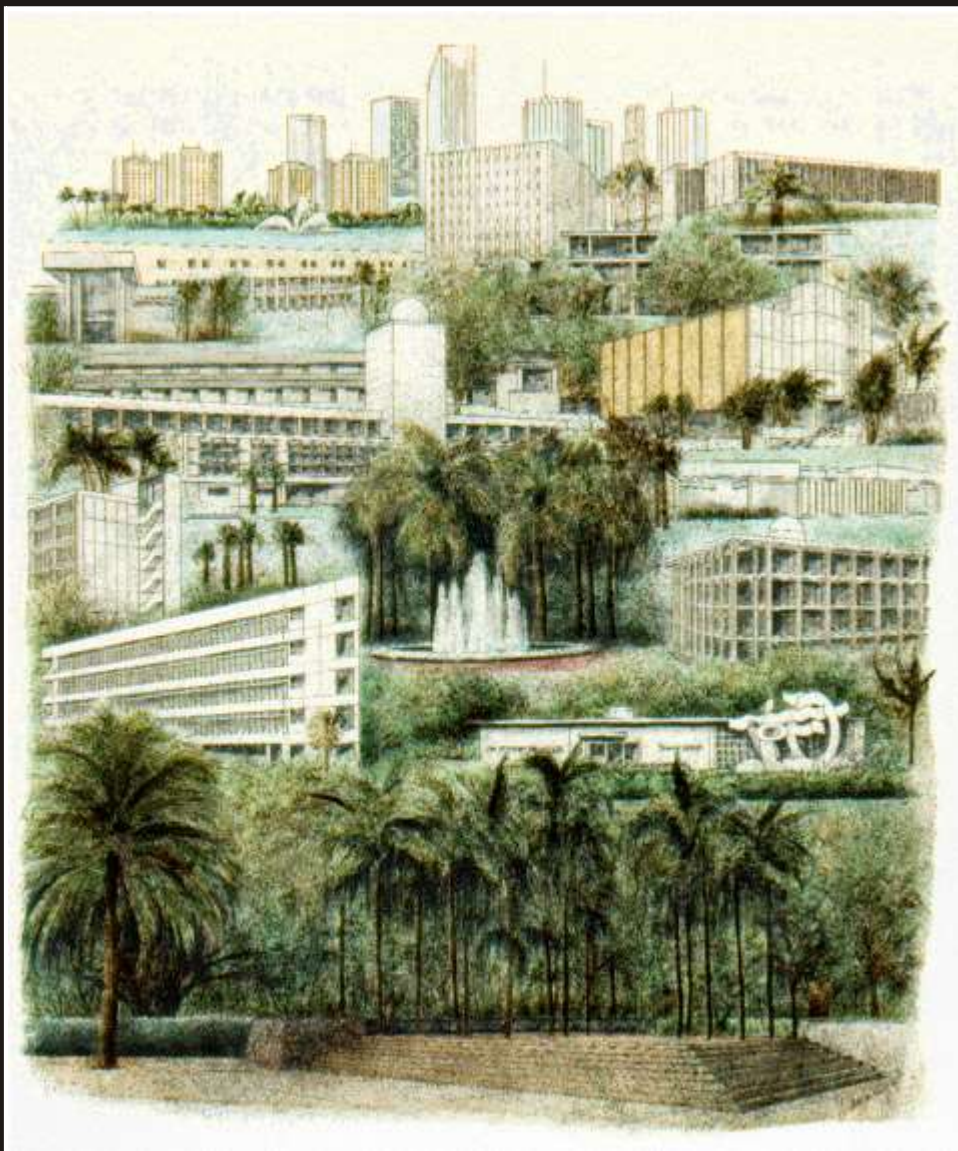




**Invariante Bildbeschreibung zur Kontrolle
mechanischer und metabolischer
Körperfunktionen**



INVARIANTE BILDBESCHREIBUNG IN DER MEDIZINISCHEN DIAGNOSTIK

JOACHIM NAGEL

Departments of
Biomedical Engineering,
Radiology, and Psychology
University of Miami

Anatomie/Pathologie/Bewegungsabläufe

Röntgen

Projektion / CT



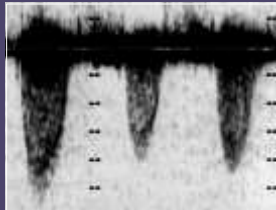
Kernspin-Resonanz

2-d / 3-d



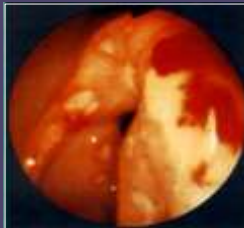
Ultraschall

Sektor Scan / Doppler



Endoskopie/Photographie

Endoskop / Fundus Kamera



Metabolische Funktion

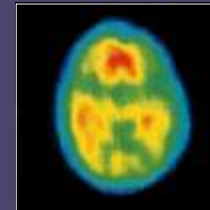
Gamma Kamera



SPECT

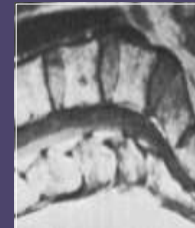


PET

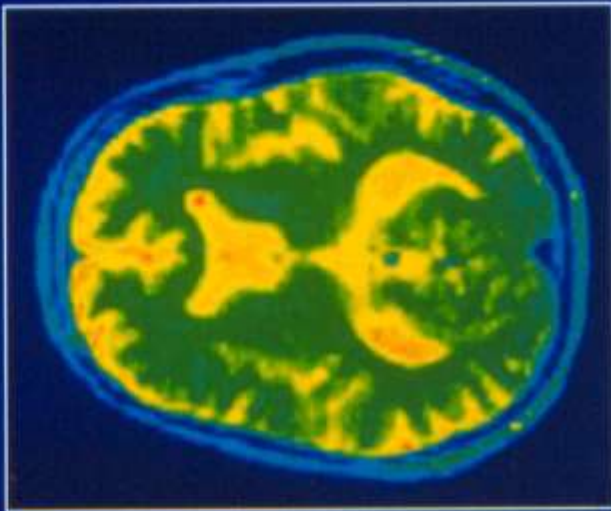


Kernspin-Resonanz

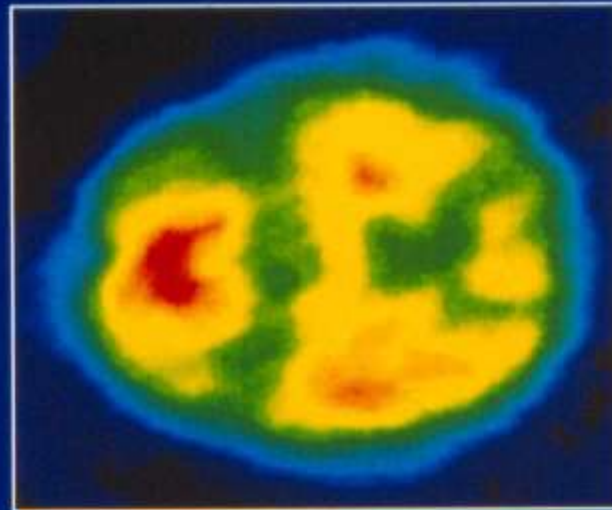
Chemische Verschiebung



MRI



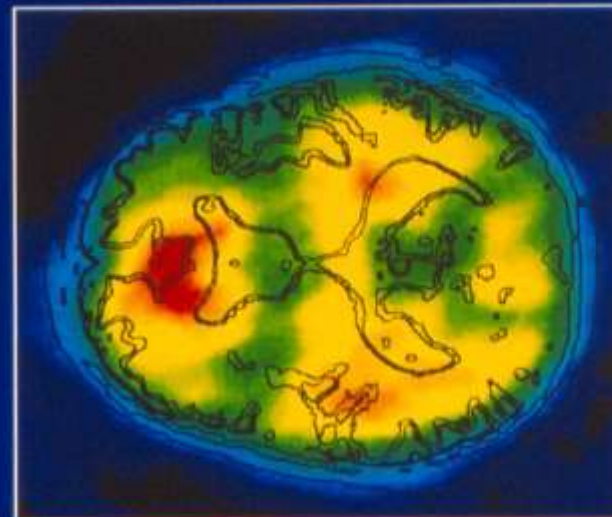
PET

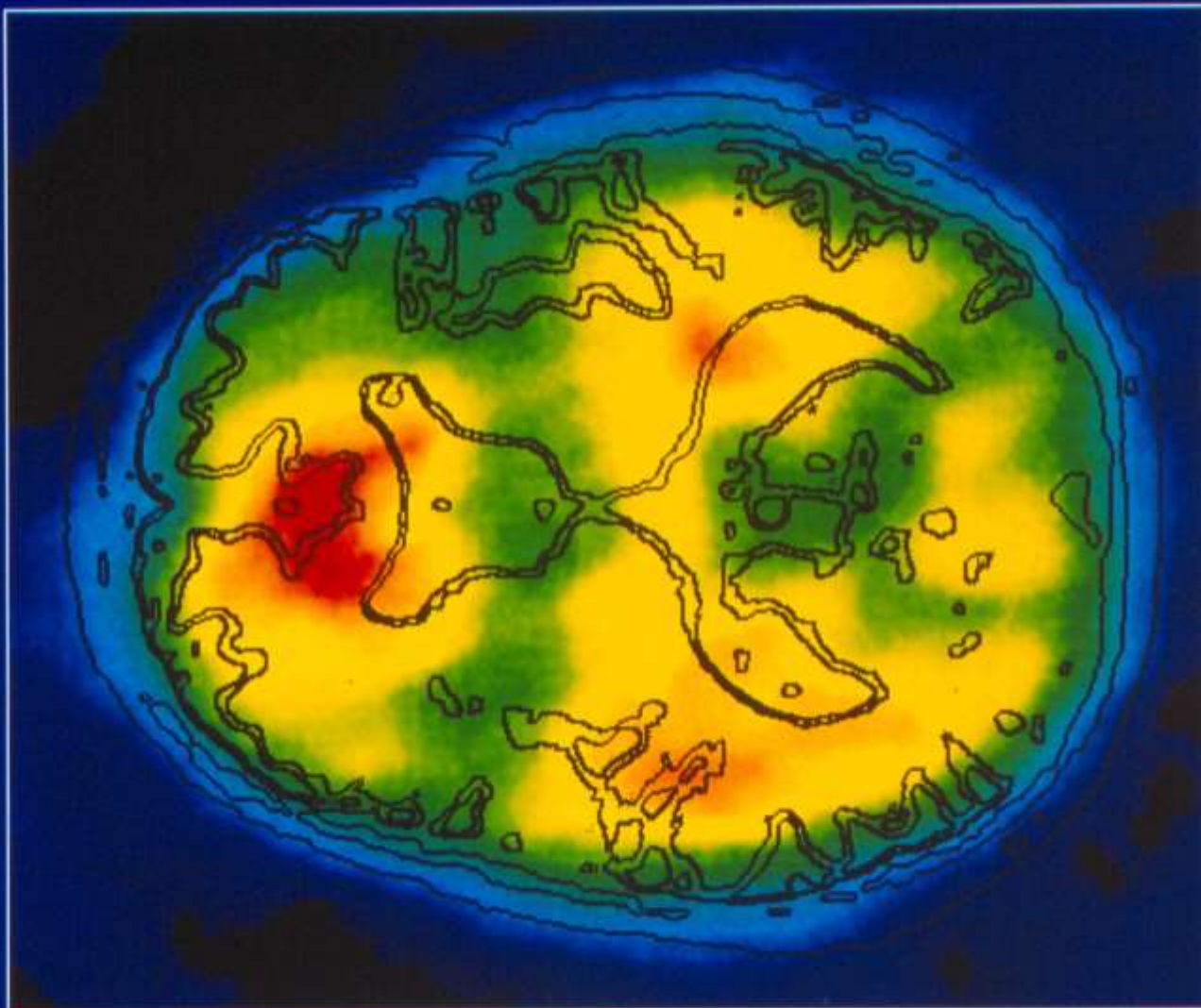


MRI
Contours



Superposition
Contours/PET

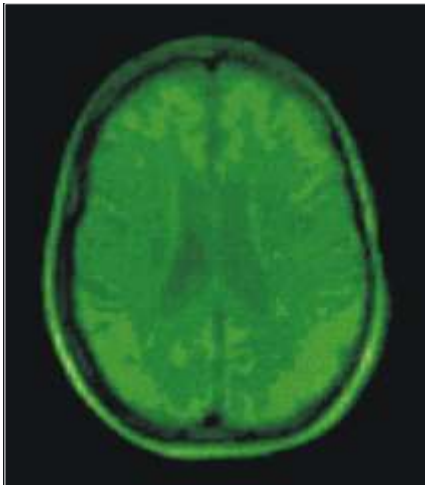




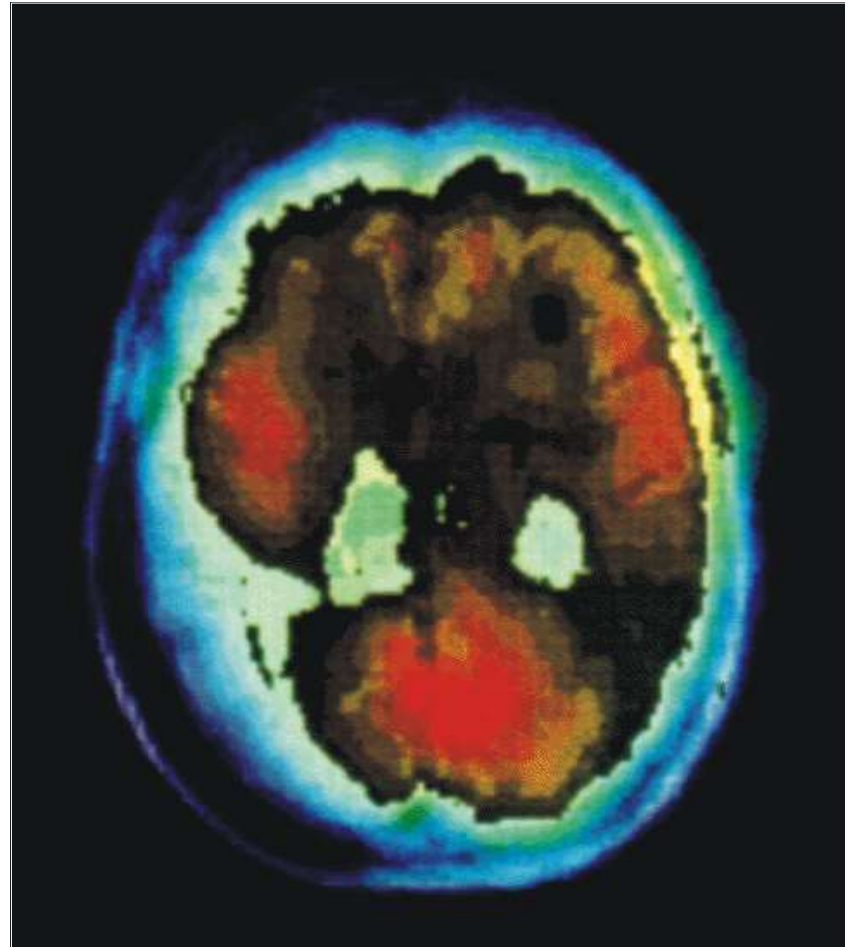
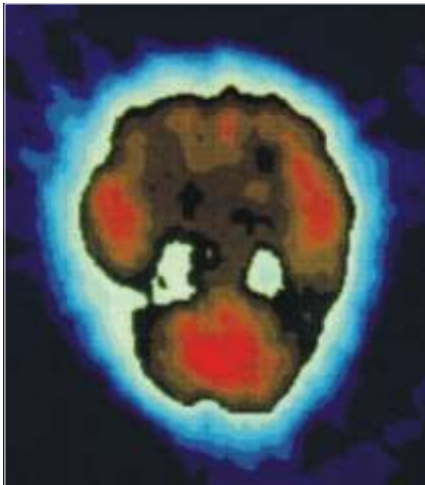
Superposition MRI-Contours/PET

Falschfarbendarstellung

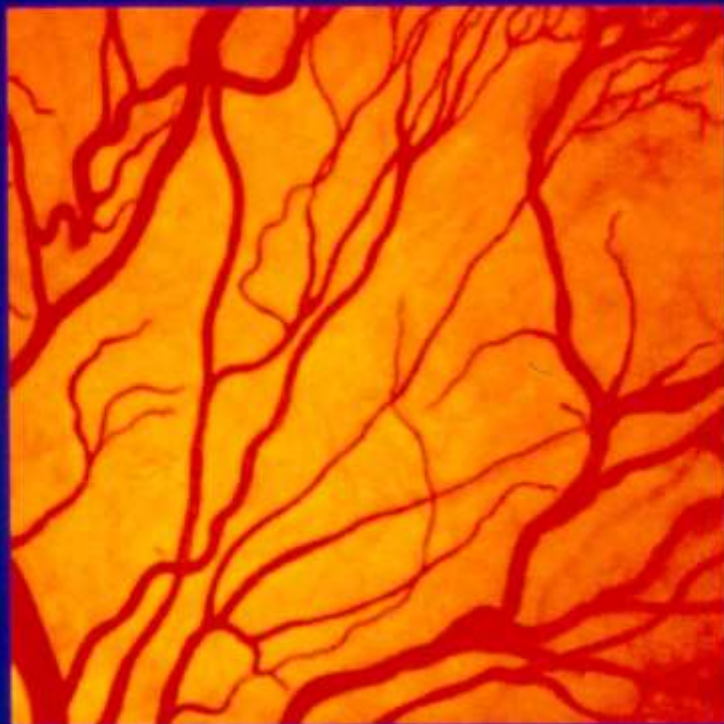
MRI



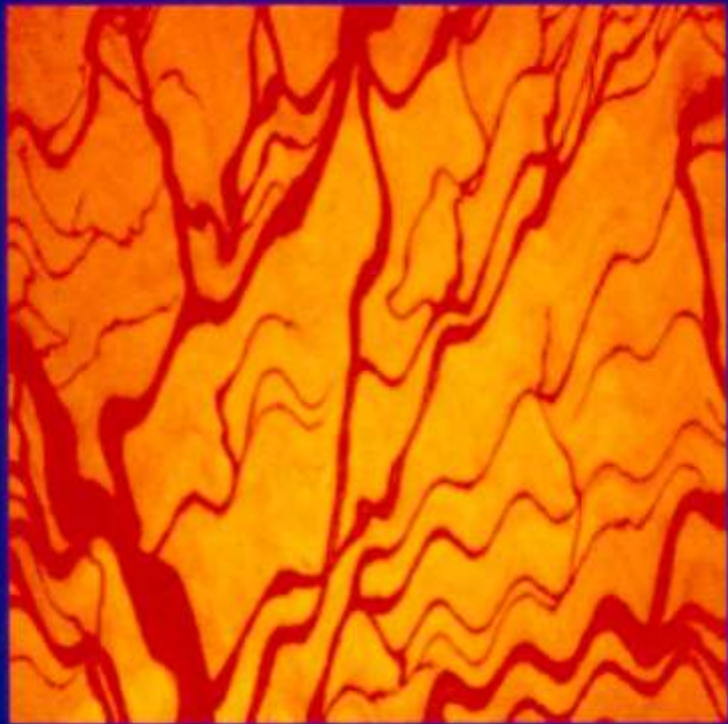
PET



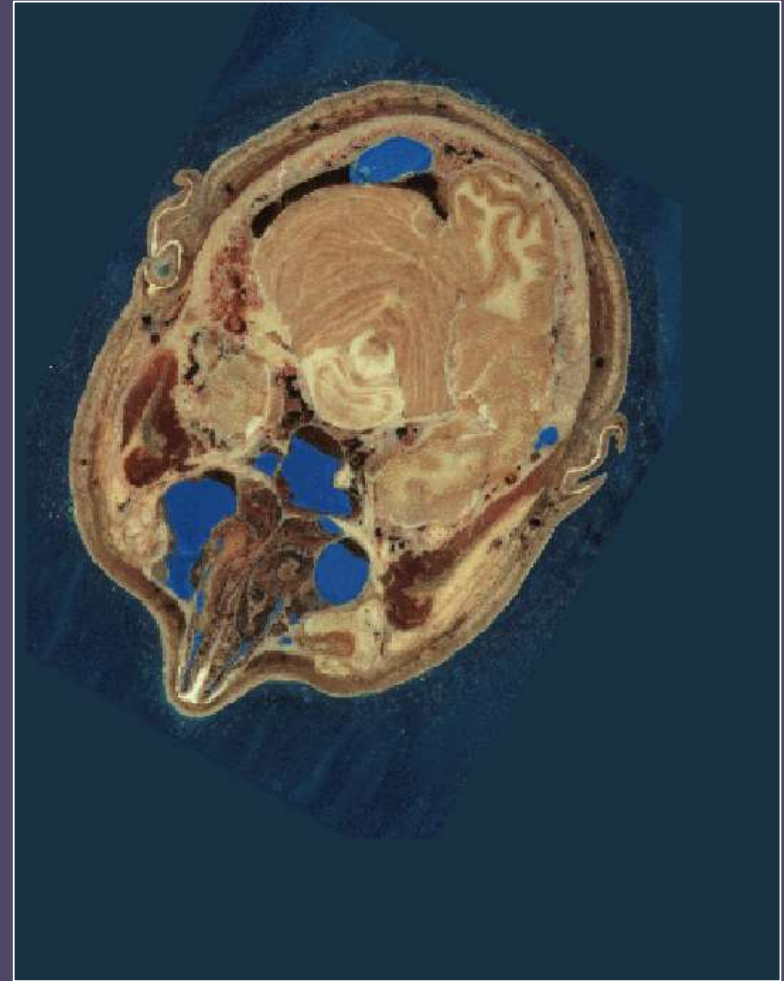
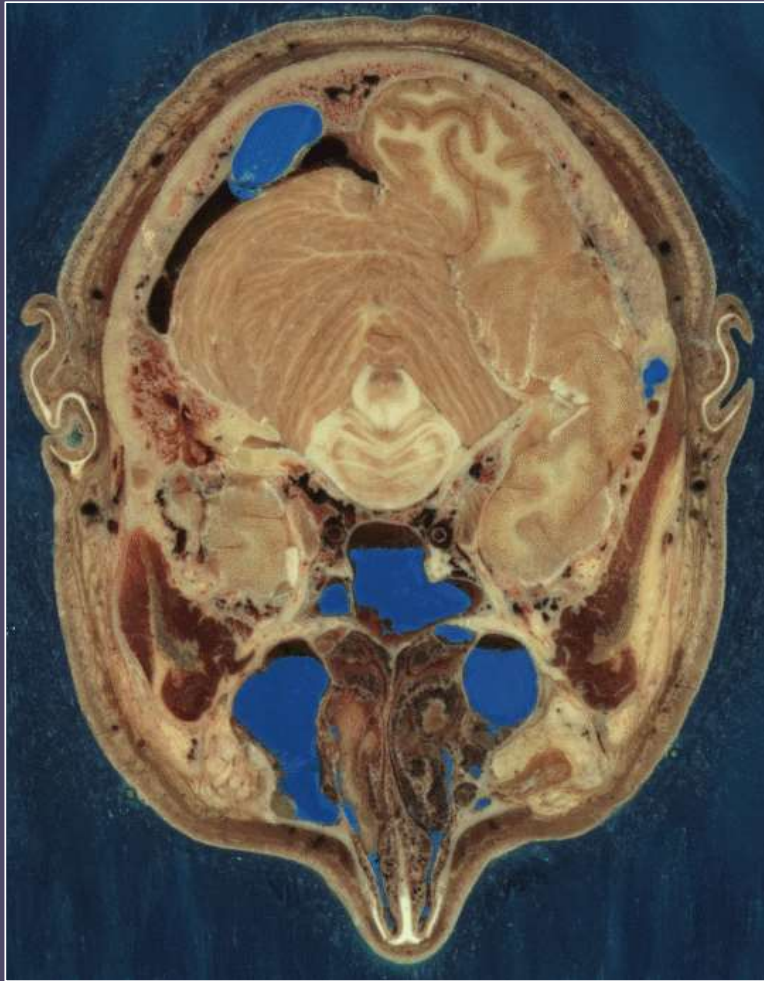
Brightness/Colour Coded MRI/PET
Image Integration



Fundus Image A



Fundus Image B

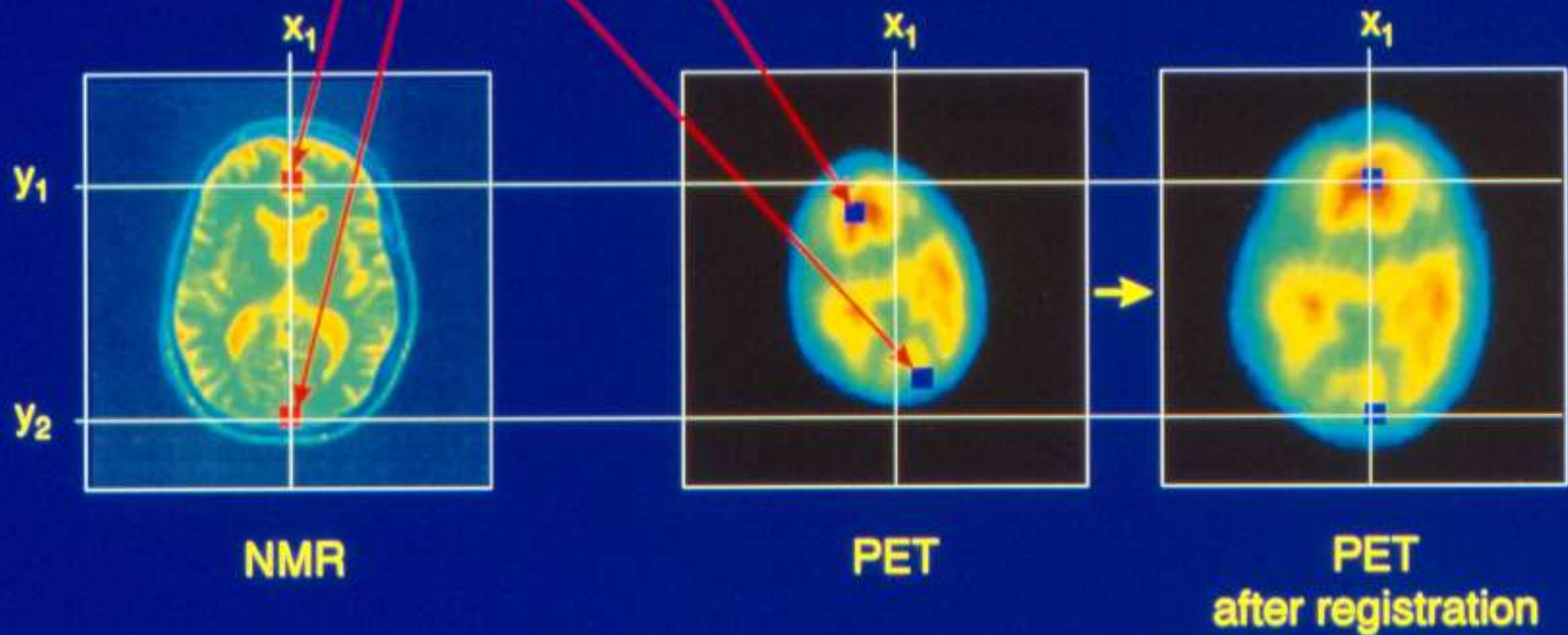


AXIAL ANATOMICAL IMAGES OF MALE HEAD

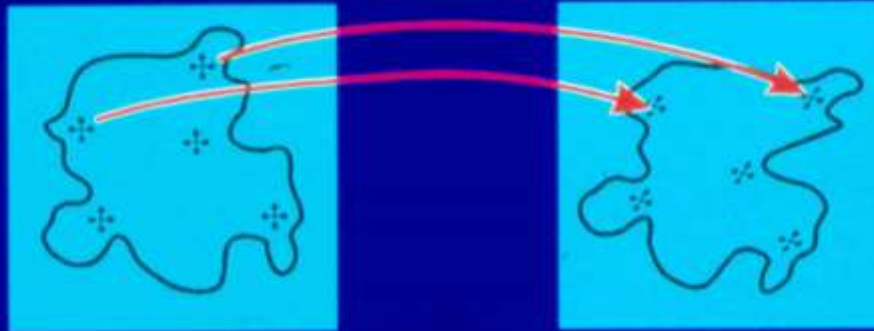
National Library of Medicine - Visible Human Data Set

Patient

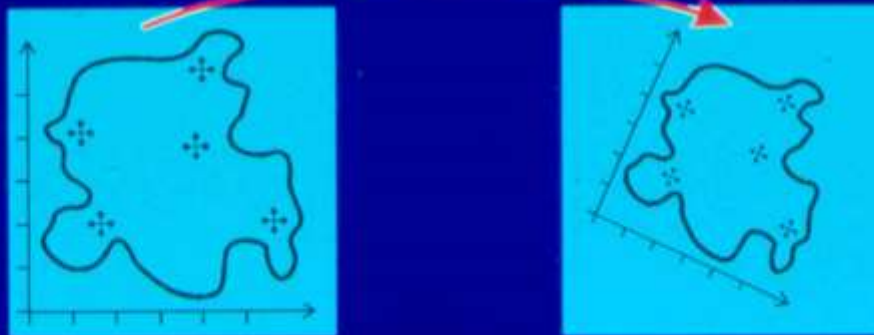
Image Registration



LOCAL REGISTRATION



GLOBAL REGISTRATION



4 PARAMETERS

$\Delta\theta$ ROTATION

$\Delta\alpha$ SCALING

$\Delta x, \Delta y$ TRANSLATION

Images: $I_1(x,y), I_2(x,y)$

Fourier Spectra: $F_1(u,v), F_2(u,v)$

Cross-Correlation Function:

$$R_{1,2}(\hat{x}, \hat{y}) = \sum_{x=-\infty}^{+\infty} \sum_{y=-\infty}^{+\infty} I_1(x+\hat{x}, y+\hat{y}) I_2(x, y)$$

or:

$$R_{1,2}(\hat{x}, \hat{y}) = FFT^{-1} \{F_1(u,v) \cdot F_2^*(u,v)\}$$

Maximum Similarity of $I_1(x,y)$ and $I_2(x,y)$: $R_{\max} = R_{1,2}(\hat{x}_{\max}, \hat{y}_{\max})$

$\hat{x}_{\max}$ and $\hat{y}_{\max}$ specify translational registration parameters Δx and Δy

Triple Invariant Image Transformation

Original Images:

Image 1: $f(x,y)$

Image 2: $f'(x,y) = f(\alpha(x\cos\beta + y\sin\beta) - \Delta x, \alpha(-x\sin\beta + y\cos\beta) - \Delta y)$

Fourier Transformation:

$$|F'(u,v)| = \frac{1}{\alpha^2} \left| F\left(\frac{(u\cos\beta + v\sin\beta)}{\alpha}, \frac{(-u\sin\beta + v\cos\beta)}{\alpha}\right) \right|$$

Conversion to Polar Coordinates:

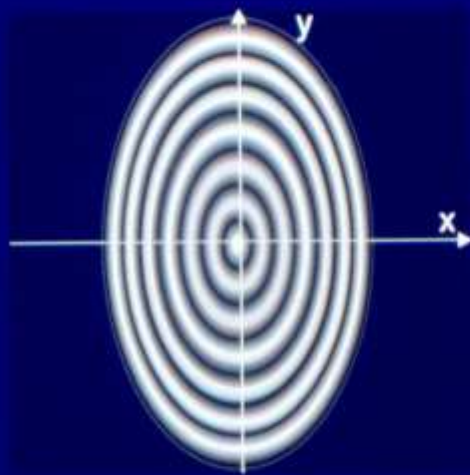
$$|F'(r,\Theta)| = \frac{1}{\alpha^2} \left| F\left(\frac{r}{\alpha}, \Theta + \beta\right) \right|$$

with $r = \sqrt{u^2 + v^2}$
and $\Theta = \tan^{-1}(v/u)$

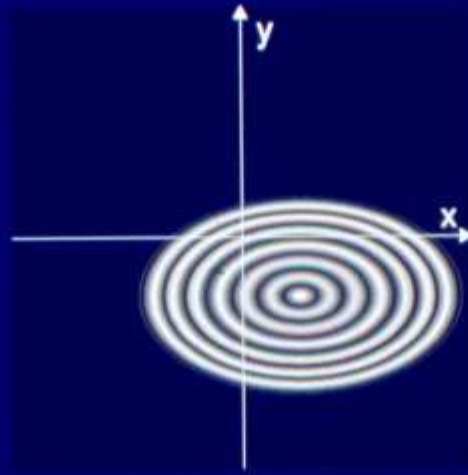
Logarithmic Transformation:

$$|F'(\rho,\Theta)| = \frac{1}{\alpha^2} \left| F\left(\rho - \ln(\alpha), \Theta + \beta\right) \right|$$

with $\rho = \ln(r)$



$f(x,y)$

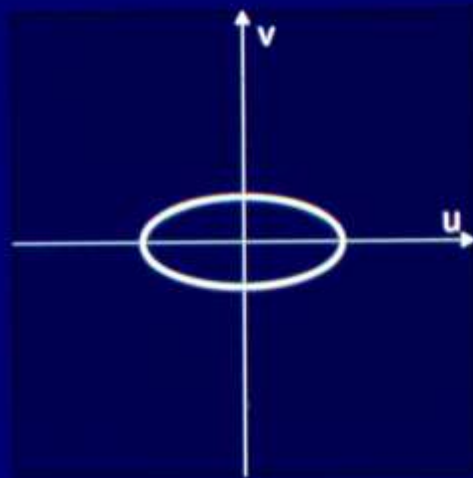


$f'(x,y)$

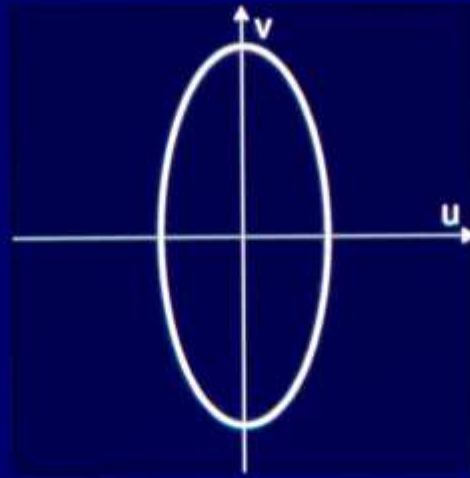
Original Images



Fourier Transformation



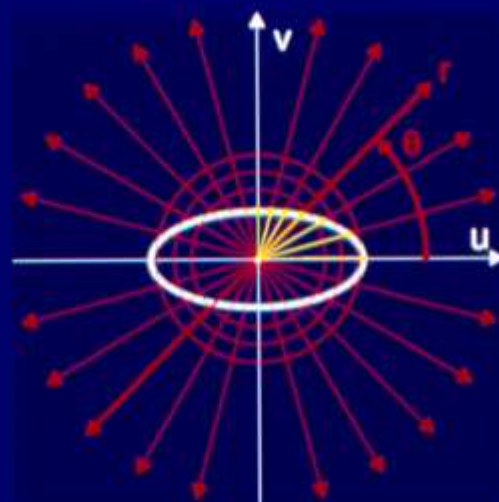
$|F(u,v)|$



$|F'(u,v)|$

Magnitude Spectra

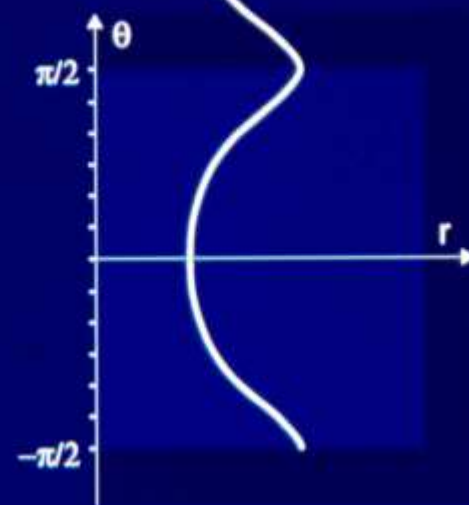
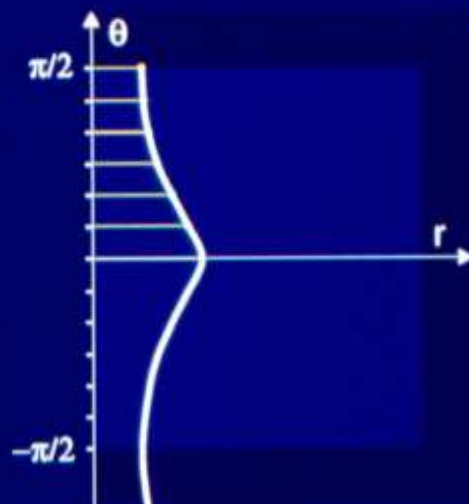
Magnitude Spectra



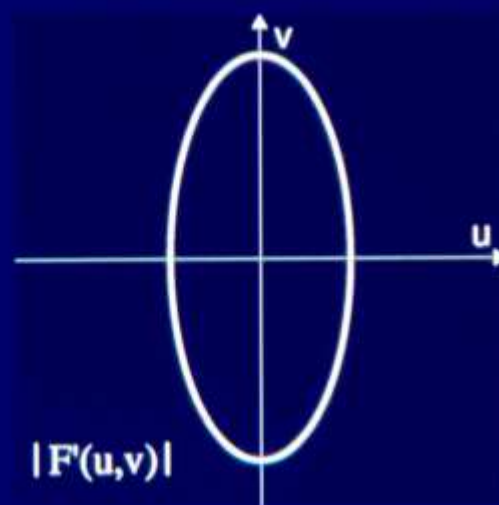
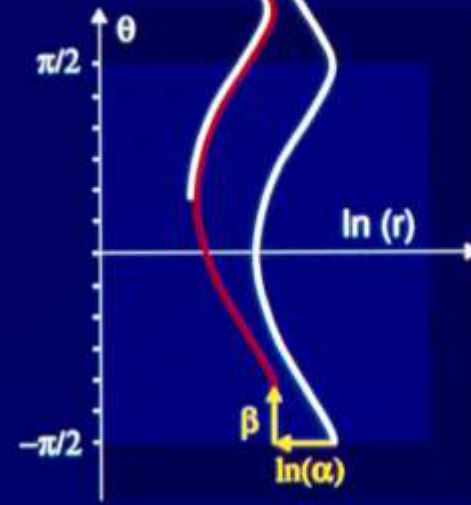
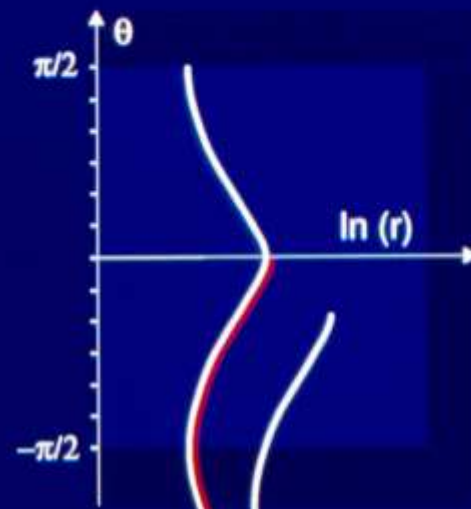
$|F(u,v)|$



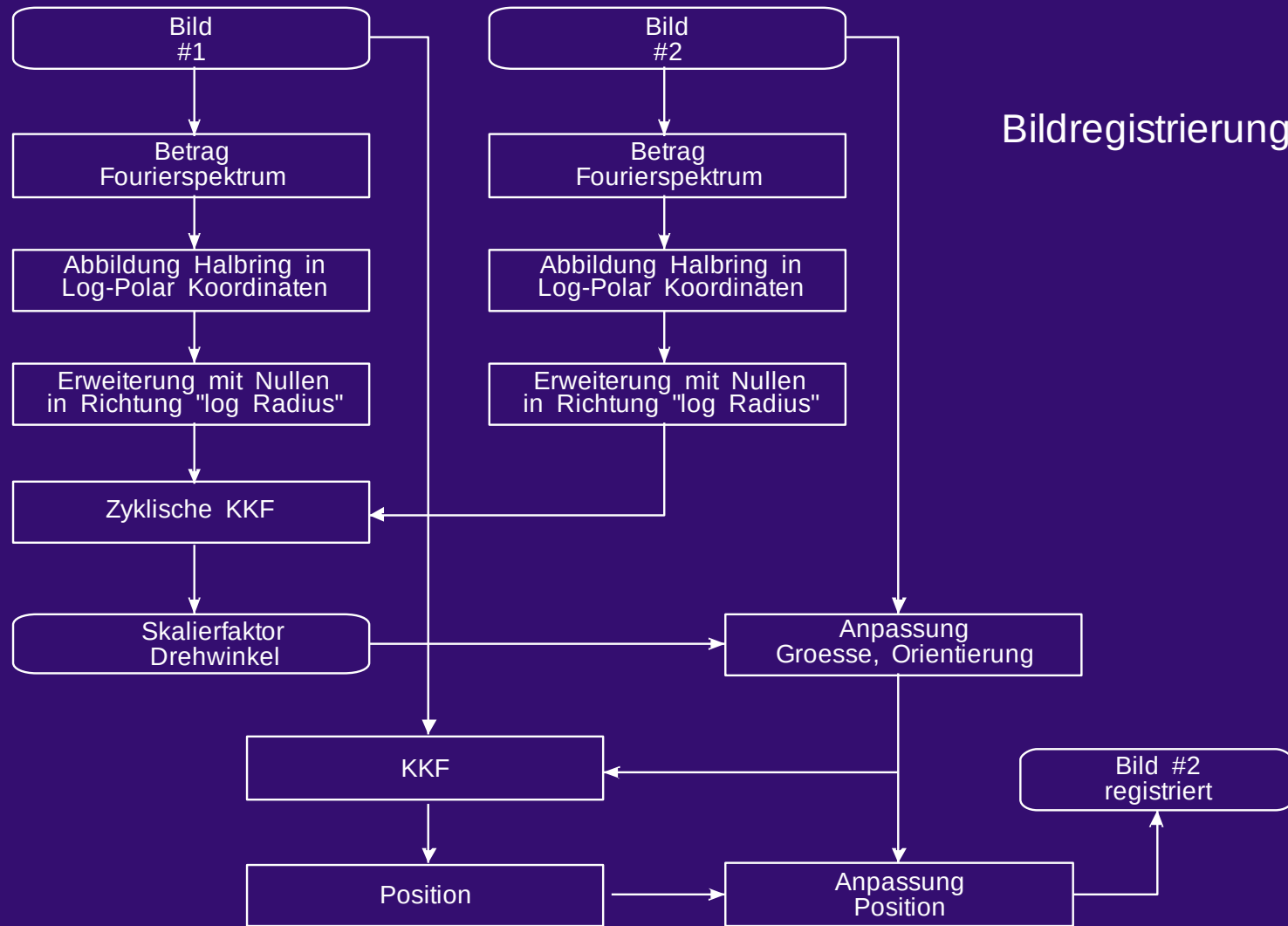
Polar Coordinates



Log-Polar Transform



$|F'(u,v)|$



Clinical Applications of Invariant Image Description:

- Functional Renal Studies**
- Alignment of Linear Accelerators for Tumor Treatment**
- Investigation and Diagnosis of Retinitis Pigmentosa**
- Diagnosis of Alzheimer's Disease**
- Quantification of Aortic Valve Stenosis**
- Determination of Cardiac Function and Structure**

DYNAMIC SCINTIGRAPHIC RENAL STUDIES

Problem: Series of scans over a long period of time -
patient moves during study

Task: Compensation of motion artifacts

Benefits: Reduction of stress for patient,
lower costs, and considerable time savings

MOTION



9 MIN



10 MIN



11 MIN



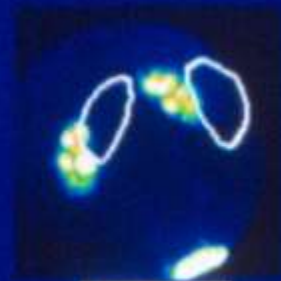
13 MIN



15 MIN



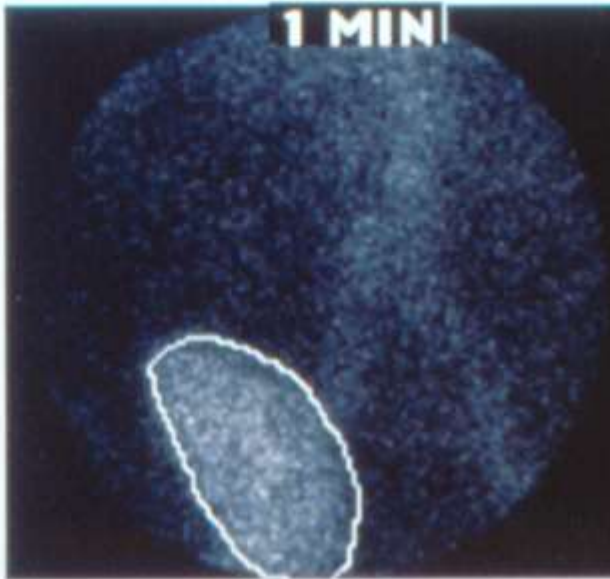
18 MIN



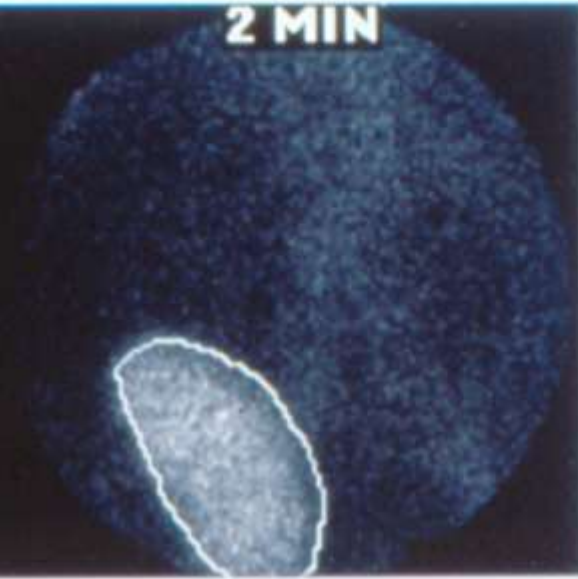
22 MIN

MOTION

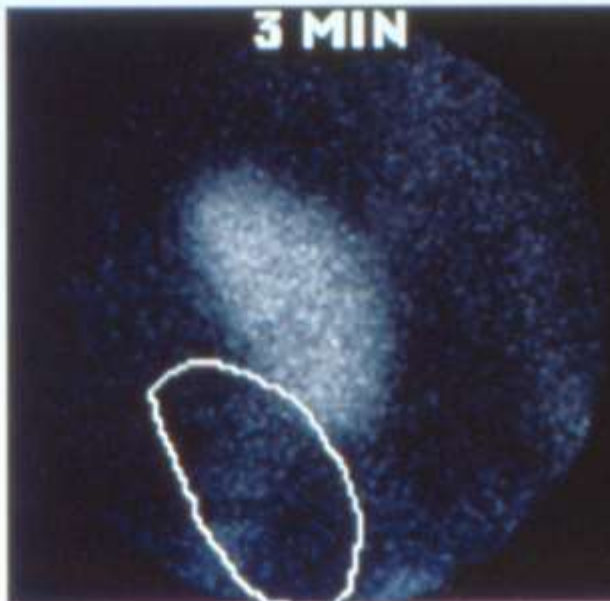
1 MIN



2 MIN



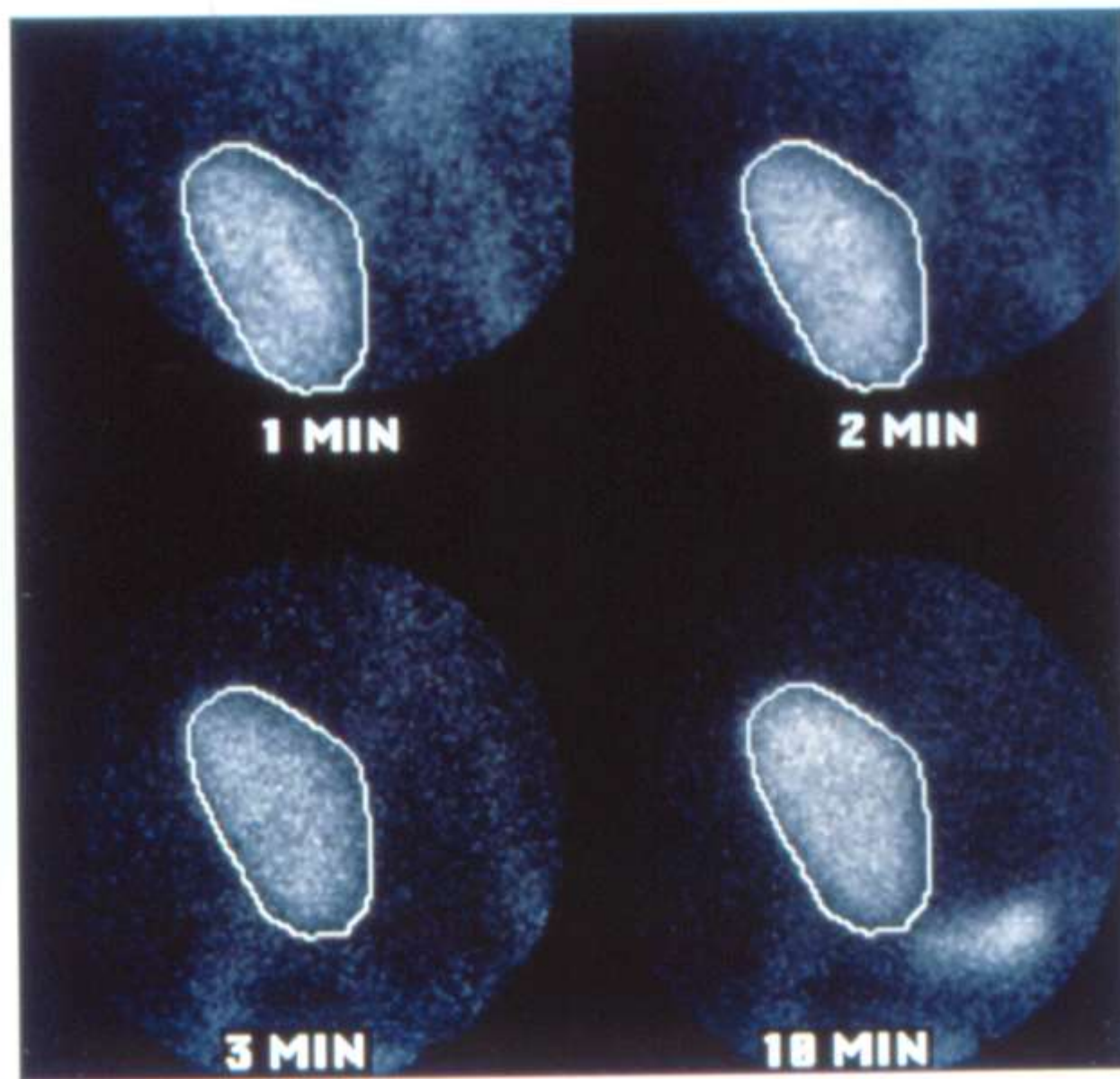
3 MIN



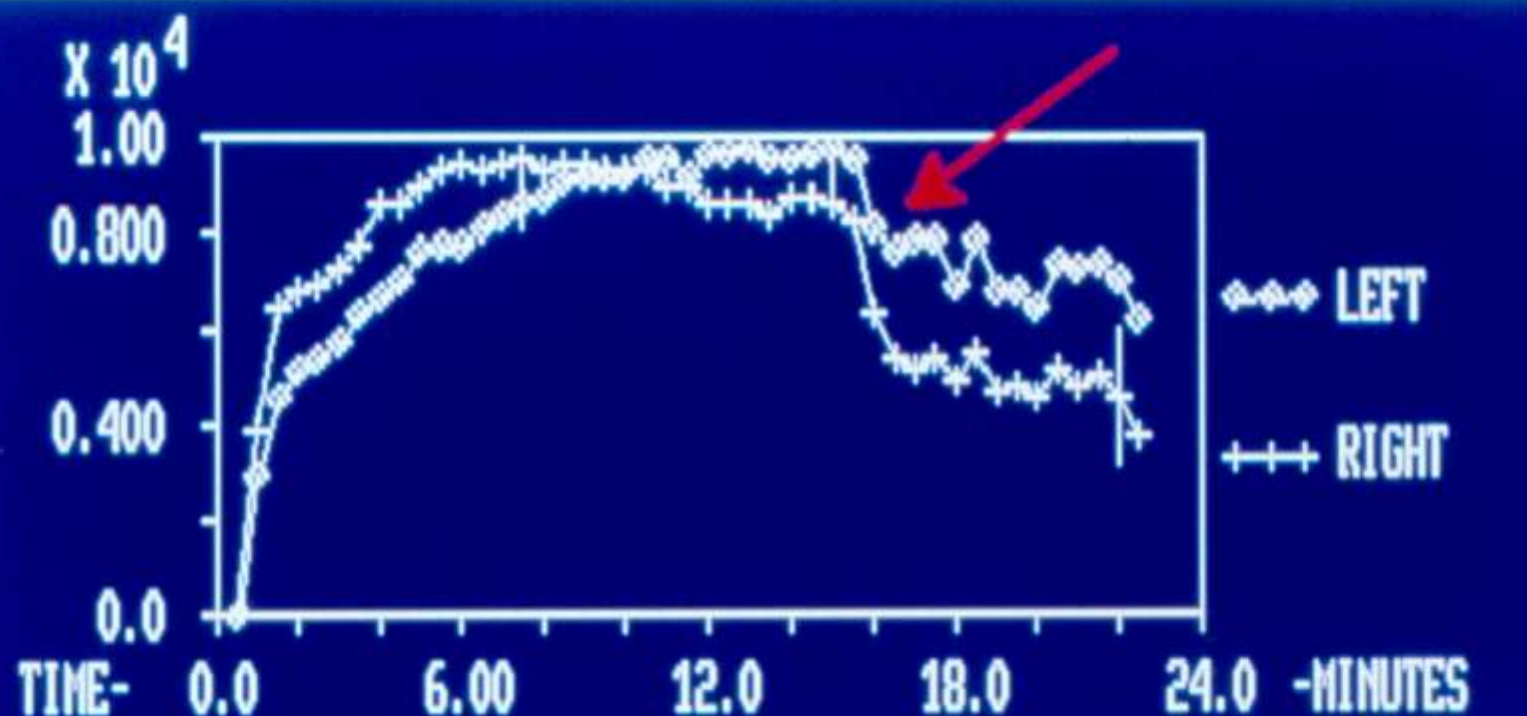
10 MIN



MOTION COMPENSATED

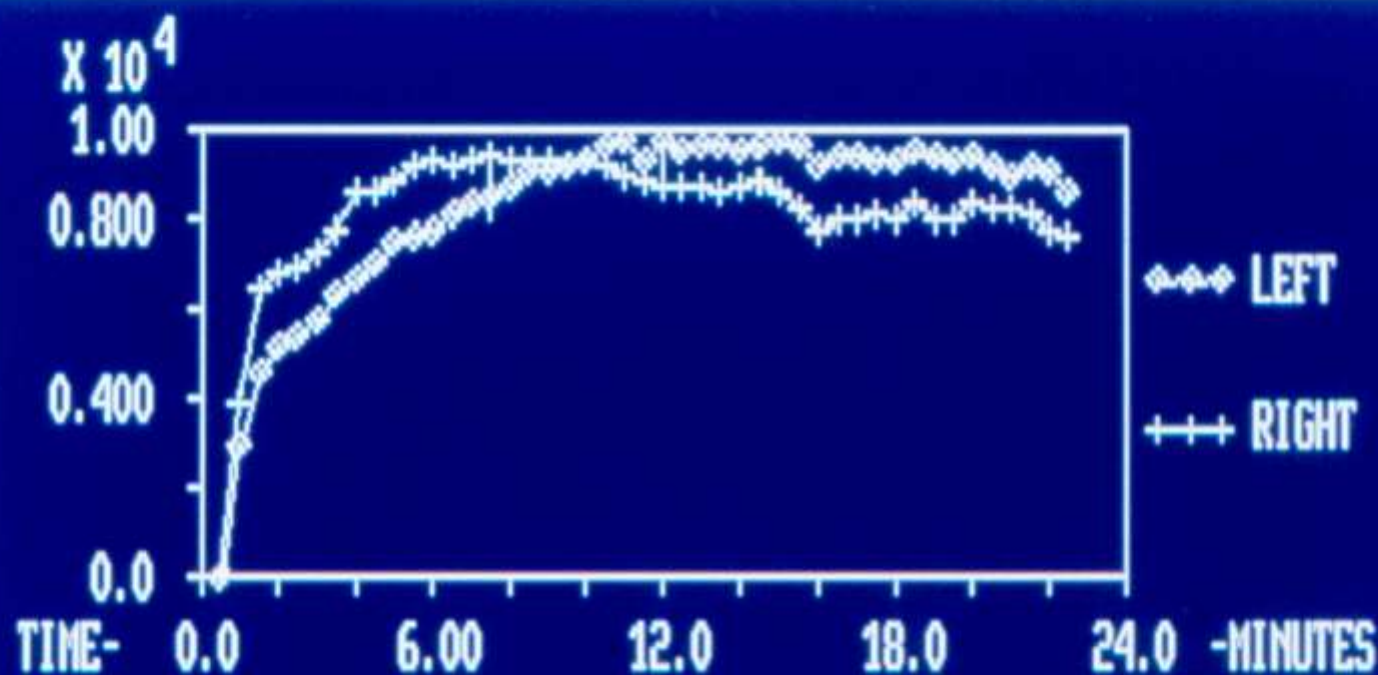


BEFORE MOTION COMPENSATION



	TOTCNTS	MAXCNTS	20-MIN COUNTS	TIME PEAK	PK To T 1/2	20-MIN %ofMAX
LEFT	3.444 E5	9642.	6951.	14.5	> 8.00	% 72.0
RIGHT	3.246 E5	9410.	4837.	7.00	14.3	% 51.4

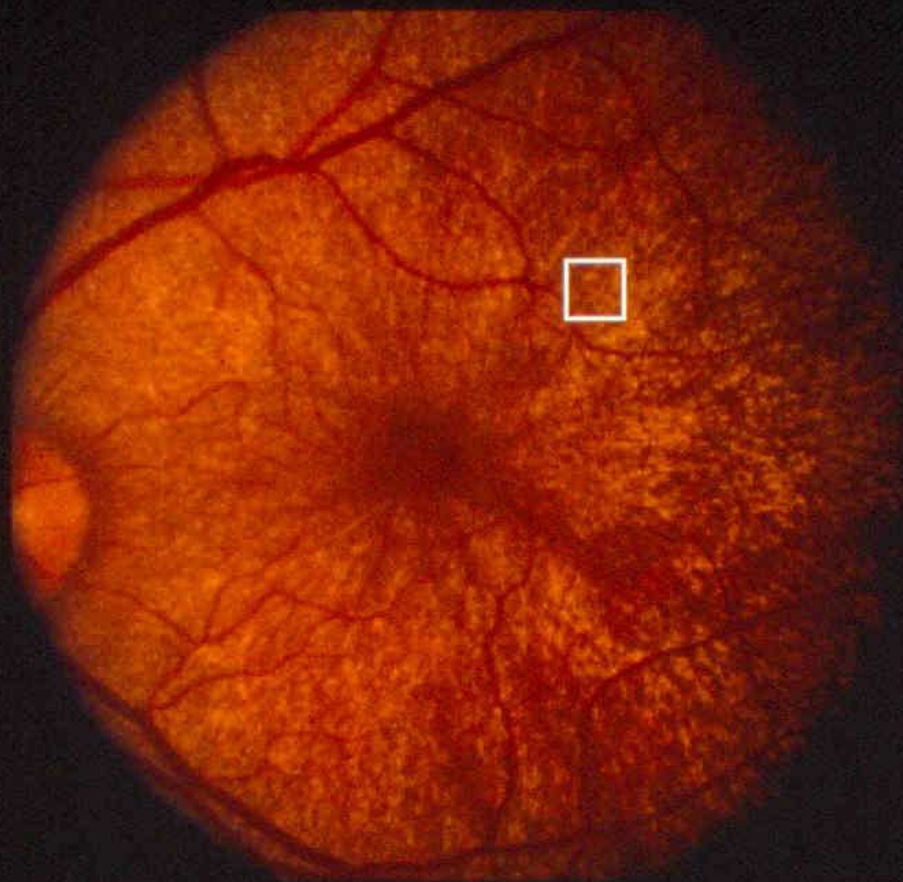
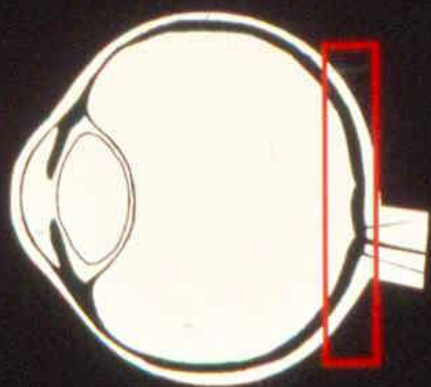
AFTER MOTION COMPENSATION



	TOTCNTS	MAXCNTS	20-MIN COUNTS	TIME PEAK	PK To T 1/2	20-MIN %ofMAX
LEFT	3.724 E5	9535.	9241.	11.5	> 11.0	% 96.9
RIGHT	3.663 E5	9341.	8146.	7.00	> 15.5	% 87.2

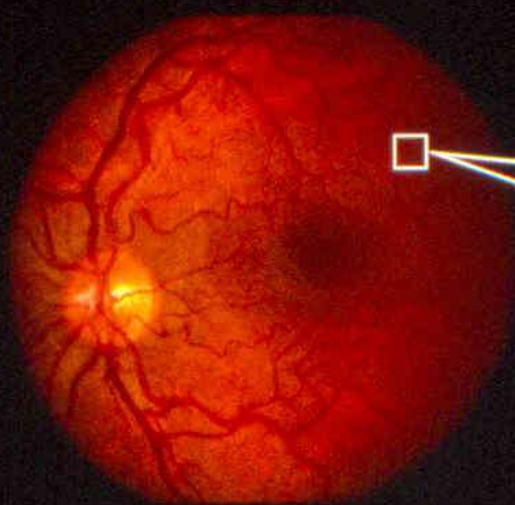
RETINITIS PIGMENTOSA

- **HEREDITARY RETINAL DISEASE**
- **INCURABLE**
- **CAUSES BLINDNESS**
- **EFFECTS >100,000 IN U.S.A.
>1,500,000 WORLDWIDE**

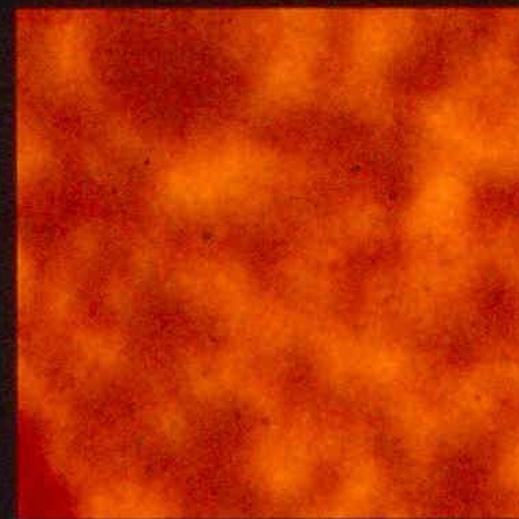
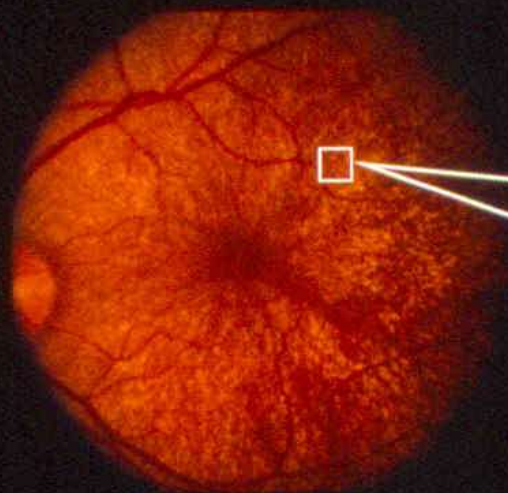


600 μm

NORMAL

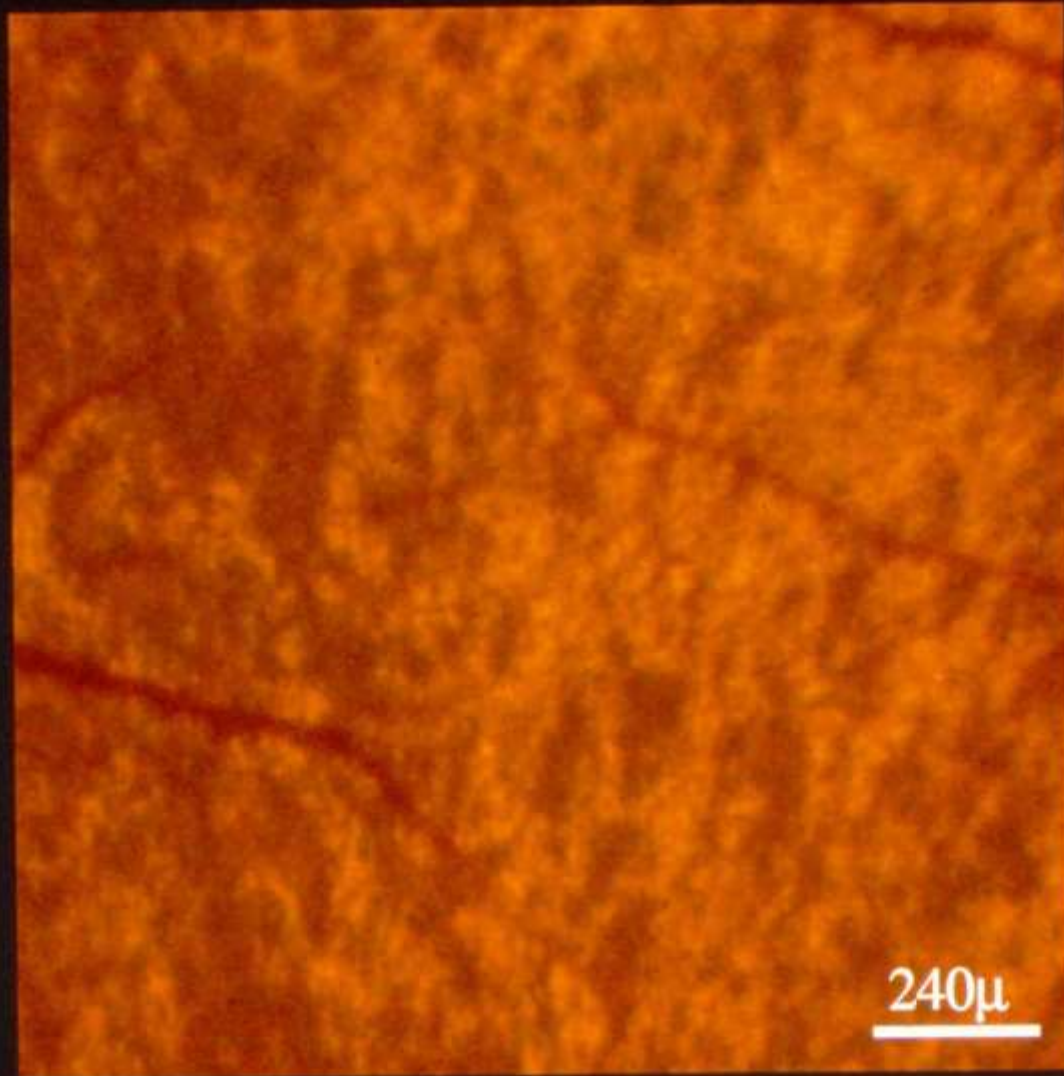


**XLRP
CARRIER**

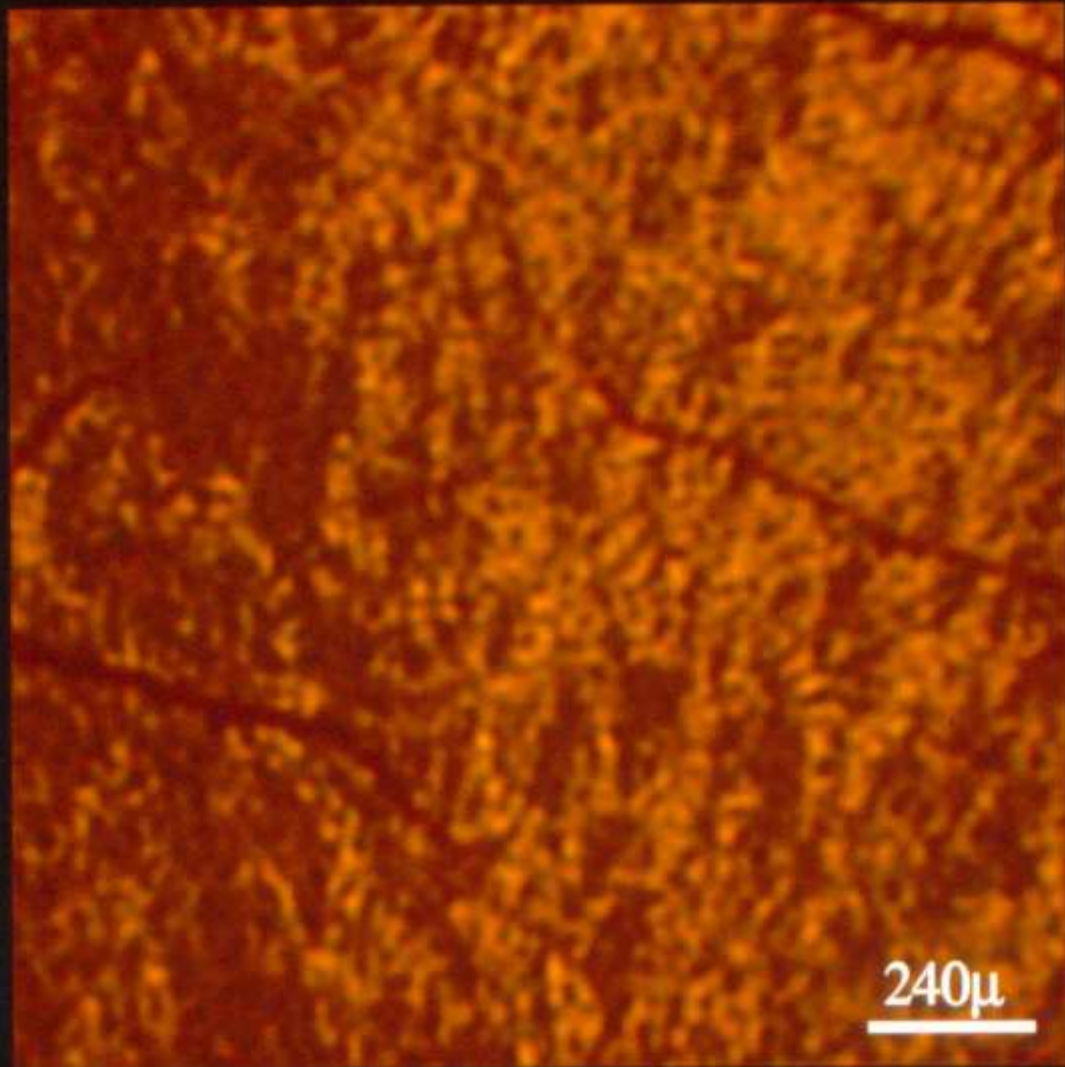


600 um

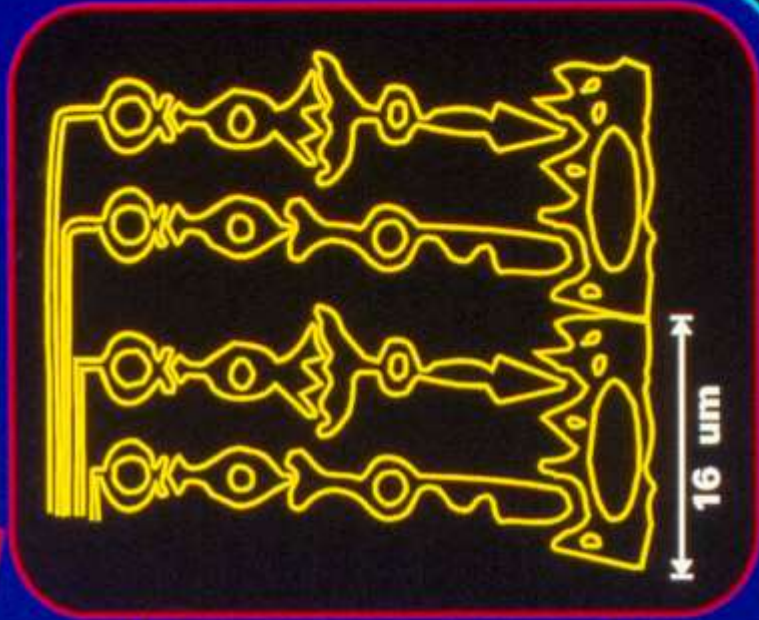
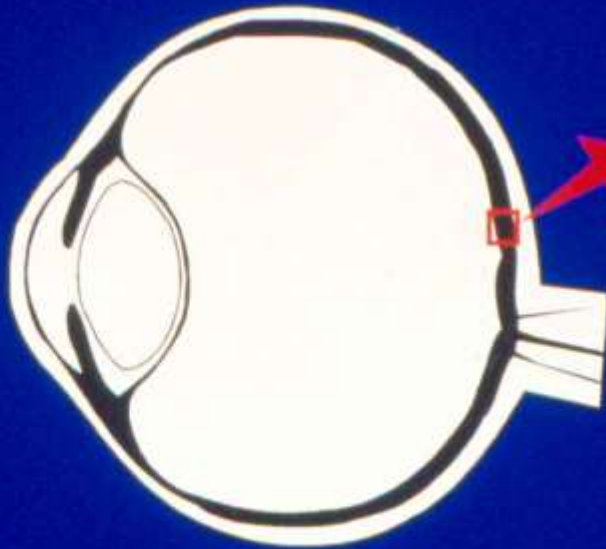
ORIGINAL
(640x640)



RESTORED



EYE & RETINA



Nerve Fiber Layer

Ganglion Cell Layer

Rods & Cones

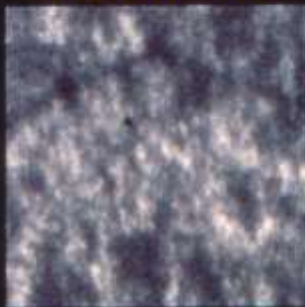
Pigment Epithelium

Stäbchen
und Zapfen

Netzhaut

QUANTITATIVE ANALYSIS

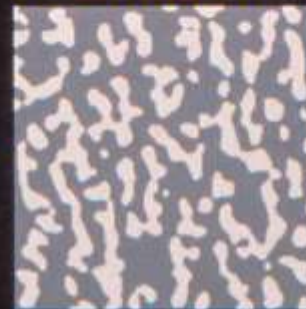
ORIGINAL



RESTORED



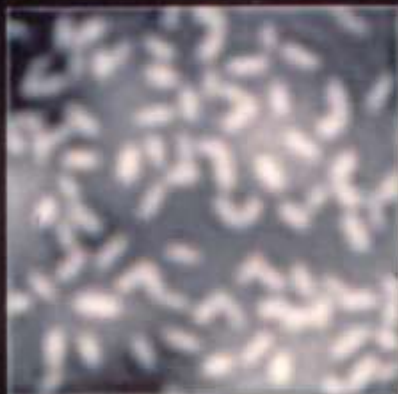
SEGMENTED



STATISTICS

- SIZE
- SHAPE
- ORIENTATION
- INTENSITY
- DENSITY
- :
- :

**BIOLOGICAL
HYPOTHESIS**



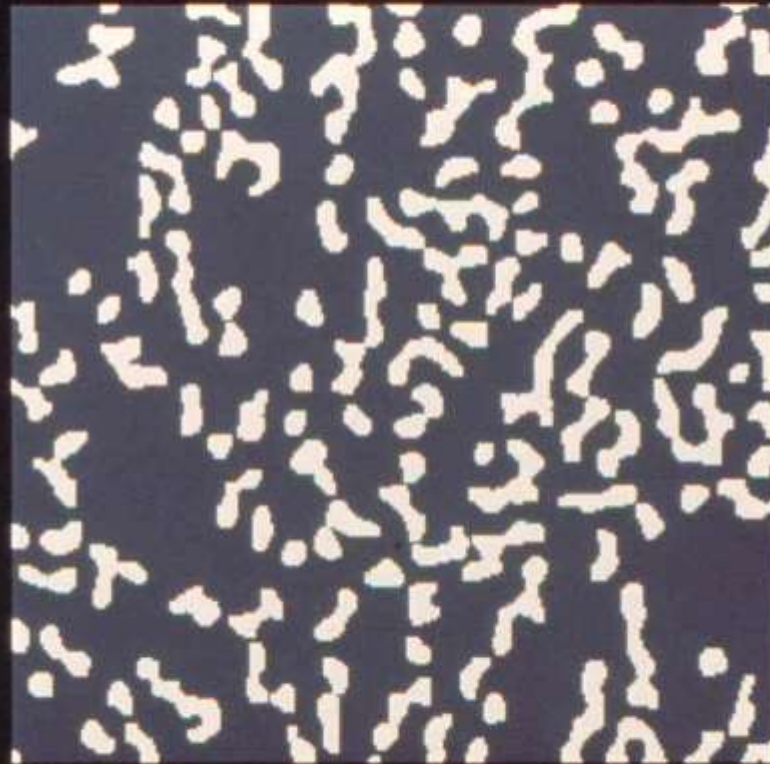
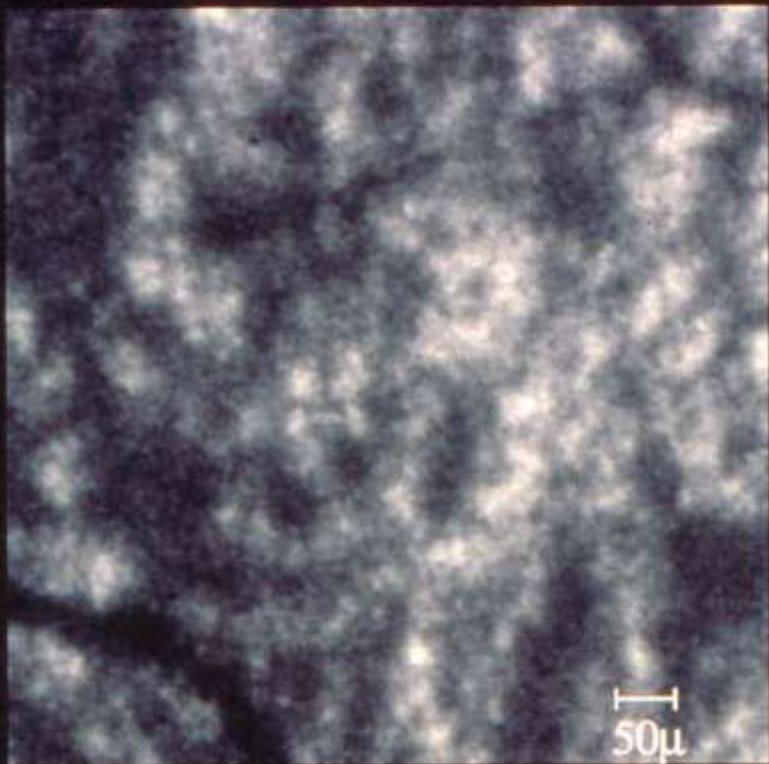
**SIMULATED
IMAGE**



"AND"



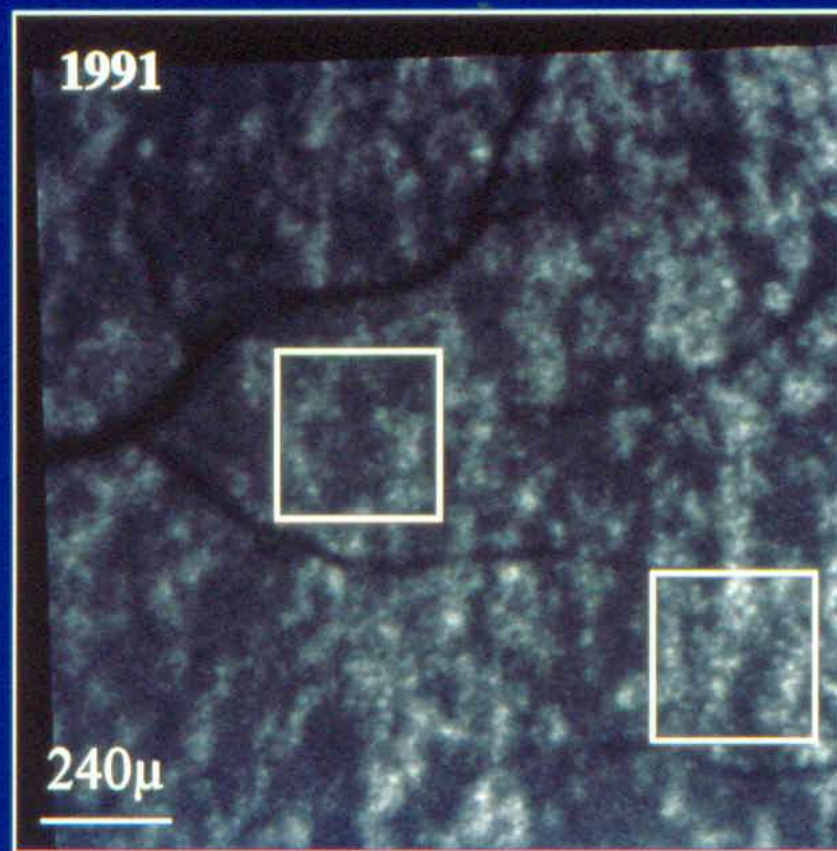
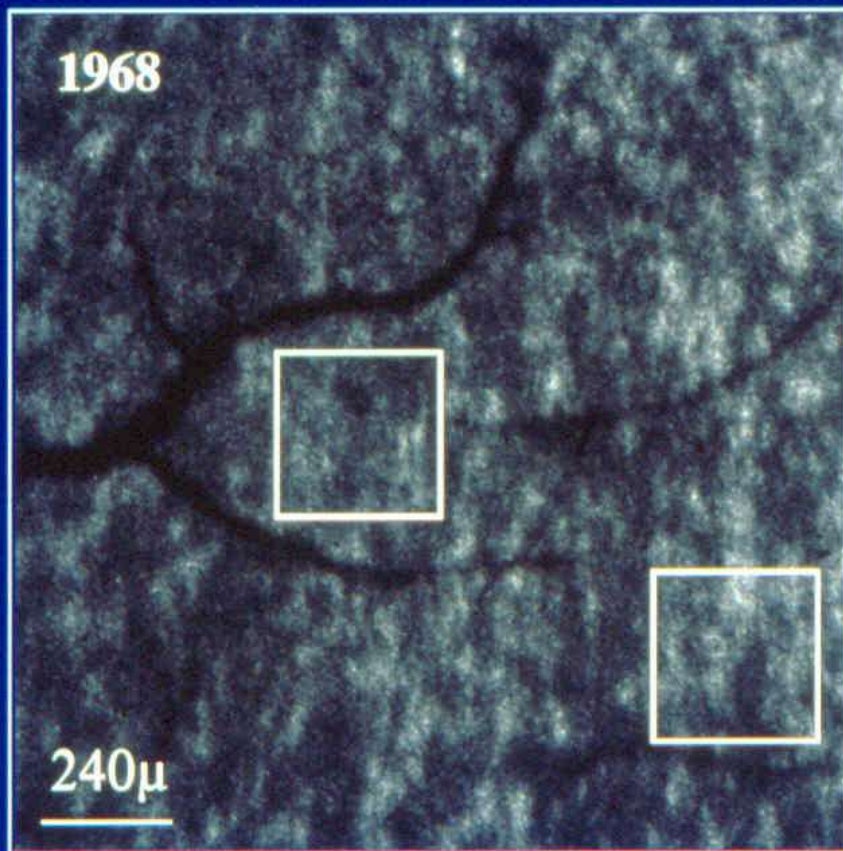
**MULTI-SCALE
SEGMENTATION &
ORIGINAL OBJECTS**

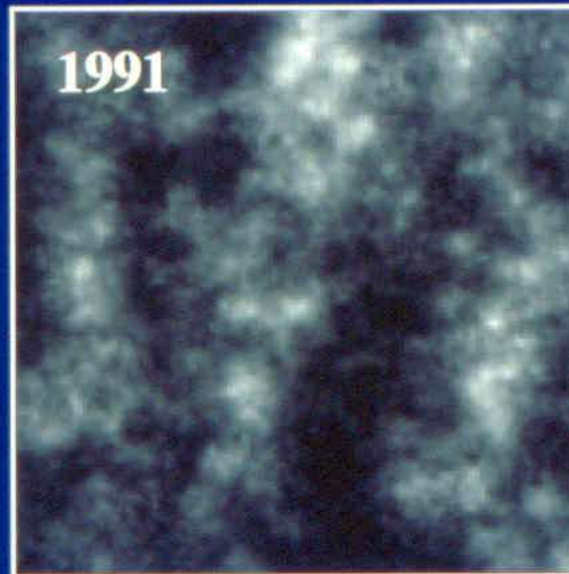
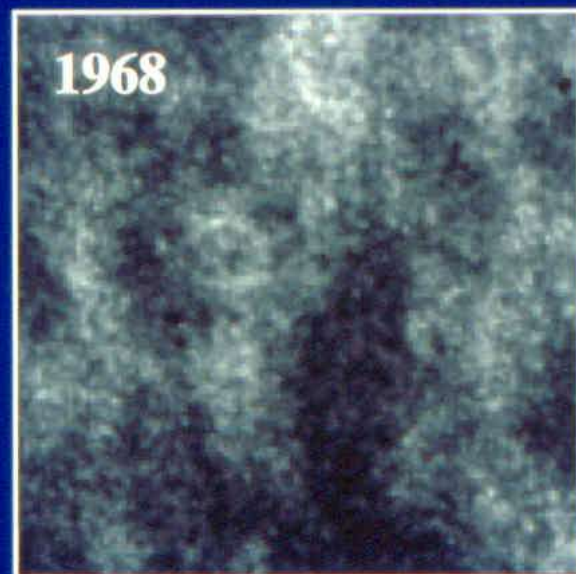
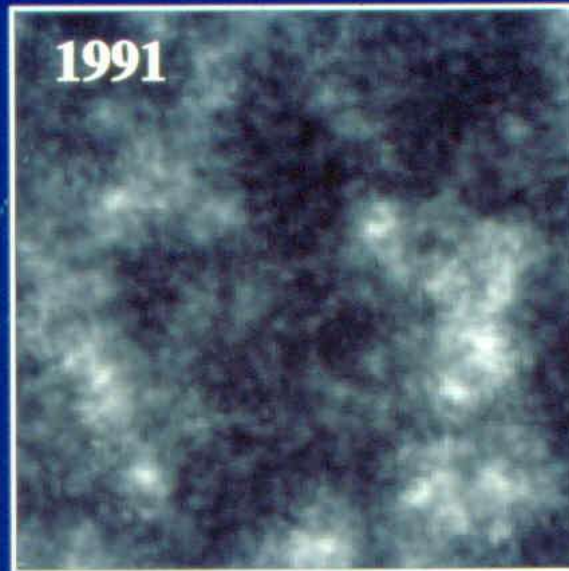
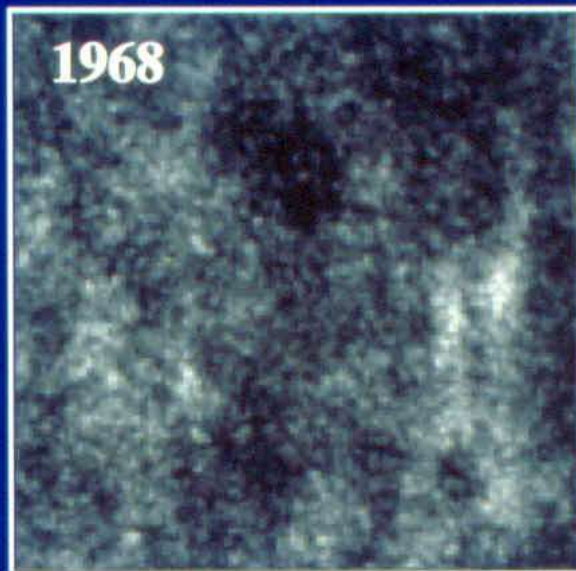


RESULTS OF TAPETAL-LIKE REFLEX ANALYSIS

the glowing of eyes in the dark

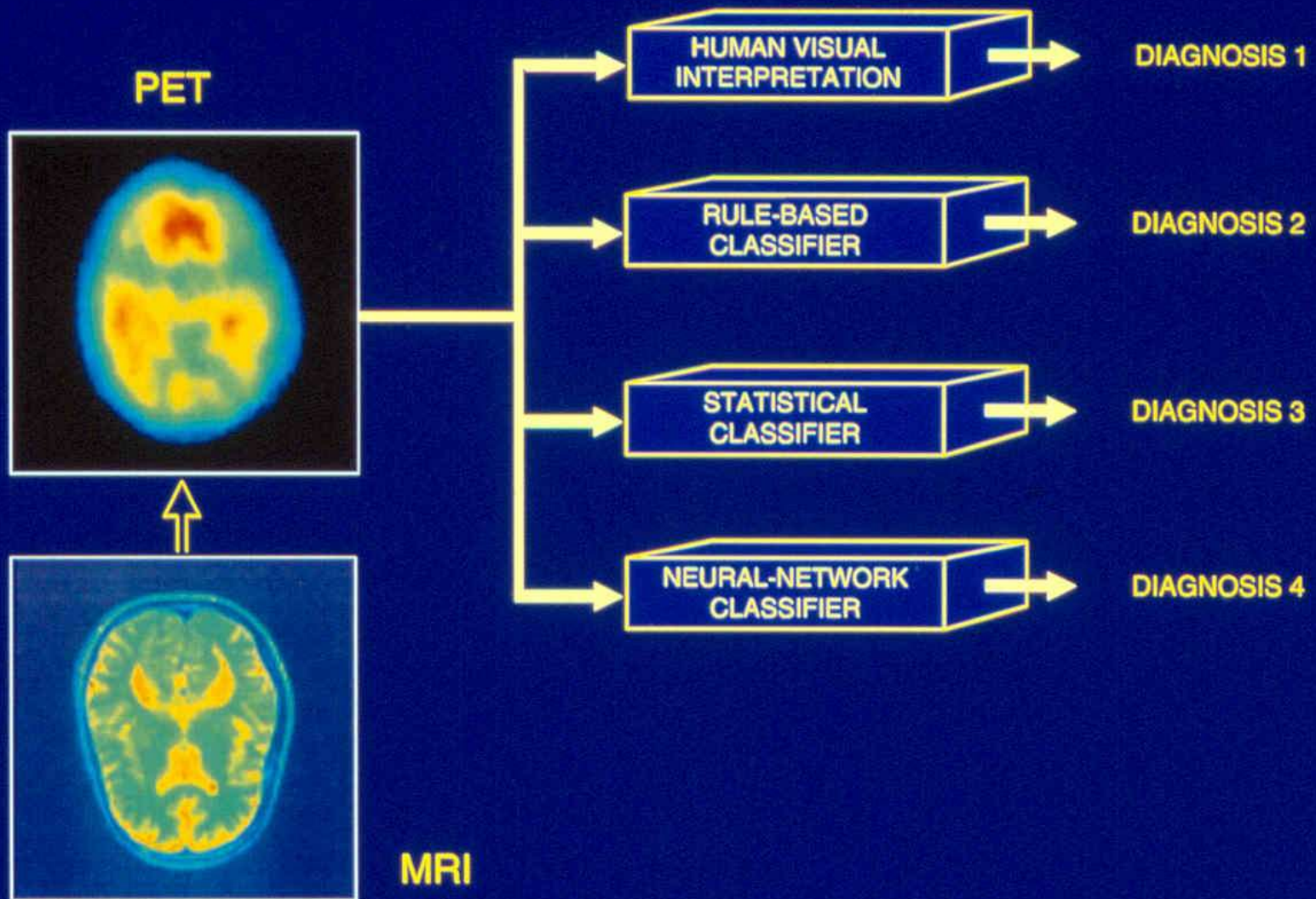
- 1) REFLECTANCE 30% HIGHER**
- 2) SIZE 14 μm OR SMALLER**
- 3) ORIENTATION TOWARDS FOVEA**
- 4) NO CHANGE OVER 23 YEARS**

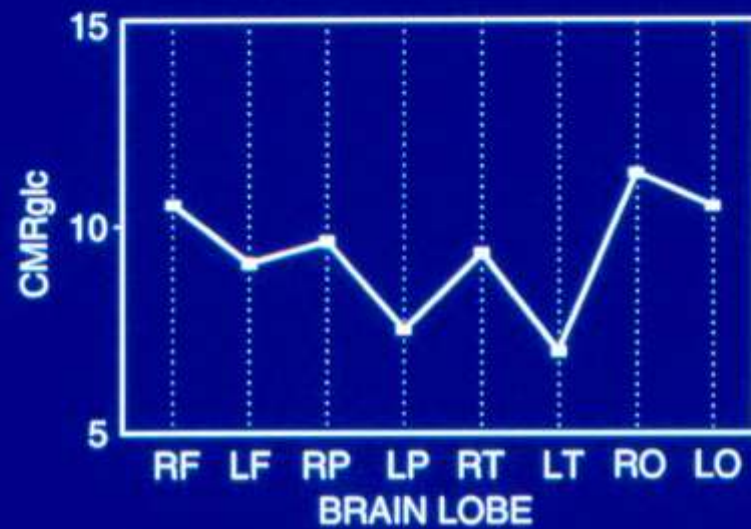
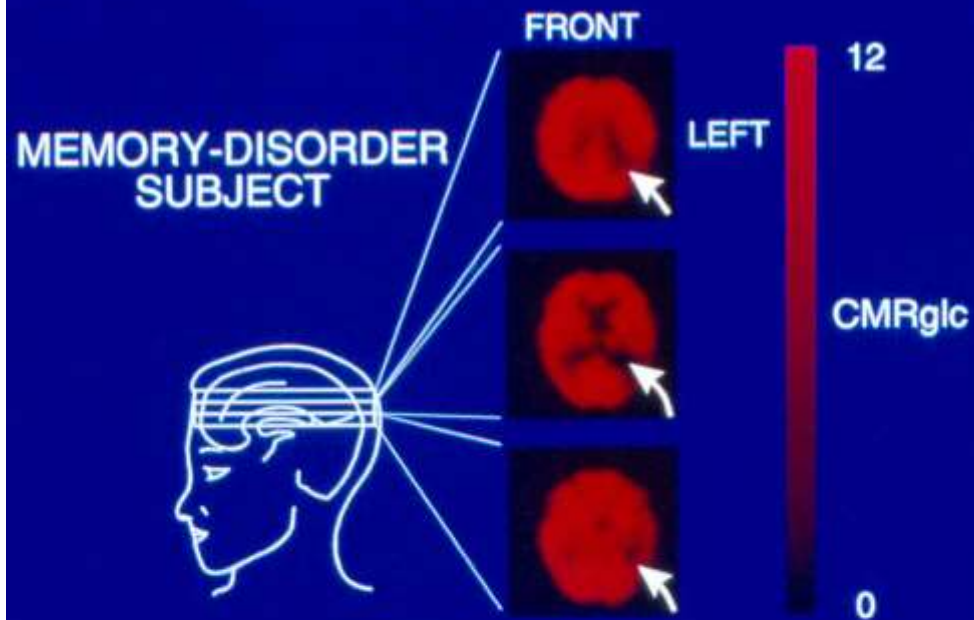




Diagnosis of Alzheimer's Disease by Neural Networks on the basis of regional brain activity, measured with fluorodeoxyglucose (FDG) PET scans, and segmentation supported by MRI scans

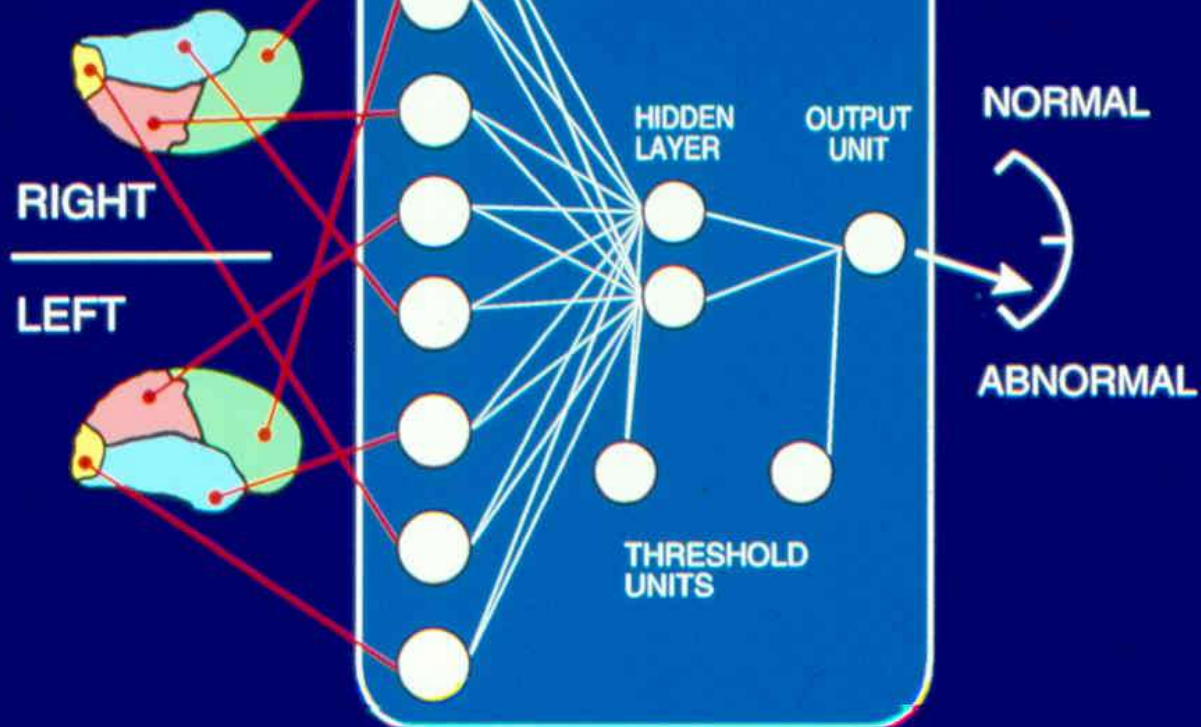
- Development of recommendations for the optimization of PET data analysis**
- Investigation of reliability of diagnosis as a function of image resolution**
- Determination of diagnostically best metabolic profiles**





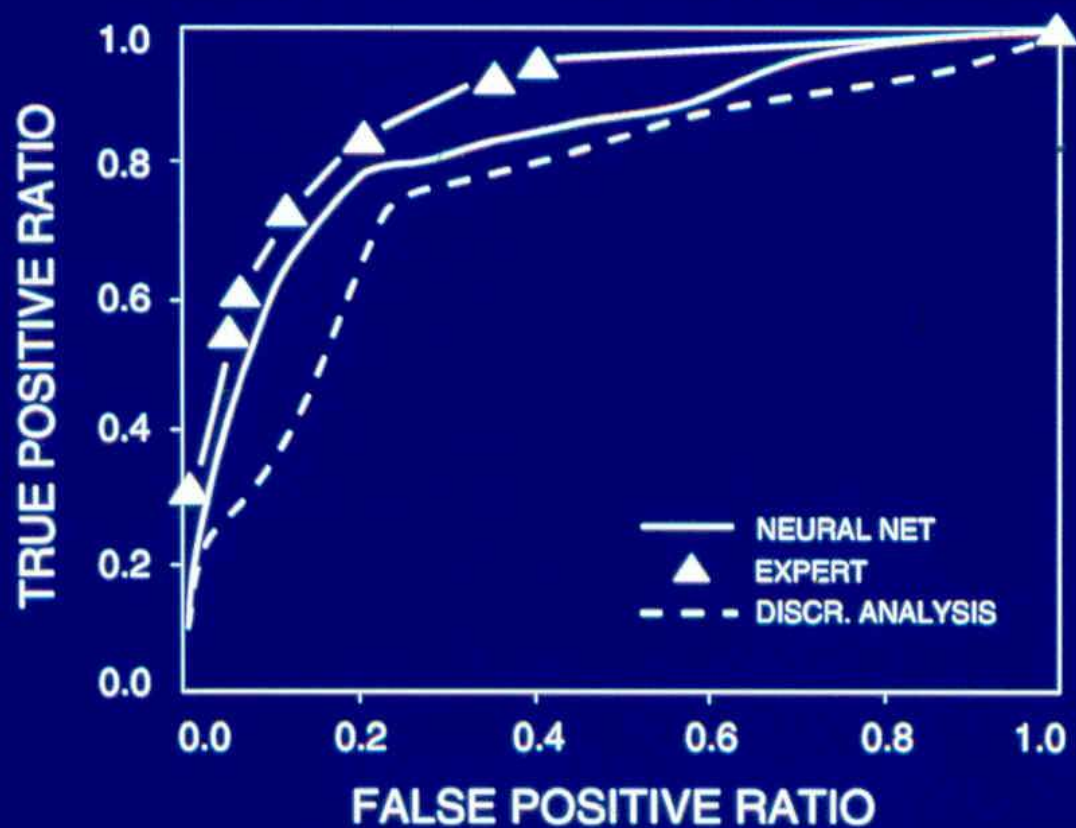
BACK-PROPAGATION NEURAL NETWORK

INPUTS
REPRESENT
REGIONAL
FUNCTION

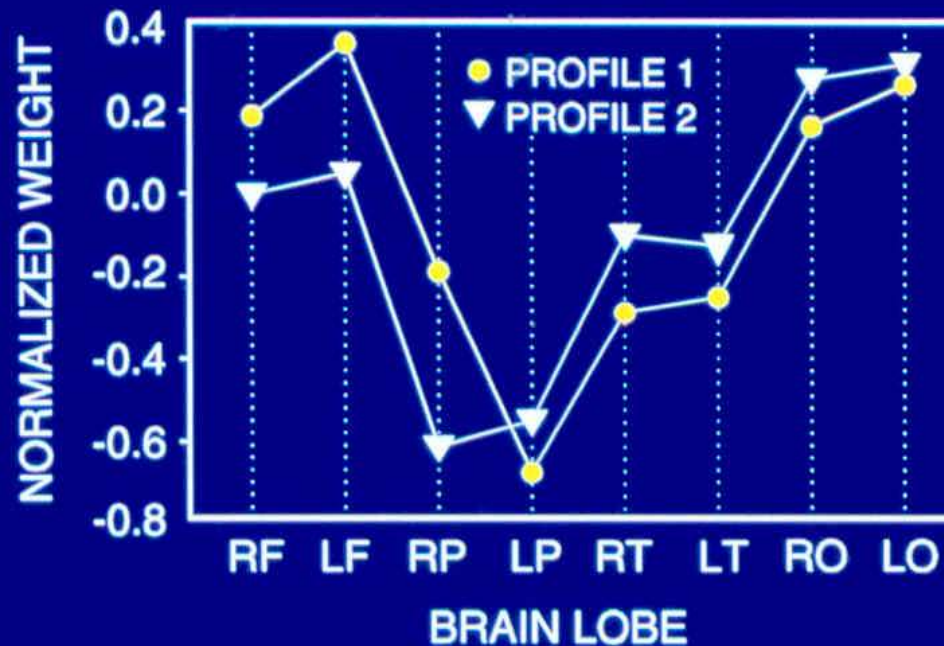


Training of neural network!!!

DIAGNOSIS OF ALZHEIMER'S DISEASE

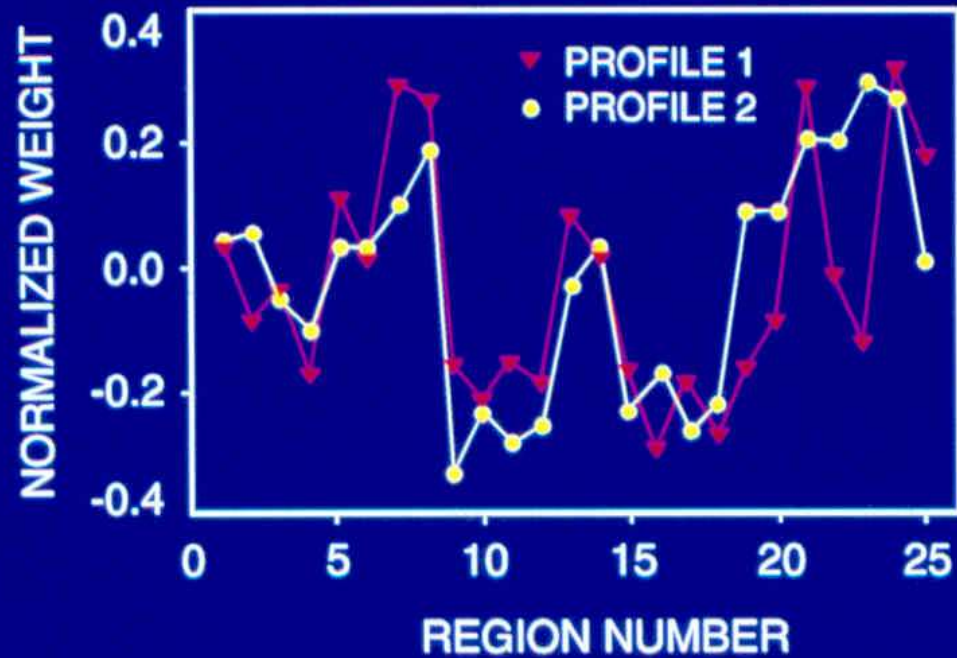


Relative Operating Characteristics (ROC) for the Classification of Alzheimer's Disease

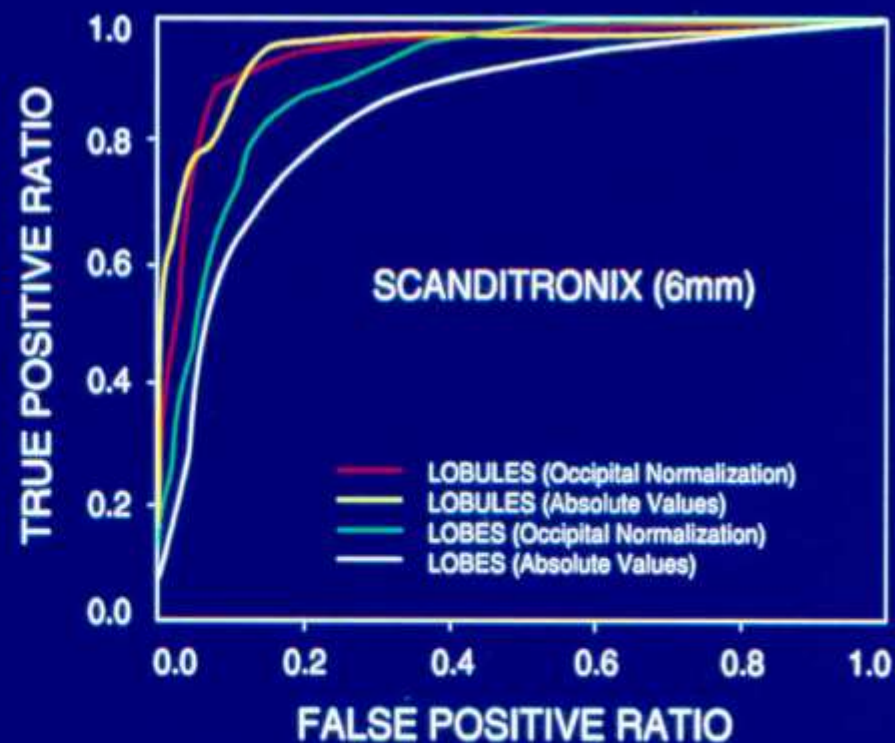
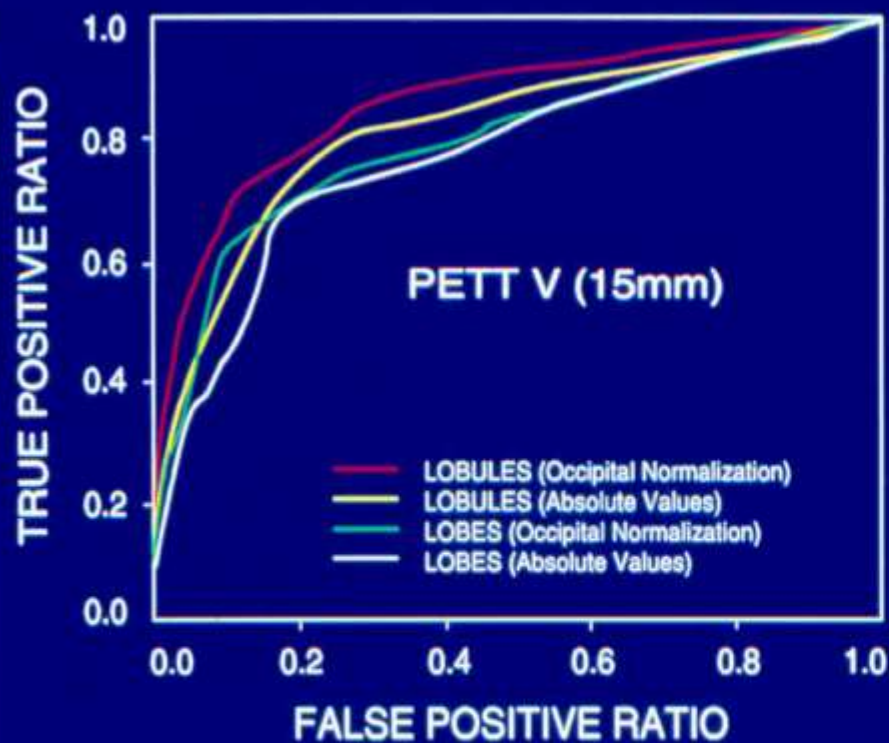


**MOST IMPORTANT AND GENERALIZABLE DISCRIMINATING PROFILES
LEARNED BY NEURAL NETWORKS FROM TWO PET DATABASES**

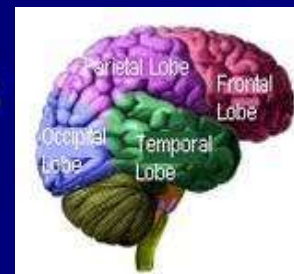
Was stellt das Ergebnis des trainierten neuronalen Netzwerks dar?
Die Kreuzkorrelationsfunktion zwischen den Musterprofilen 1 und 2 und den
aktuellen Aktivitätsmustern.



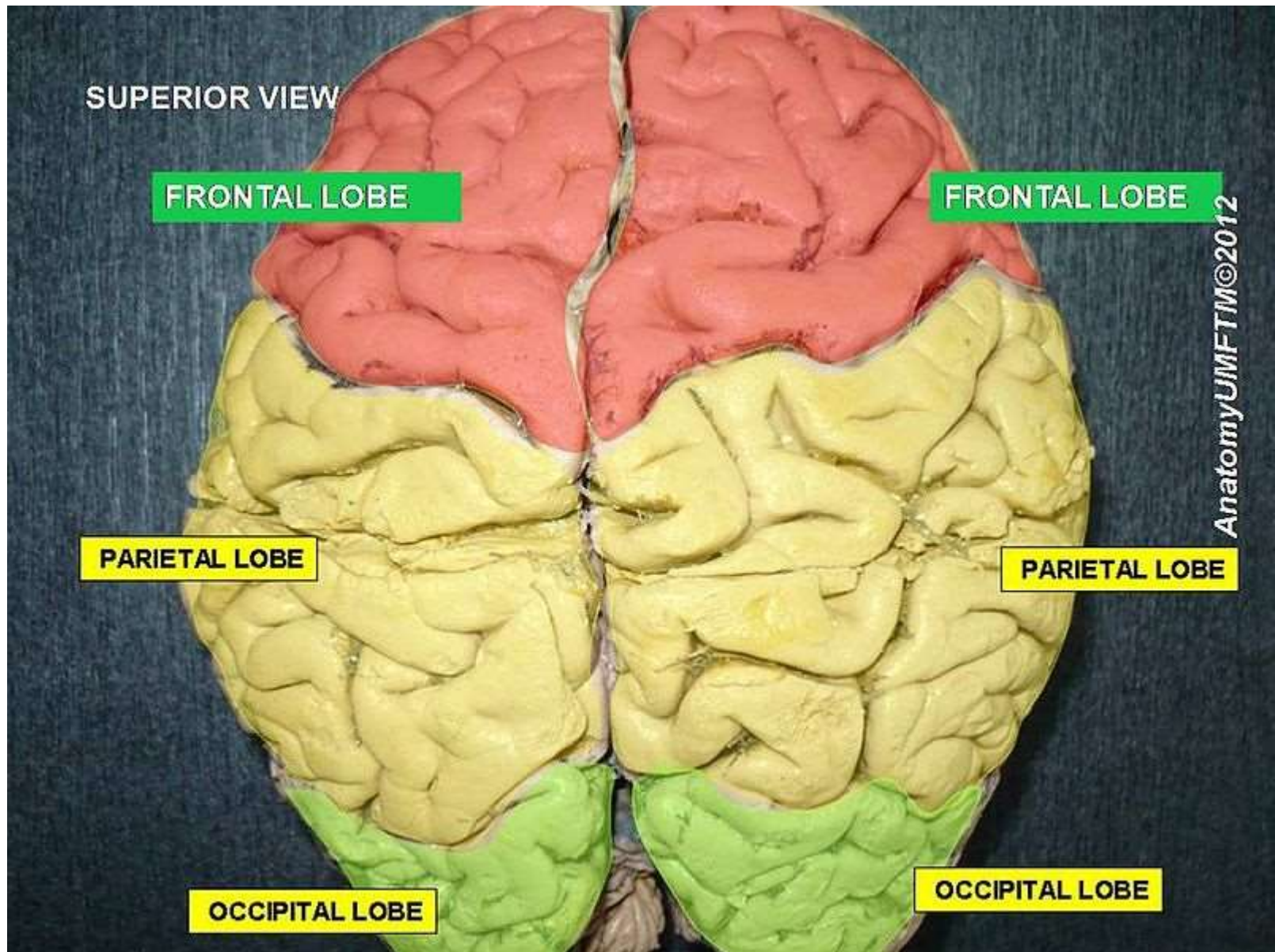
**MOST IMPORTANT AND GENERALIZABLE LOBULE-LEVEL
DISCRIMINATING PROFILES
LEARNED BY NEURAL NETWORKS FROM TWO PET DATABASES**



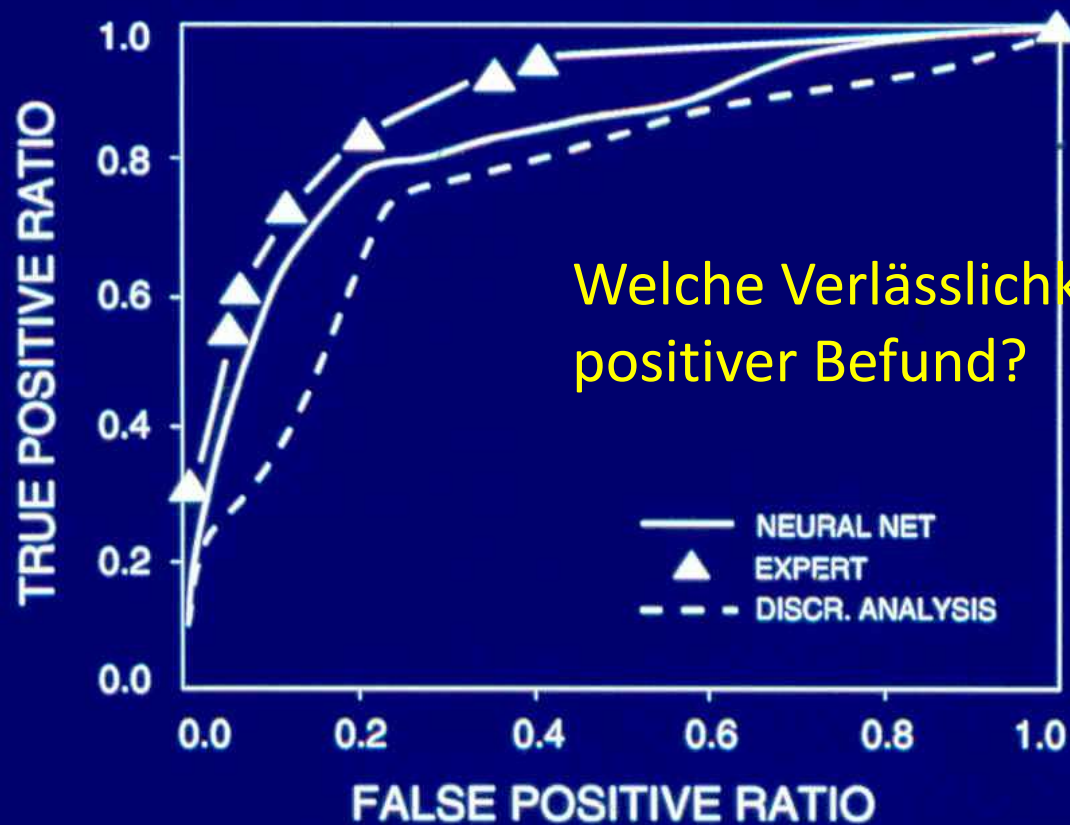
**Relative Operating Characteristics for Neural Networks
Applied to PETT V and Scanditronix Data
at Lobar and Lobular Levels**



Occipital: Hinterhaupt, Lobe: Lappen, Lobule: Läppchen



Occipitaler Lappen: Unterteilung in unteres und oberes Lppchen



Relative Operating Characteristics (ROC) for the Classification of Alzheimer's Disease

Beispiel: HIV-ELISA-Test

Insgesamt 1.000.000 getestete Personen. Wie viel Prozent der positiv getesteten Personen sind wirklich HIV infiziert?

Sensitivität = 95%

Spezifität = 95%

Am. J. Epid., 1996

Prävalenz = 0.1%

Beispiel: HIV-ELISA-Test

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Spezifität = 95%

Am. J. Epid., 1996

Prävalenz = 0.1%

	Tatsächlicher Sachverhalt	
	krank	gesund
Positiver Befund	950	49950
Negativer Befund	50	949050
	1000	999000

Beispiel: HIV-ELISA-Test

Insgesamt 1.000.000 getestete Personen. Wie viel Prozent der positiv getesteten Personen sind wirklich HIV infiziert?

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Am. J. Epid., 1996

Prävalenz = 0.1%

	Tatsächlicher Sachverhalt	
	krank	gesund
Positiver Befund	950	49950
Negativer Befund	50	949050
	1000	999000

Positiver Vorhersagewert = $950 / (950 + 49950) = 1.87\%$

Negativer Vorhersagewert = $949050 / 949100 = 99.995\%$