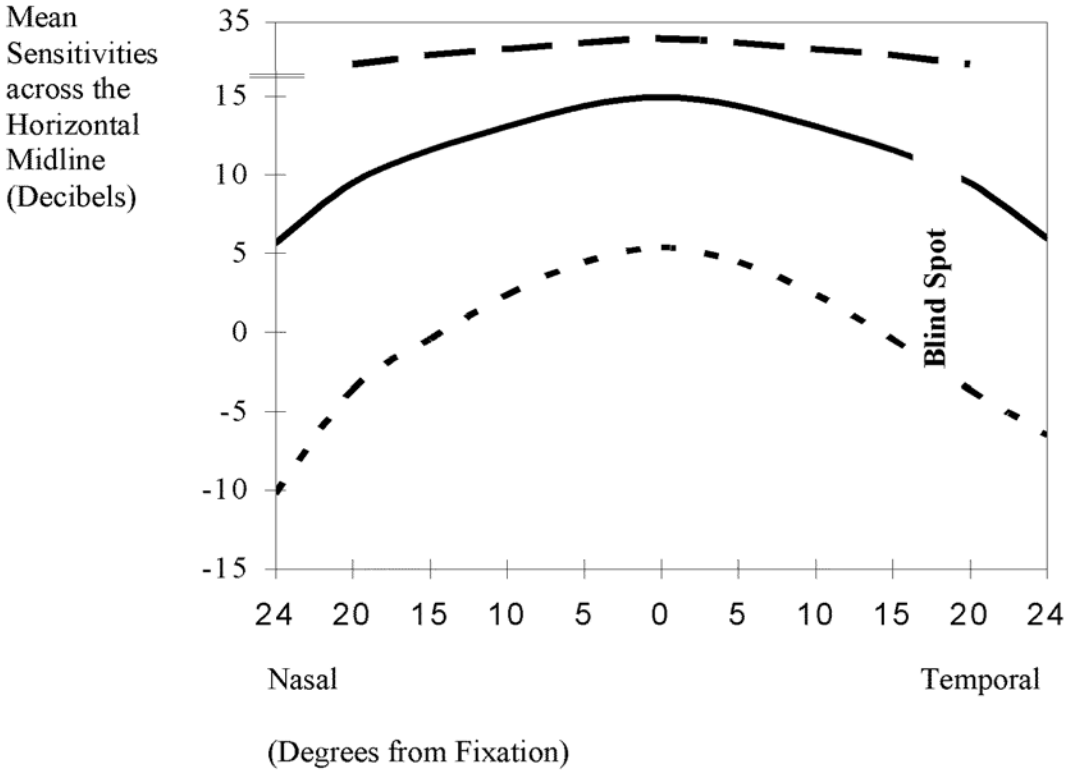


Figure 33. Graph of Mean Sensitivities across the Horizontal Midline of the Visual Field for: ——— Achromatic Automated Perimetry, ····· Short Wavelength Automated Perimetry and — — — Frequency Doubling Perimetry.

(N.B Mean Sensitivities for Achromatic Automated Perimetry and Short Wavelength Automated Perimetry have been converted to Contrast Decibels in order to be Comparable with Frequency Doubling Perimetry)

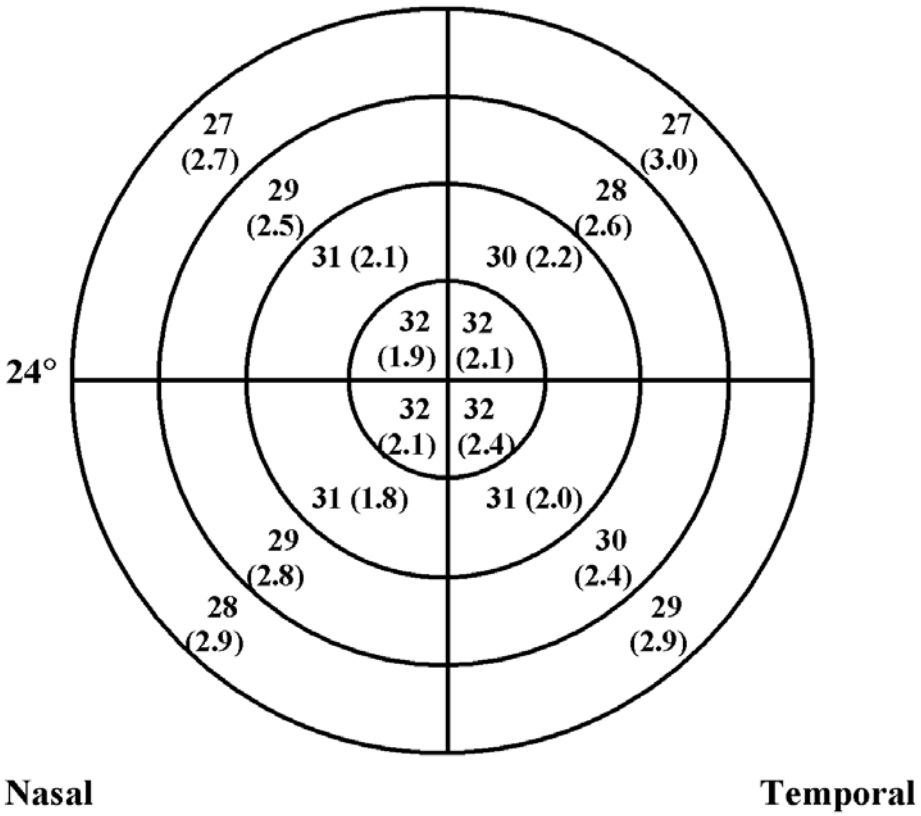


Figure 34. Mean Visual Field Sensitivities in Decibels (Standard Deviation) for each Quadrant of each Zone for Achromatic Automated Perimetry using the Humphrey Field Analyzer.

(Eccentricity of the visual field is indicated)

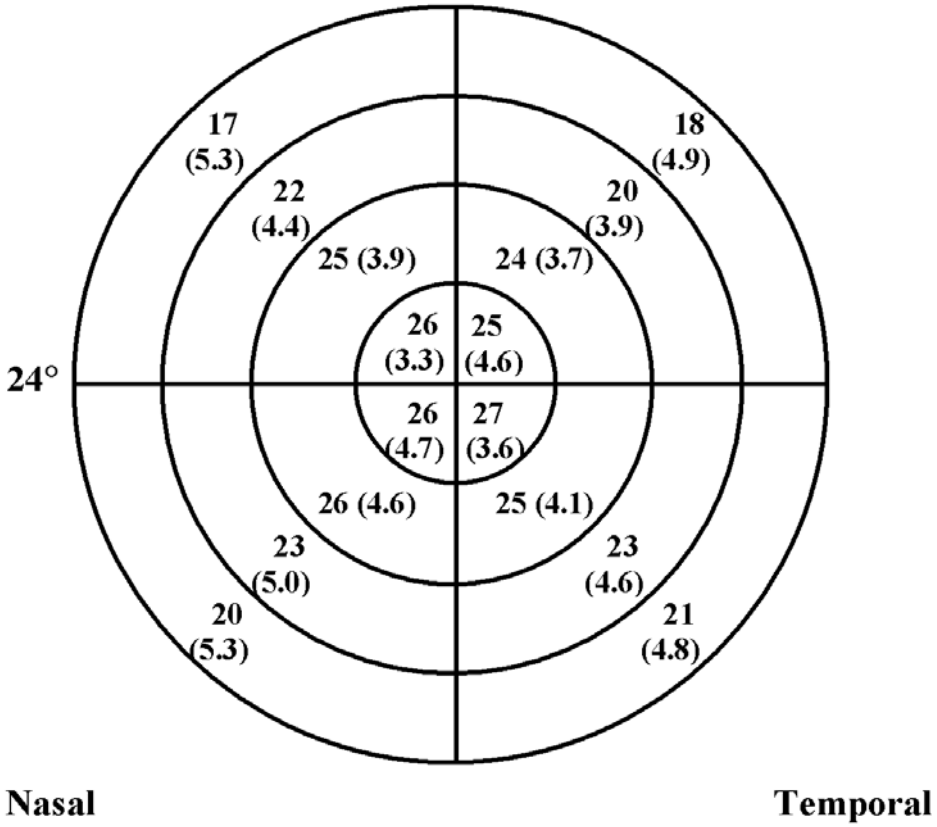


Figure 35. Mean Visual Field Sensitivities in Decibels (Standard Deviation) for each Quadrant of each Zone for Short Wavelength Automated Perimetry using the Humphrey Field Analyzer.

(Eccentricity of the visual field is indicated)

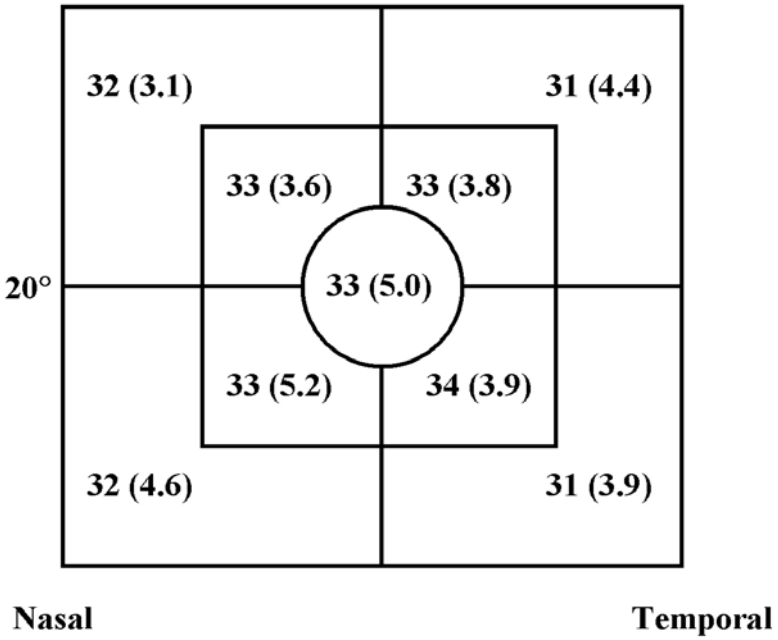


Figure 36. Mean Visual Field Sensitivities in Decibels (Standard Deviation) for each Quadrant of each Zone for the Frequency Doubling Perimeter.

(Eccentricity of the visual field is indicated)

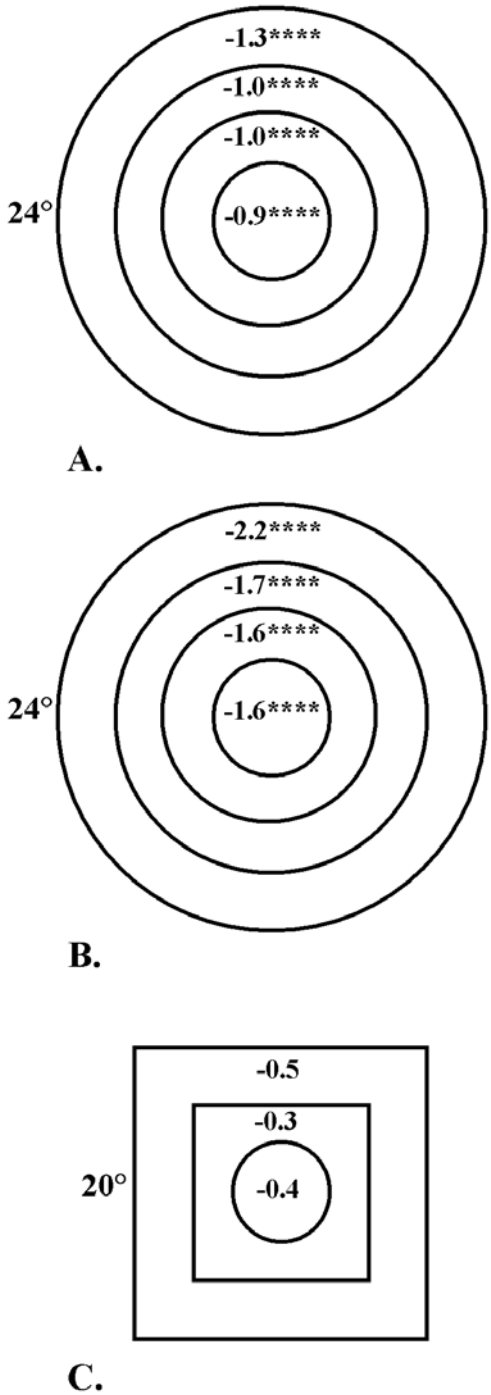


Figure 37. The Slope of the Regression of Mean Sensitivity (Decibels) at each Visual Field Zone as a function of Decade of Age for **A.** Achromatic Automated Perimetry, **B.** Short Wavelength Automated Perimetry and **C.** Frequency Doubling Perimetry.

(* P<0.05, ** P<0.01, ***P<0.001, ****P<0.0001)

(Eccentricity of the visual field is indicated)

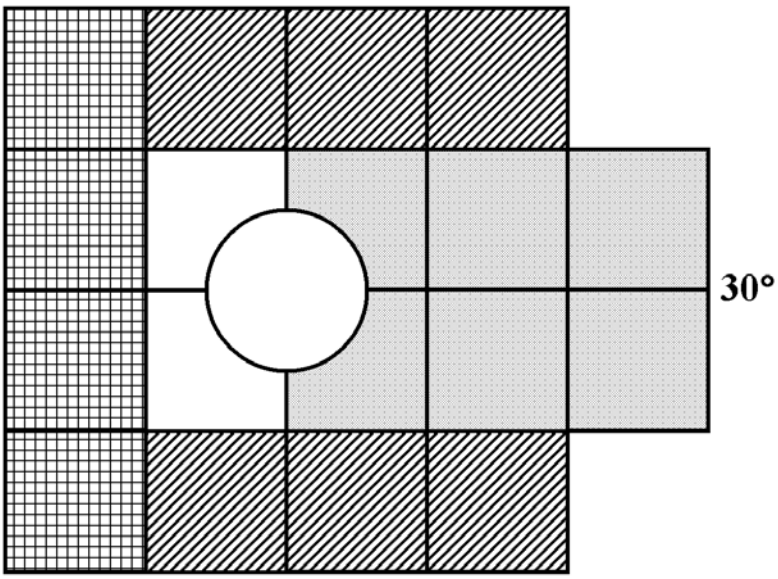


Figure 38. Showing the Area Contributing to a Nasal Step location, an Arcuate location, and a Temporal Wedge Above and Below the Horizontal Midline in the Left Visual Field.

(Eccentricity of the visual field is indicated)

A)

0.07 0.07	0.00 0.00	0.00 0.00	0.00 0.00	
0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
0.00 0.00	0.00 0.00	0.13 0.00	0.00 0.00	0.00 0.00
0.07 0.00	0.00 0.00	0.00 0.00	0.00 0.00	

30°

B)

0.10 0.05	0.10 0.05	0.00 0.00	0.00 0.00	
0.05 0.05	0.00 0.00	0.00 0.00	0.05 0.00	0.14 0.00
0.10 0.00				
0.10 0.10	0.10 0.00	0.05 0.00	0.17 0.05	0.19 0.10
0.05 0.10	0.14 0.05	0.14 0.00	0.10 0.00	

30°

C)

0.63 **0.50**	**0.69** **0.59**	**0.66** **0.63**	**0.69** **0.63**	
0.66 0.41	0.43 0.38	**0.59** **0.59**	**0.72** **0.59**	**0.75** **0.63**
0.41 0.28				
0.43 0.41	0.43 0.34	**0.60** **0.51**	**0.66** **0.50**	**0.69** **0.50**
0.66 0.41	**0.56** 0.38	**0.53** 0.34	**0.56** **0.50**	

30°

Figure 39. Showing Frequencies of Abnormal Zones for A) Controls, B) Glaucoma Suspects and C) Open-Angle Glaucoma Patients in the Left Visual Field.

(P<5%; upper frequency, P<1%; lower frequency)

(Frequencies ≥ 0.50 are Highlighted)

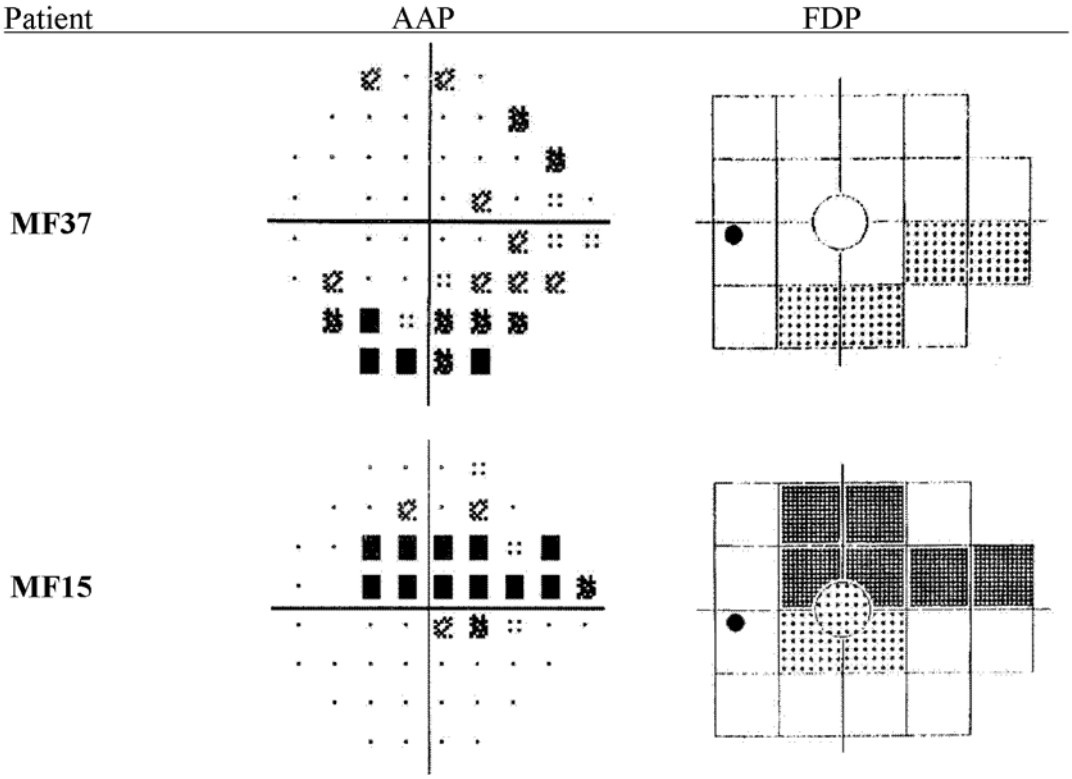


Figure 40a. Showing Pattern Deviations from Patients Classified by Frequency Doubling Perimetry as True Positives Under a Nasal-Step Protocol.

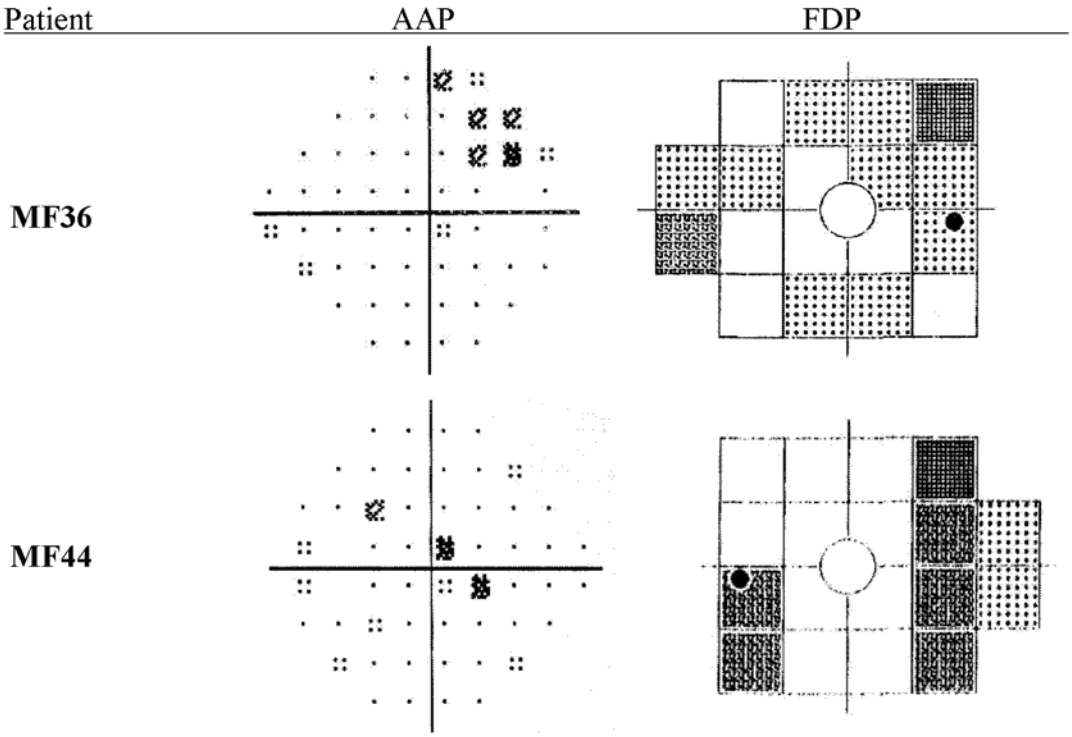


Figure 40b. Showing Pattern Deviations from Patients Classified by Frequency Doubling Perimetry as False Positives Under a Nasal-Step Protocol.
(AAP Probabilities: ∷ , P < 5%; ⊠, P < 2%; ▨, P < 1%; ■, P < 0.5%)

(FDP Probabilities: ▒ P<5%, ▒ P<1%, ▒ P<0.5%)

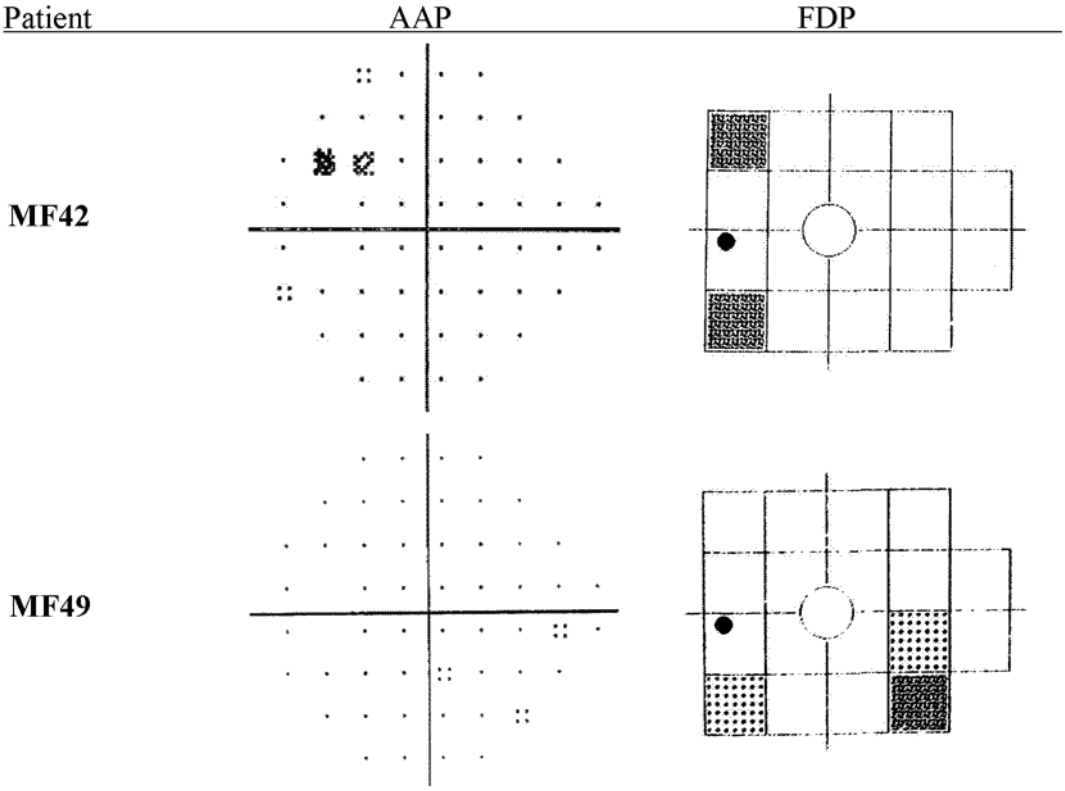


Figure41a.Showing Pattern Deviations from Patients Classified by Frequency Doubling Perimetry as True Negatives Under a Nasal-Step Protocol.

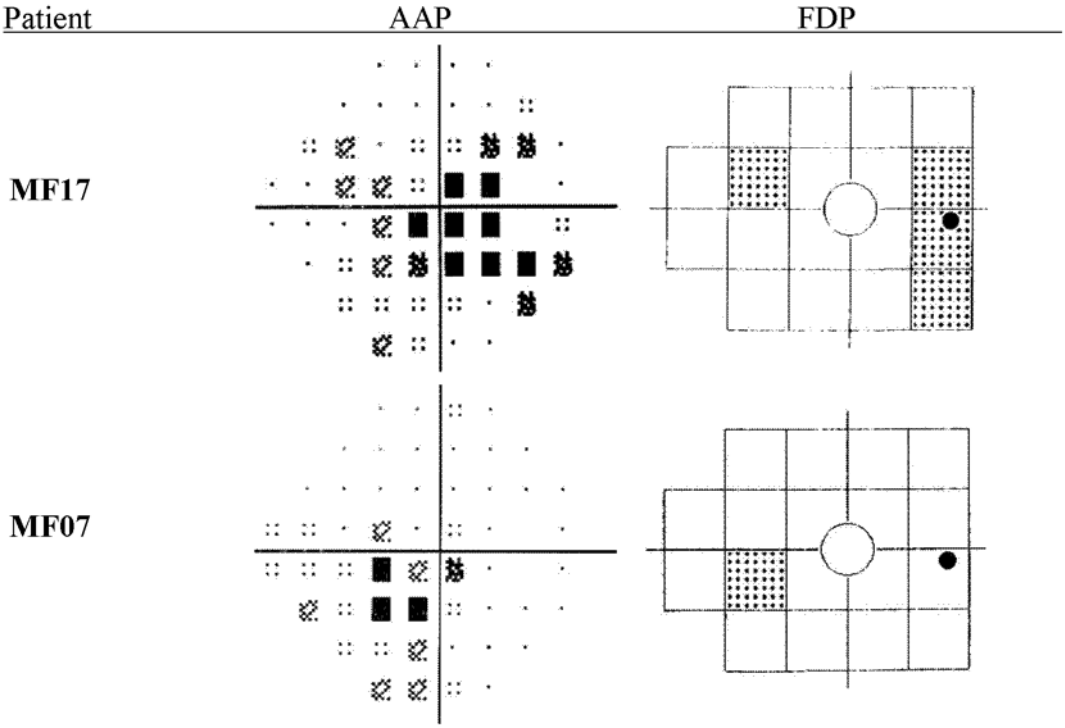
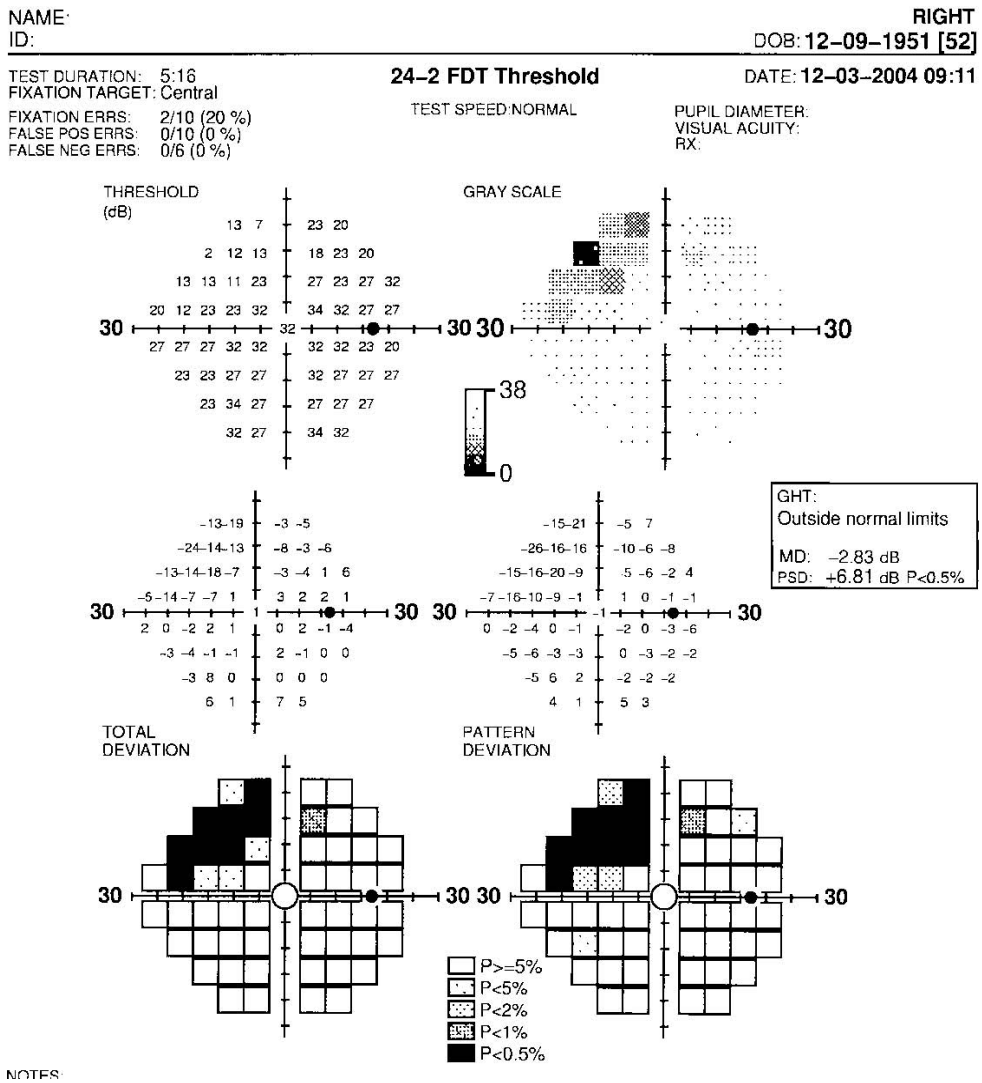


Figure41b.Showing Pattern Deviations from Patients Classified by Frequency Doubling Perimetry as False Negatives Under a Nasal-Step Protocol.
(AAP Probabilities: ∷ , P < 5%; ⊠, P < 2%; ▨, P < 1%; ■, P < 0.5%)

(FDP Probabilities: P<5%, P<1%, P<0.5%)

Figure 42. The Humphrey Matrix perimeter

A



B

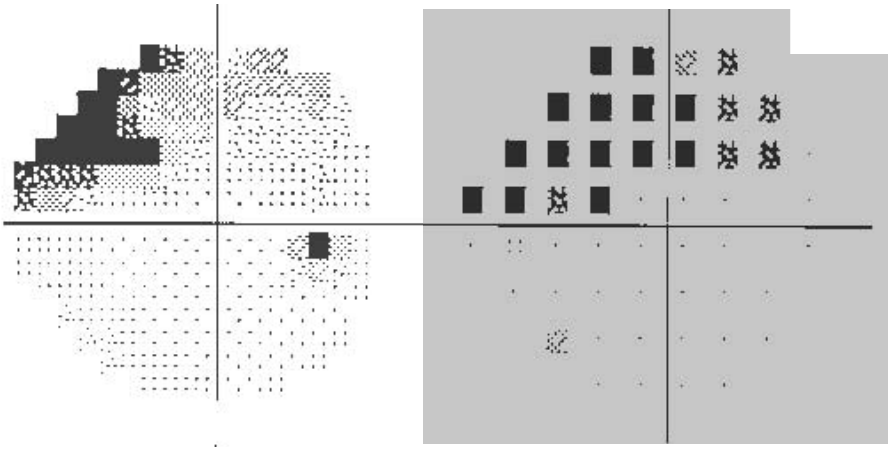


Figure 43. The print-out from (A) the Humphrey Matrix perimeter, compared with (B) the Humphrey Field Analyzer

	Short Wavelength Automated Perimetry		
	Abnormal	Normal	TOTAL
Frequency Doubling Perimetry			
Abnormal	8	2	10
Normal	1	51	52
TOTAL	9	53	62

Table 1. Numbers of Normal and Abnormal Frequency Doubling Perimetry and Short Wavelength Automated Perimetry in the patient sample.

FDP result	SWAP result		
	Abnormal	Normal	Total
Abnormal	3	0	3
Normal	1	8	9
Total	4	8	12

Table 2. Results of short wavelength automated perimetry (SWAP) compared with frequency doubling perimetry (FDP) for patients with an abnormal clinical optic disc assessment.

FDP result	SWAP result		
	Abnormal	Normal	Total
Abnormal	3	1	4
Normal	0	34	34
Total	3	35	38

Table 3. Results of short wavelength automated perimetry (SWAP) compared with frequency doubling perimetry (FDP) for patients with a normal clinical optic disc assessment.

SWAP result	Clinical optic disc assessment		
	Abnormal	Normal	Total
Abnormal	4	3	7
Normal	8	35	43
Total	12	38	50

Table 4. Results of short wavelength automated perimetry (SWAP) compared with clinical optic disc assessment.

SWAP result	Clinical optic disc assessment		
	Abnormal	Normal	Total
Abnormal	3	4	7
Normal	9	34	43
Total	12	38	50

Table 5. Results of frequency doubling perimetry (FDP) compared with clinical optic disc assessment.

–

Group	Number	Males (%)	Mean age (SD)	Range
Control	15	7 (47%)	52 years (15 years)	29–75 years
Glaucoma suspects	8	5 (63%)	56 years (16 years)	35–77 years
Ocular hypertension	8	1 (13%)	60 years (9 years)	47–74 years
Open angle glaucoma	32	16 (50%)	64 years (9 years)	41–79 years

Table 6 Description of patients within the study groups

	Humphrey Full Threshold MD		
Group	Average	(SD)	Range
Control	- 0.75	(1.05)	0.59 to -2.34
Glaucoma Suspects	- 0.66	(1.23)	1.57 to -1.72
Ocular Hypertension	- 1.19	(2.39)	0.90 to -6.41
Open Angle Glaucoma	- 8.20	(7.51)	1.04 to -26.58

Table 7. Description the amount of visual field loss for patients within the study groups

	Mean Test Time	Standard Deviation
Medmont Central Threshold	10 minutes 51 seconds	51 seconds
Medmont Flicker Perimetry	9 minutes 47 seconds	1 minutes 6 seconds
Humphrey Full Threshold	10 minutes 43 seconds	1 minutes 26 seconds
Humphrey SITA	5 minutes 44 seconds	1 minutes 12 seconds
Short Wavelength Automated Perimetry	10 minutes 35 seconds	1 minutes 43 seconds
Frequency Doubling Perimetry	5 minutes 8 seconds	30 seconds

Table 8. Mean test time (standard deviation) for Humphrey and Medmont perimetry

	Humphrey Full Threshold		Humphrey SITA	
	Abnormal	Normal	Abnormal	Normal
Medmont Central Threshold (Strict)				
Abnormal	24	2	25	1
Normal	1	36	2	35
Medmont Central Threshold (Loose)				
Abnormal	25	9	26	8
Normal	0	29	1	28

Table 9. Numbers of normal and abnormal Medmont Central Threshold, Humphrey Full Threshold and SITA in the patient sample.

	Medmont Central Threshold (Strict)		Medmont Central Threshold (Loose)	
	Compared with		Compared with	
	Humphreys Full Threshold	Humphreys SITA	Humphreys Full Threshold	Humphreys SITA
Kappa Statistic	0.90	0.87	0.72	0.72
AUC	0.94	0.92		
Sector Correlation (r^2 statistic):				
Superonasal	0.86**	0.85**		
Superotemporal	0.80**	0.72**		
Inferonasal	0.69**	0.62**		
Inferotemporal	0.29**	0.23**		
Mean Defect Correlation (r^2 statistic):				
	0.89**	0.88**		

(*P <0.001, **P <0.0001)

Table 10. Comparison of Medmont Central Threshold with Humphreys Full Threshold and Humphreys SITA showing, Kappa Statistic, area under the ROC curve (AUC), quadrant analysis and mean defect correlation.

	Humphrey short wavelength Perimetry		Humphrey frequency doubling perimetry	
	Abnormal	Normal	Abnormal	Normal
Medmont Flicker (Strict)				
Abnormal	23	8	29	2
Normal	3	29	2	30
Medmont Flicker (Loose)				
Abnormal	24	10	29	5
Normal	2	27	2	27

Table 11 Numbers of normal and abnormal Medmont flicker perimetry, Humphrey short wavelength perimetry, and Humphrey frequency doubling perimetry in the patient sample

	Medmont Flicker (Strict)		Medmont Flicker (Loose)	
	Compared with		Compared with	
	Humphreys SWAP	Humphreys FDP	Humphreys SWAP	Humphreys FDP
Kappa Statistic	0.65	0.87	0.62	0.78
AUC	0.81	0.96		
Sector Correlation (r^2 statistic):				
Superonasal	0.48**	0.67**		
Superotemporal	0.25**	0.79**		
Inferonasal	0.17*	0.64**		
Inferotemporal	0.02	0.72**		
Mean Defect Correlation (r^2 statistic):				
	0.57**	0.79**		

(*P <0.001, **P <0.0001)

Table 12 Comparison of Medmont flicker perimetry with Humphrey short wavelength perimetry (SWAP) and Humphrey frequency doubling perimetry (FDP) showing kappa statistic, area under the ROC curve (AUC), quadrant analysis, and mean defect correlation

FDP result	SWAP result		
	Abnormal	Normal	Total
	All Subjects at Start of Study		
Abnormal	8	2	10
Normal	1	51	52
Total	9	53	62
Subjects With Abnormal AAP Findings at End of Study			
Abnormal	5	0	5
Normal	0	0	0
Total	5	0	5
Subjects With Normal AAP Findings at End of Study			
Abnormal	3	2	5
Normal	1	51	52
Total	4	53	57

Table 13 SWAP Results Compared With FDP Results

	Global Indices Compared Between Tests, r^2 (P value)	
Tests Compared	MD	PSD
AAP and SWAP	0.084 (<0.001)	0.122 (<0.001)
AAP and FDP	0.113 (<0.001)	0.021 (0.07)
SWAP and FDP	0.108 (<0.001)	0.005 (0.37)

Table 14 Comparison of Global Indices Among AAP, SWAP and FDP Throughout the Study

Quadrant	Univariate Analysis		Multivariate Analysis	
	Coefficient	Test Statistic	Coefficient	Test Statistic
SWAP				
Superonasal	-2.90	10.72****	-2.90	12.09****
Superotemporal	-2.56	9.44****	-2.56	10.90****
Inferonasal	-2.00	6.46****	-2.00	7.62****
Inferotemporal	-1.82	6.79****	-1.82	8.05****
AAP				
Superonasal	-1.57	10.74****	-1.54	11.98****
Superotemporal	-1.70	10.91****	-1.65	12.10****
Inferonasal	-1.54	10.12****	-1.50	11.10****
Inferotemporal	-1.20	7.89****	-1.19	8.57****
FDP				
Superonasal	-0.52	1.32	-0.47	1.14
Superotemporal	-1.16	2.66**	-1.11	2.35*
Inferonasal	-0.80	1.63	-0.70	1.32
Inferotemporal	-1.14	2.63**	-1.05	2.37*

Table 15. Showing Linear Regression Coefficients and Test Statistics for the Relationship between Visual Field Mean Sensitivities and Increasing Eccentricity. Multivariate Analysis was Adjusted for Age.

(Short Wavelength Automated Perimetry: SWAP, Achromatic Automated Perimetry: AAP, Frequency Doubling Perimeter: FDP)

(* P<0.05, ** P<0.01, ***P<0.001, ****P<0.0001)

FDP		AAP Abnormal	AAP Normal
Conventional Protocol	Abnormal	24	8
	Normal	2	34
Nasal Step	Abnormal	23	5
	Normal	3	37
Arcuate	Abnormal	22	6
	Normal	4	36
Temporal Wedge	Abnormal	16	5
	Normal	10	37

Table 16. Showing Results of Achromatic Automated Perimetry (AAP) Compared with Frequency Doubling Perimetry (FDP) For Each Testing Pattern