Medical Image Quality and Dose Optimization in the Digital Era: Clinically Focused Issues

Perry Sprawls, Ph.D.

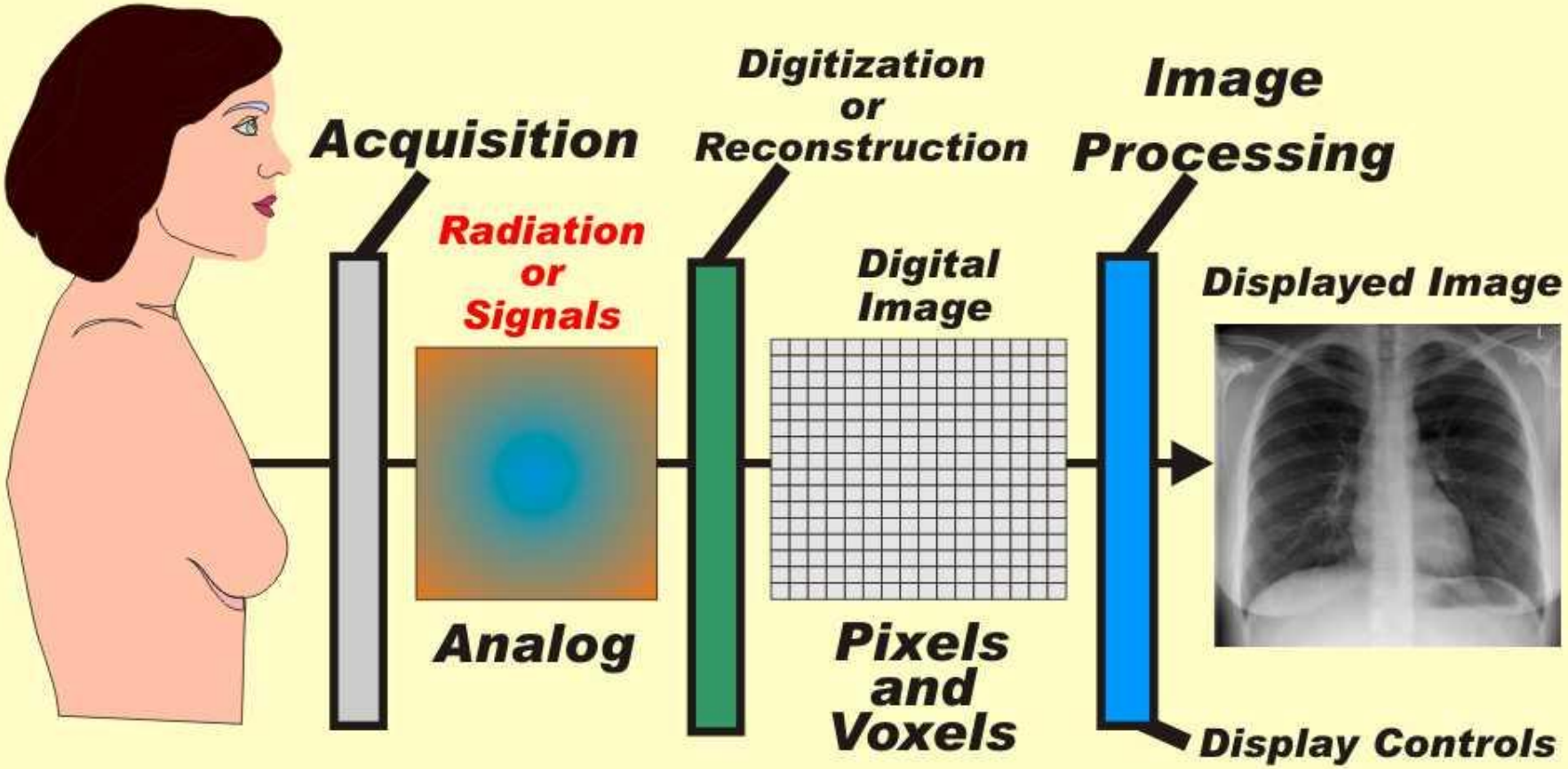
To follow on ipad

. http://www.sprawls.org/ipad

January 23, 1896


Computed Tomography
Magnetic Resonance Imaging
Positron Emission Tomography
Ultrasound
Single Photon Emission Tomography
Radiography
Fluoroscopy
Digital Image Management Systems

The Medical Imaging Process
All Modalities



Sprawls

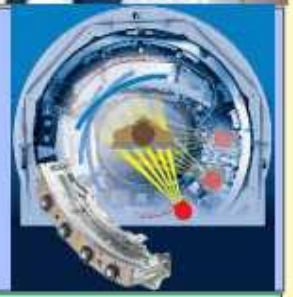
Computed Tomography

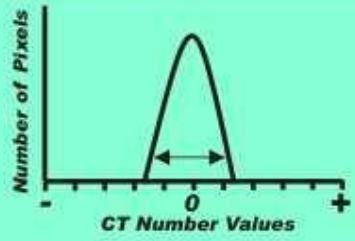
Image Characteristics and Quality

Radiation Dose

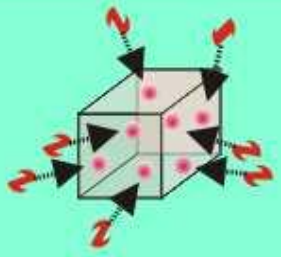
Imaging Protocols

Technology





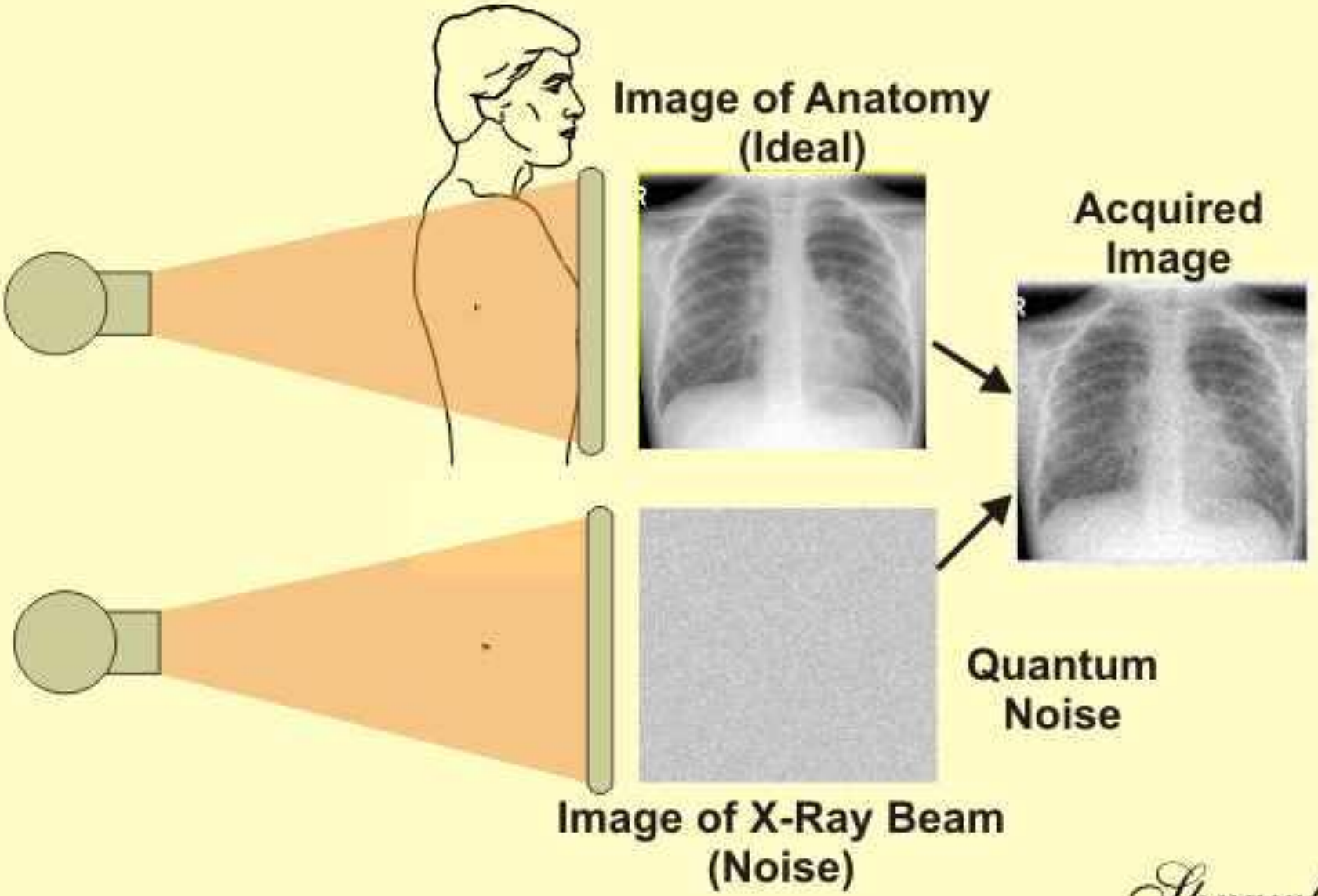
Science



Sprawls

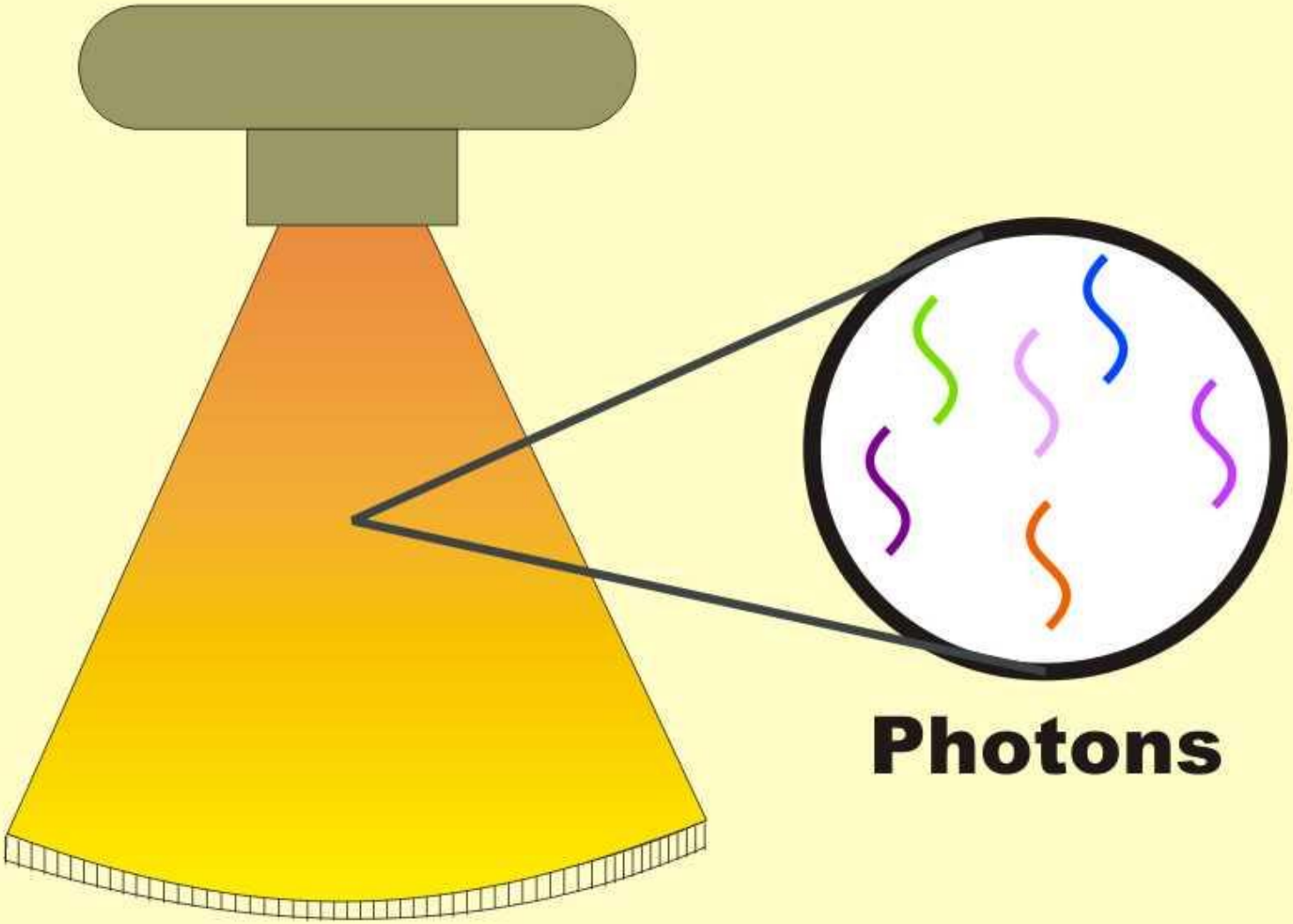
Have you ever seen an image of an X-ray beam?

X-Ray Image Noise



Sprawls

The Quantum Structure of the X-ray Beam



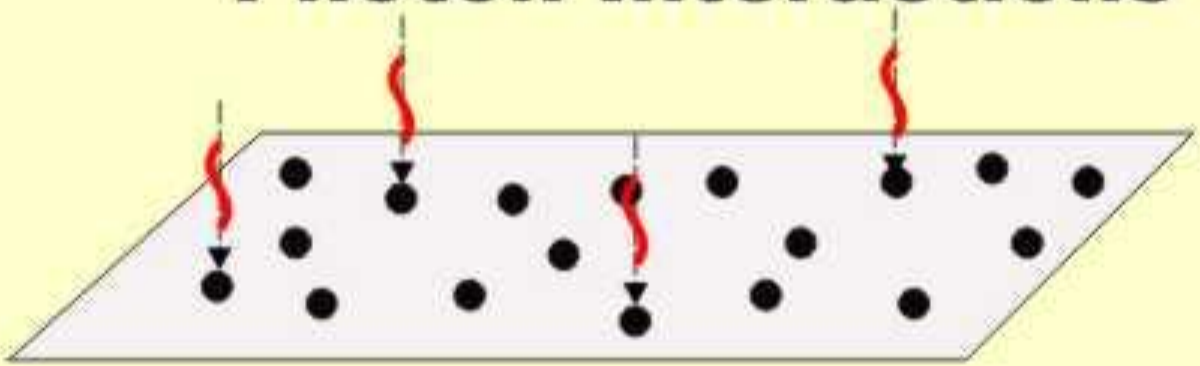
Sprawls

Randomly Distributed

In

Space

Photon Interactions



Produces

Image Noise

Sprawls

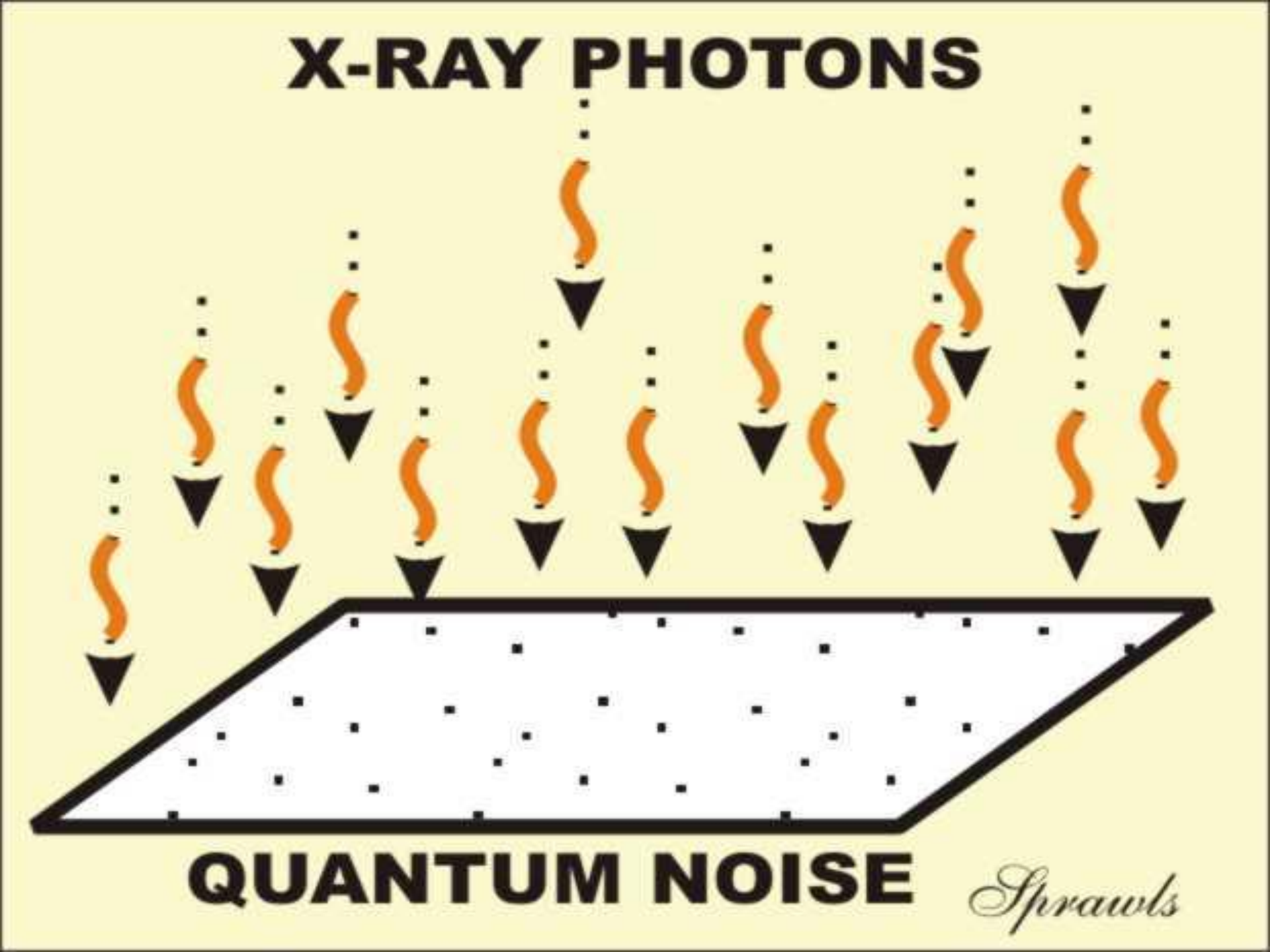
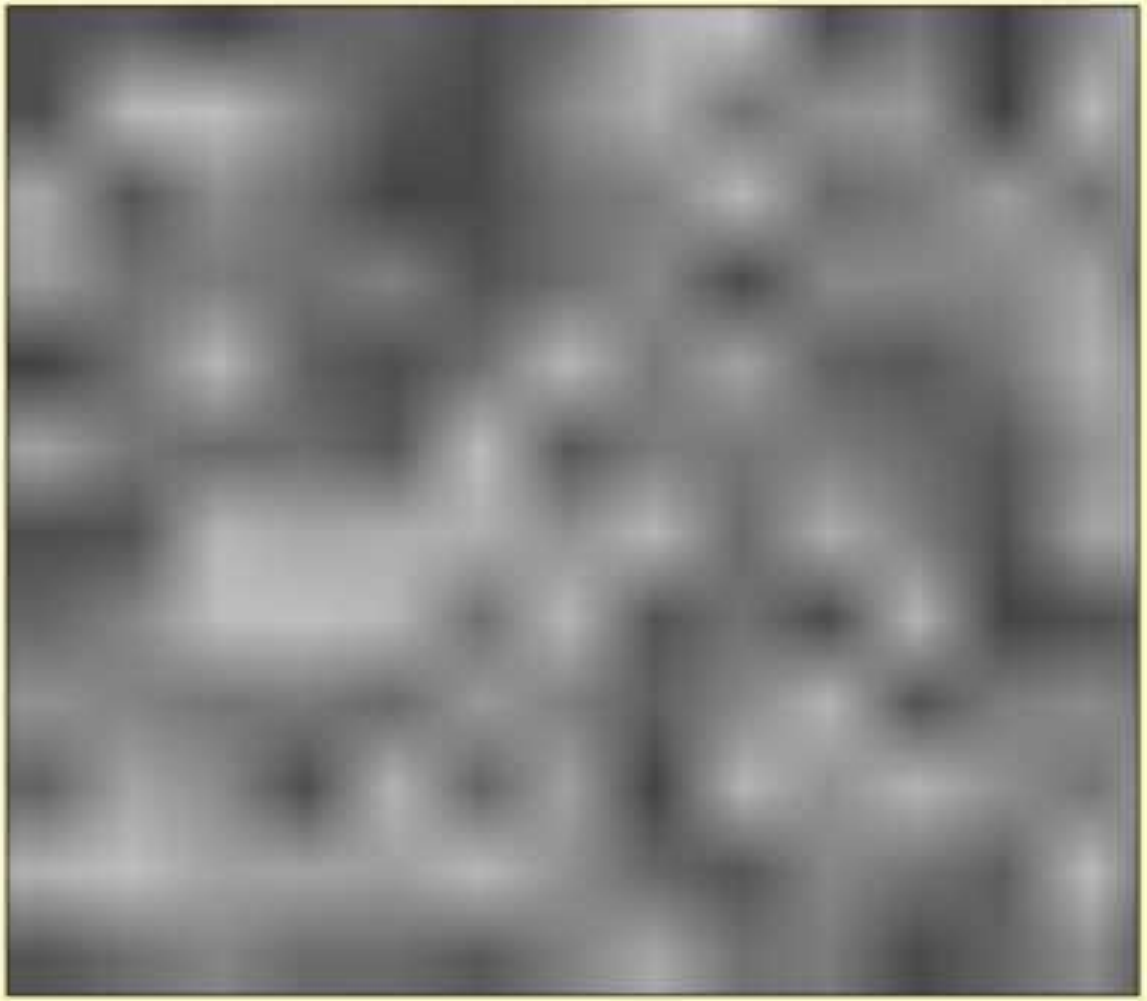

X-RAY PHOTONS
QUANTUM NOISE
Sprawls

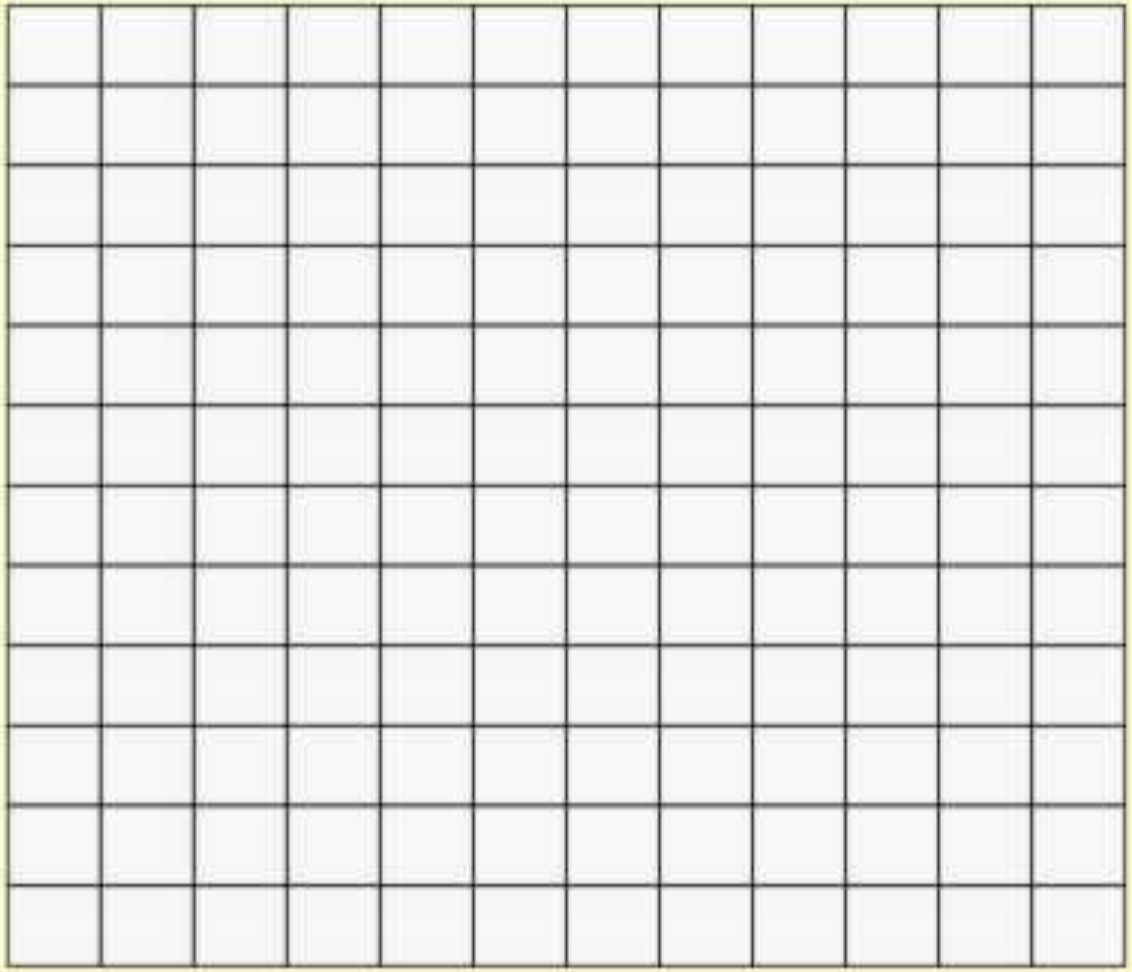
IMAGE RECEPTOR



Small Areas (Pixels)

Sprawls

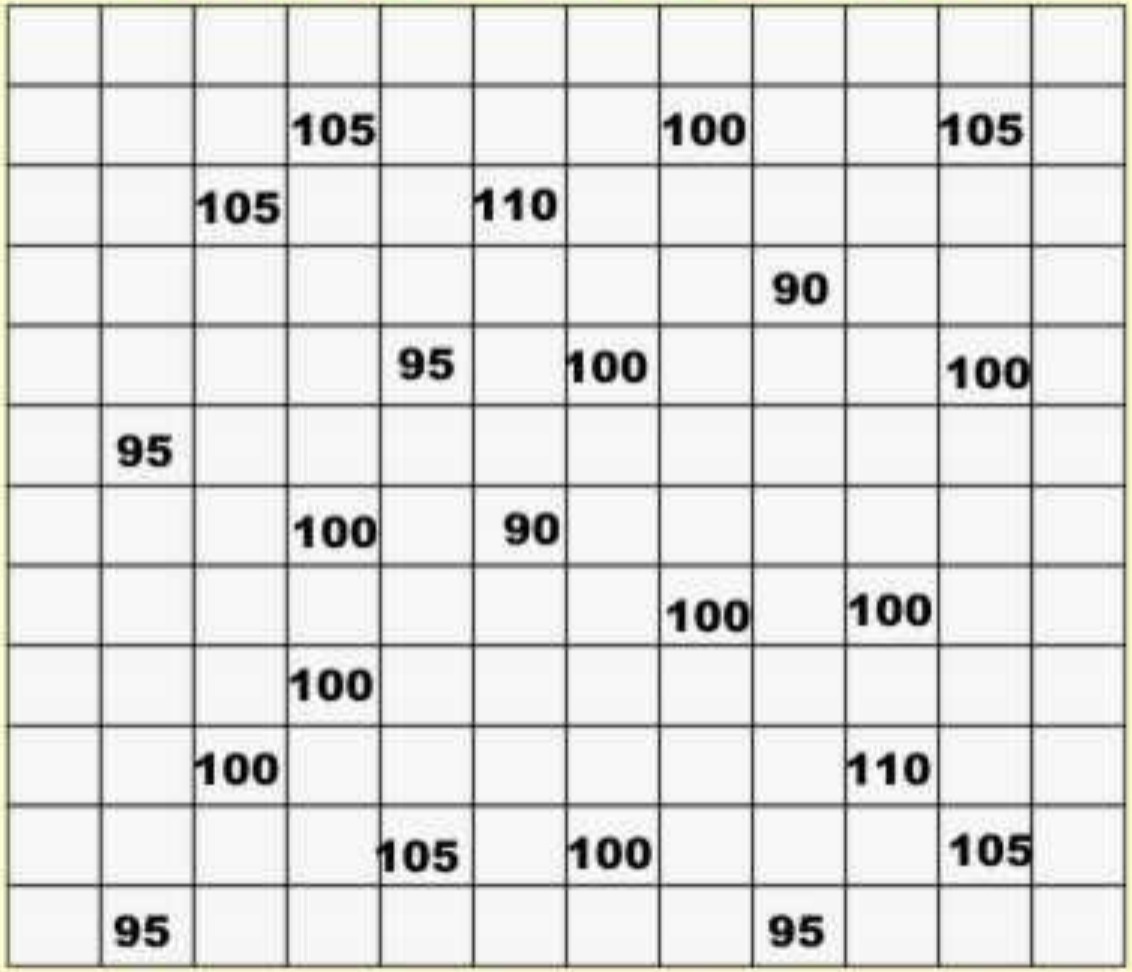
IMAGE RECEPTOR



Small Areas (Pixels)

Sprawls

IMAGE RECEPTOR



(Small Areas/Pixels)

Sprawls

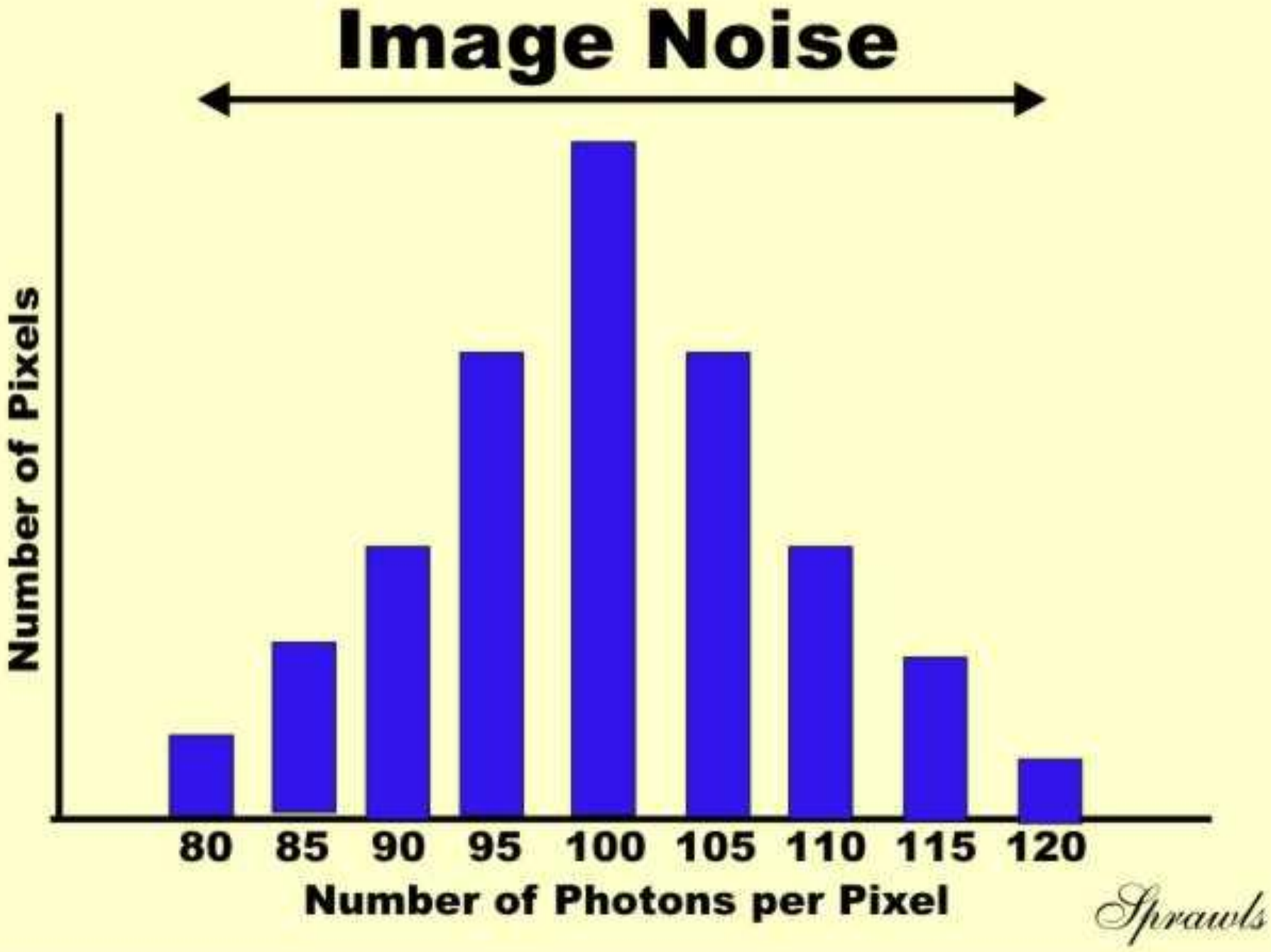


Image Noise
Number of Pixels
80
85
90
95
100
105
110
115
120
Number of Photons per Pixel
Sprawls

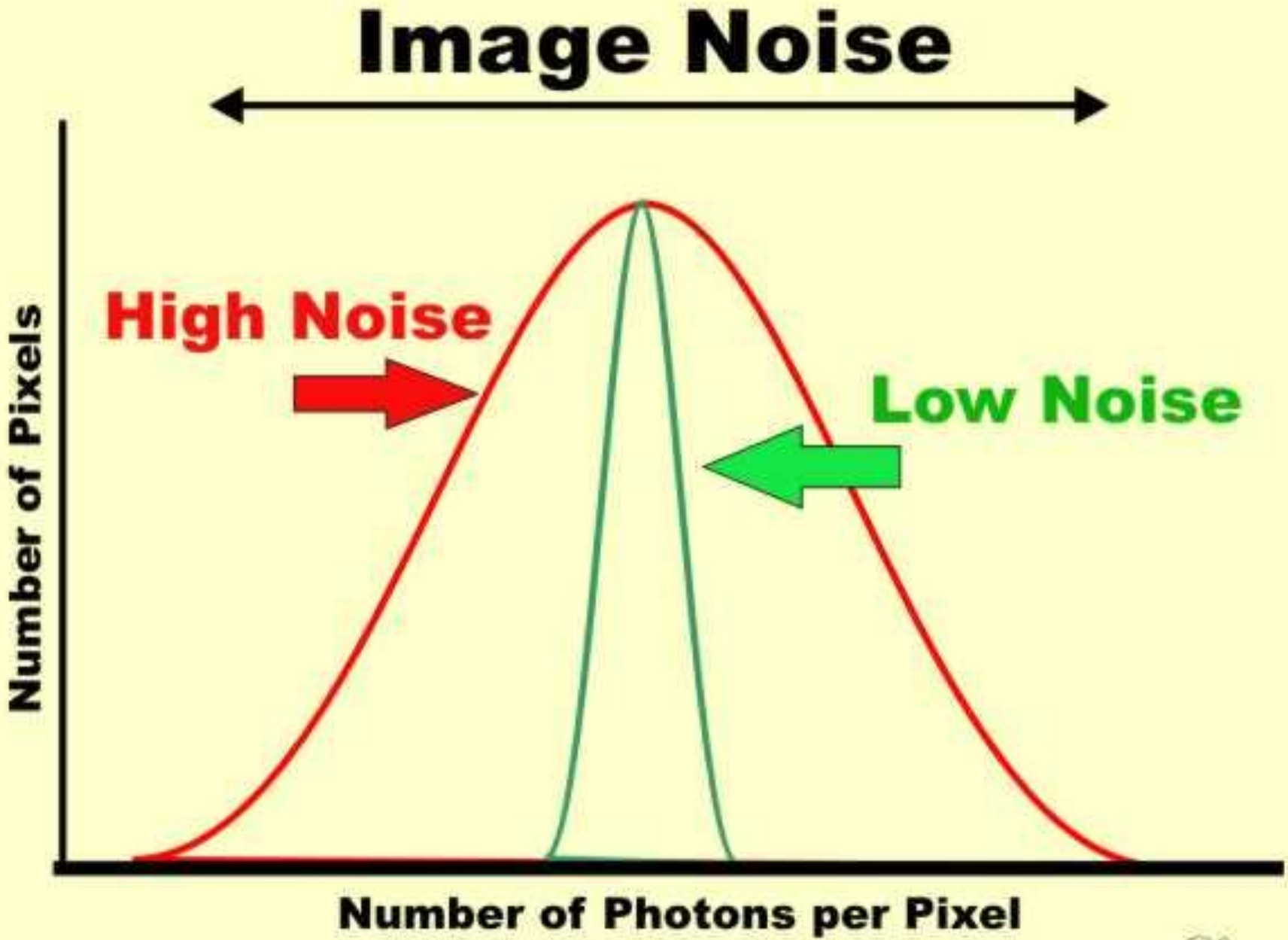


Image Noise
High Noise
Low Noise
Number of Pixels
Number of Photons per Pixel
Sprawls

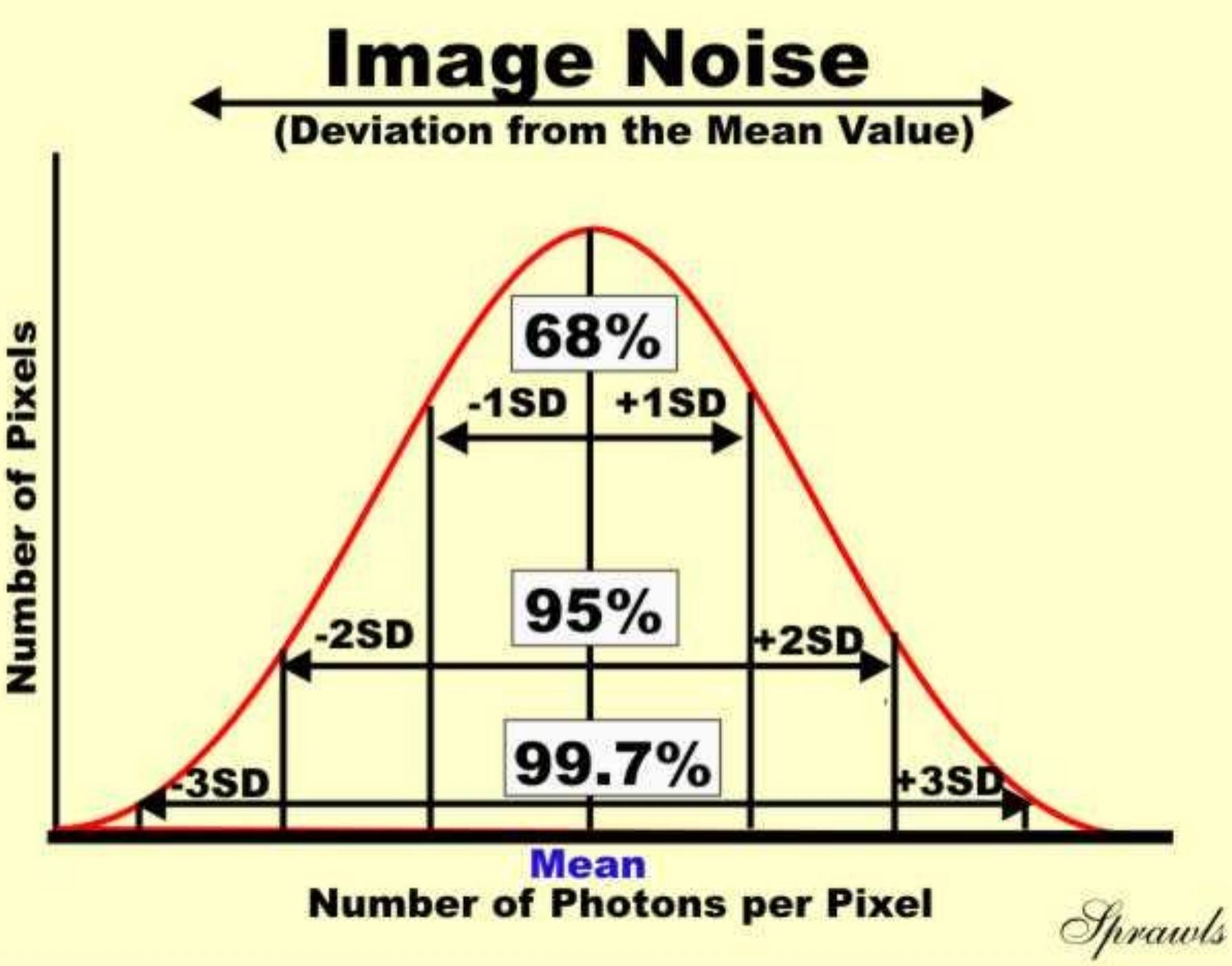


Image Noise
(Deviation from the Mean Value)
Number of Pixels
68%
-1SD
+1SD
95%
-2SD
+2SD
99.7%
-3SD
+3SD
Mean
Number of Photons per Pixel
Sprawls

$$\text{Standard Deviation} = \sqrt{\text{Mean}}$$

Mean	Standard Deviation
100	10 (10%)
1000	32 (3.2%)
10,000	100 (1%)

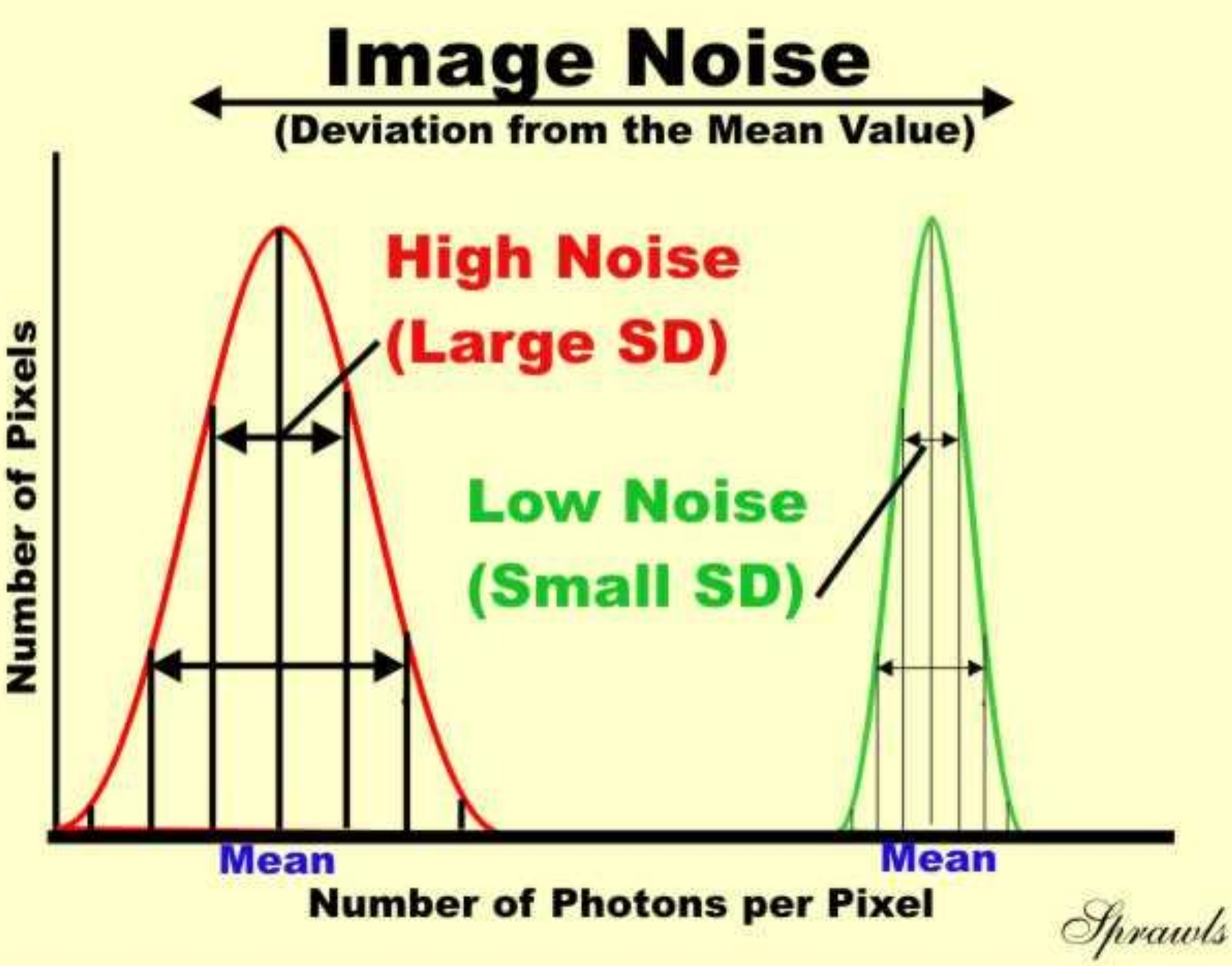
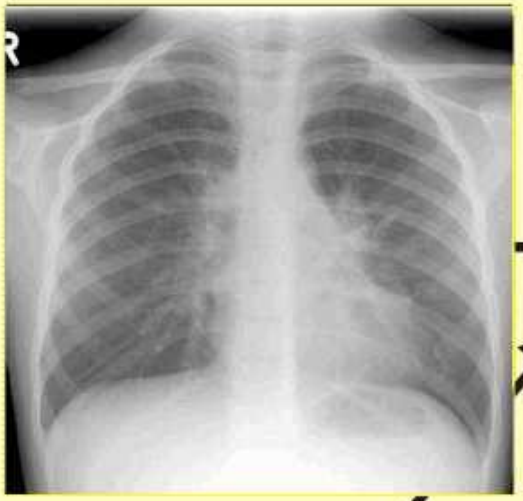
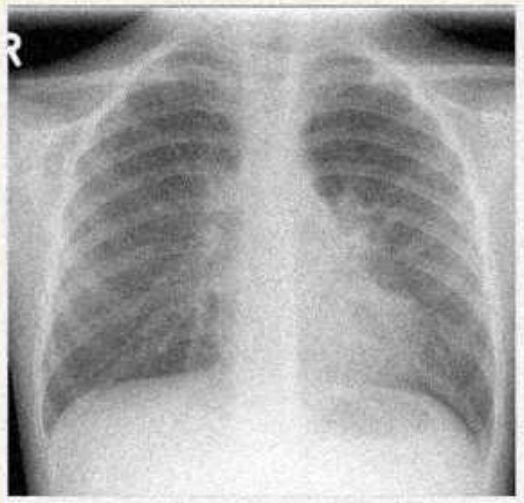


Image Noise
(Deviation from the Mean Value)
High Noise
(Large SD)
Low Noise
(Small SD)
Number of Pixels
Mean
Mean
Number of Photons per Pixel
Sprawls

Visibility of Low Contrast Anatomy Limited By



NOISE



Electronic

Receptor/Display Structure

X-Ray Beam

Receptor Exposure

Reduced By

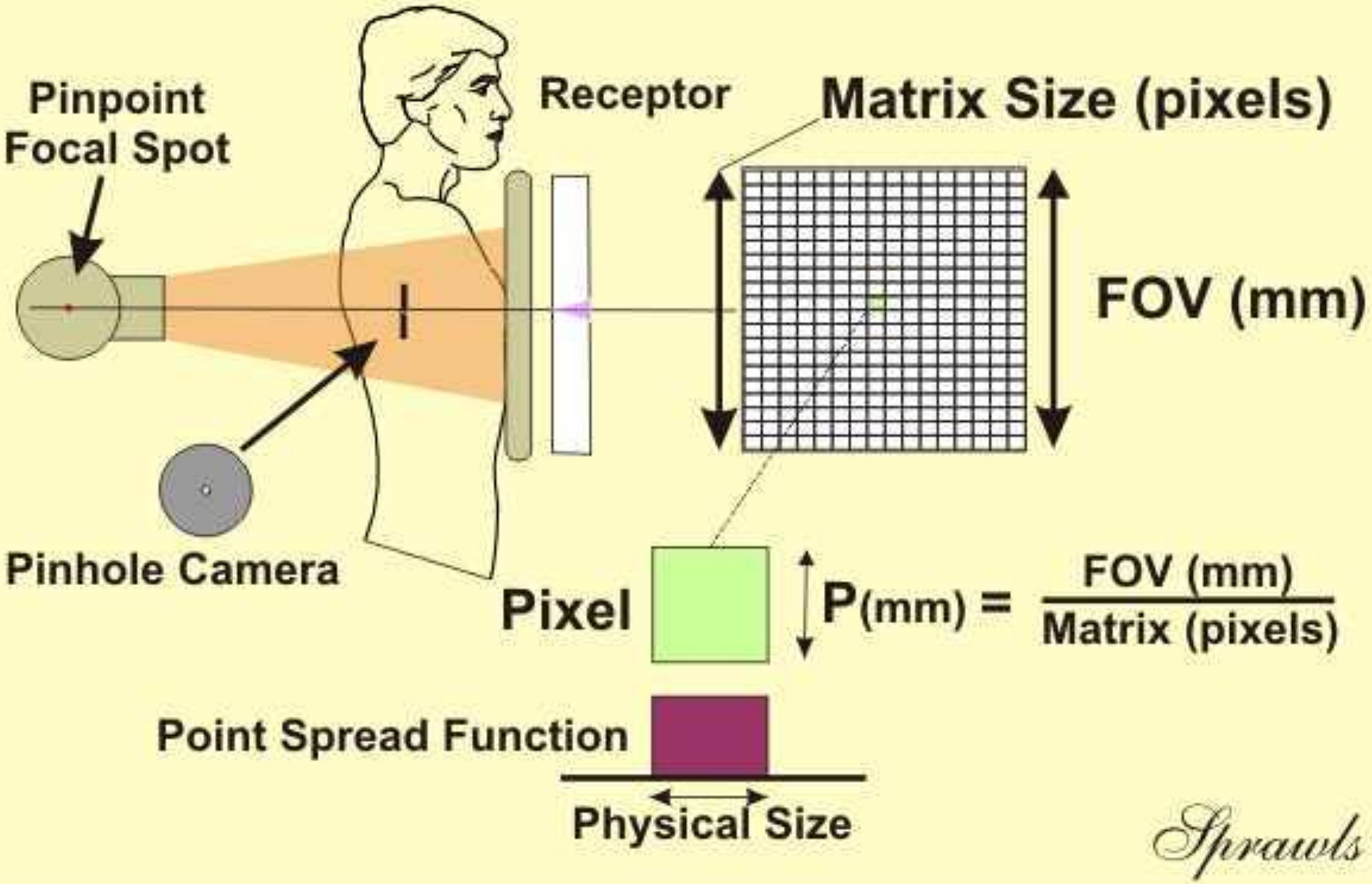
BLUR

(Pixel Size)

Digital Processing

Sprawls

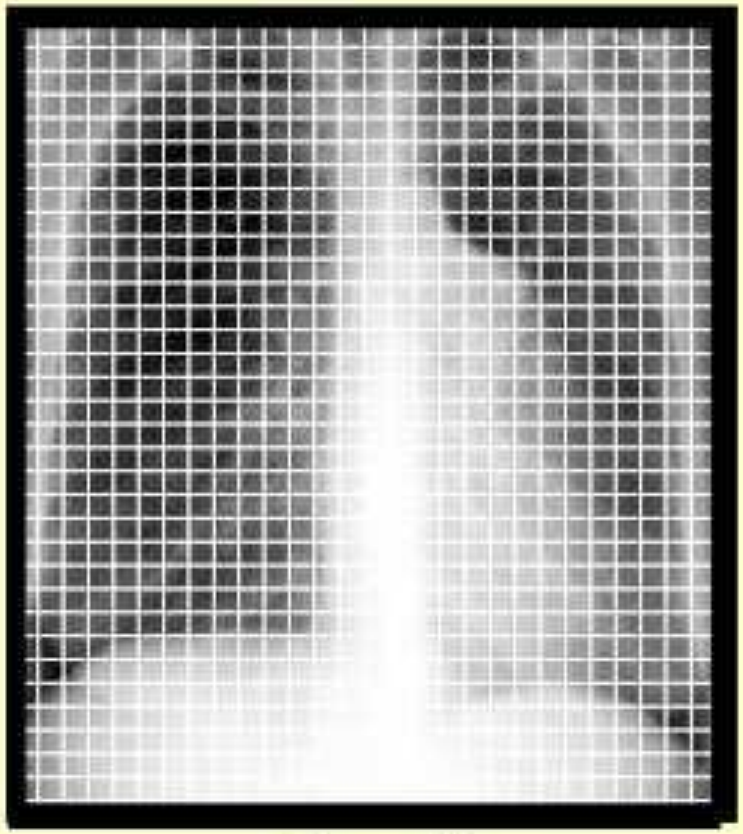
Pixel Blurring



Sprawls

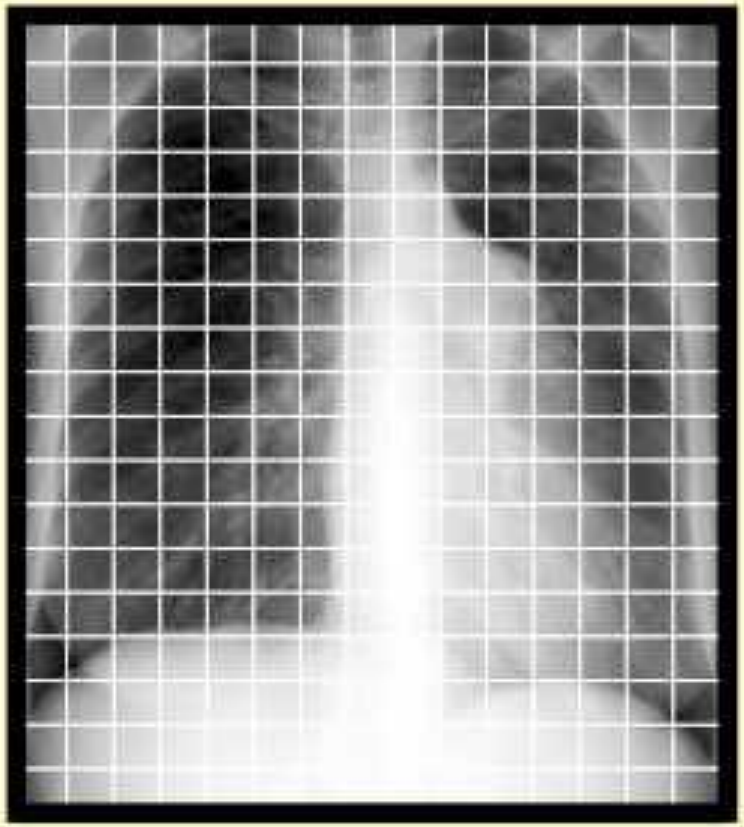
Digital Image Detail
Effect of Matrix Size

Large Matrix



Small

Small Matrix



Large

Pixel Size

Sprawls

Digital X-ray Imaging

Pixel Size

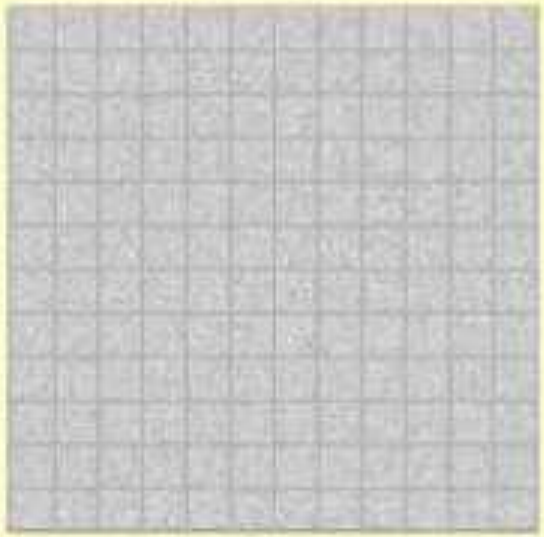
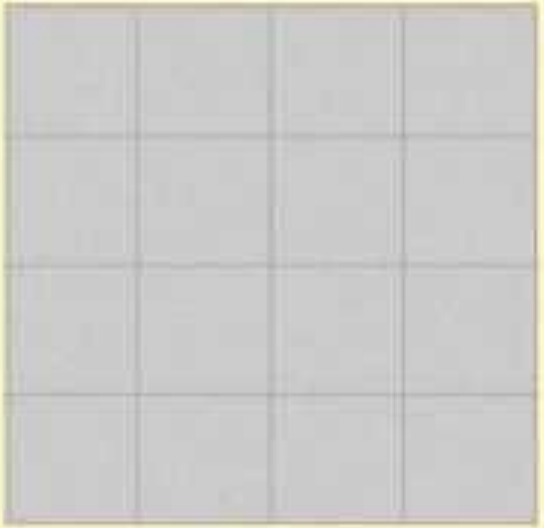
Small	Medium	Large
		
High	Medium	Low

Image Noise

Numerical Size of Digital Images

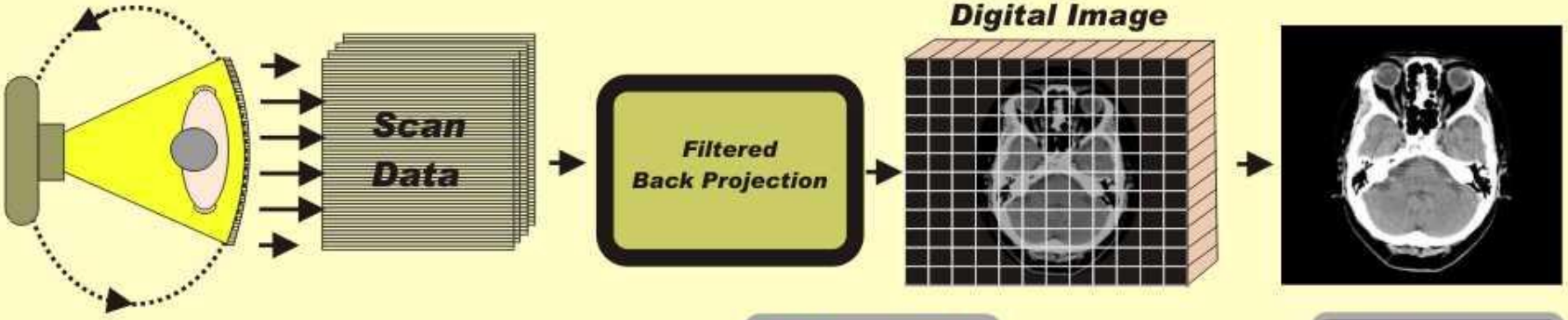
Modality	Matrix	Bits/Pixel	Image Size (bytes)
Radionuclide Imaging	128 x 128	8	16,384.
MRI	256 x 256	12	98,304.
Ultrasound	256 x 256	8	65,536.
CT	512 x 512	12	393,216.
Fluoroscopy	1024 x 1024	8	1,048,576.
General Radiography	2048 x 2048	12	6,291,456.
Mammography	4,096 x 5120	12	31,457,280.

The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

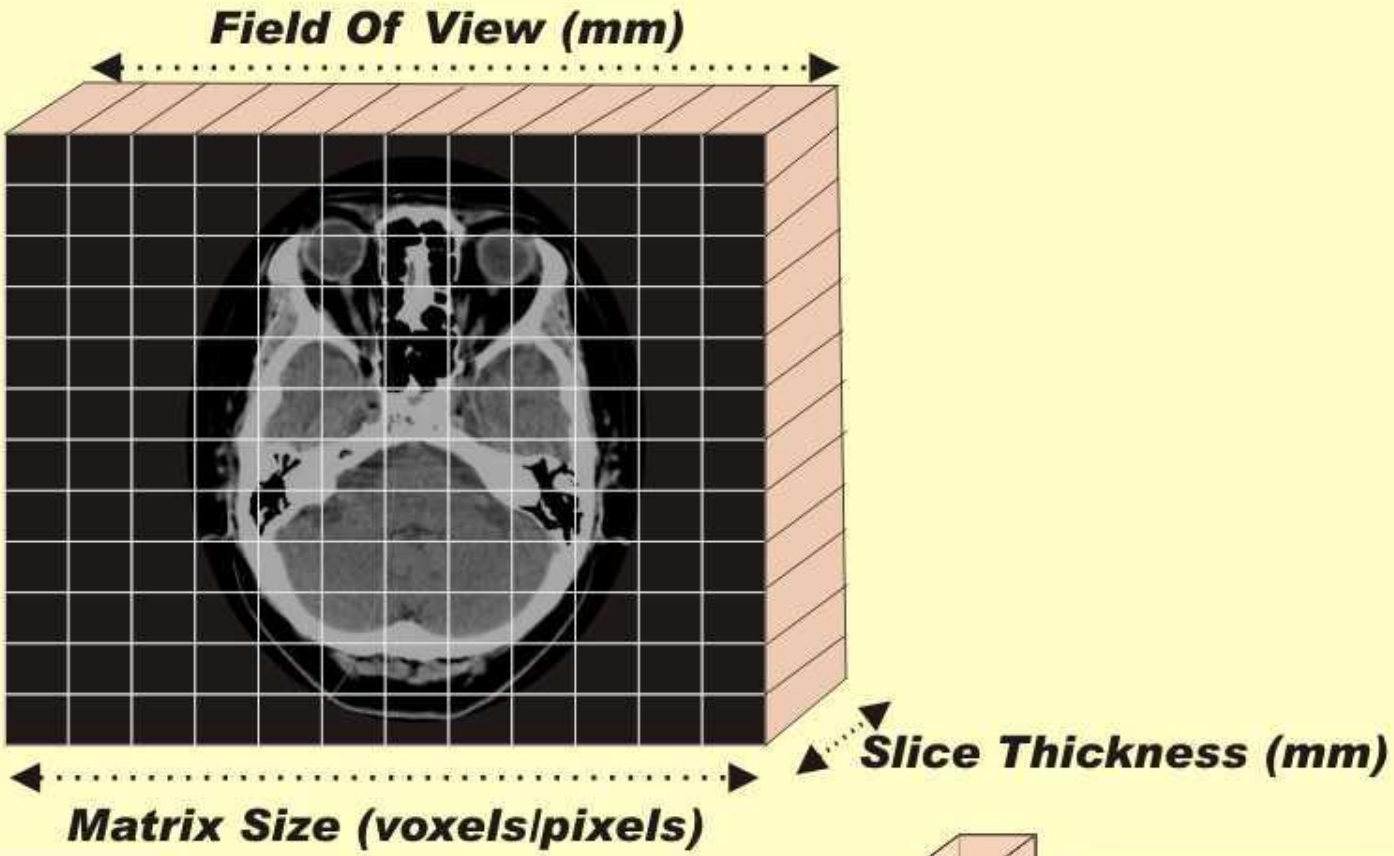


- KV
- MA
- Time
- Pitch
- Beam Wid.
- Slice Th.
- FOV
- Matrix
- Filter
- Window Width
- Window Level
- Zoom

Major Protocol Factors

Sprawls

CT Slice Divided into Matrix of Voxels



Voxel Size Controlled By

Sprawls

X-ray Photons Interact With Tissue in A Voxel

Radiation Dose

determined by

Concentration of Absorbed Energy

per voxel

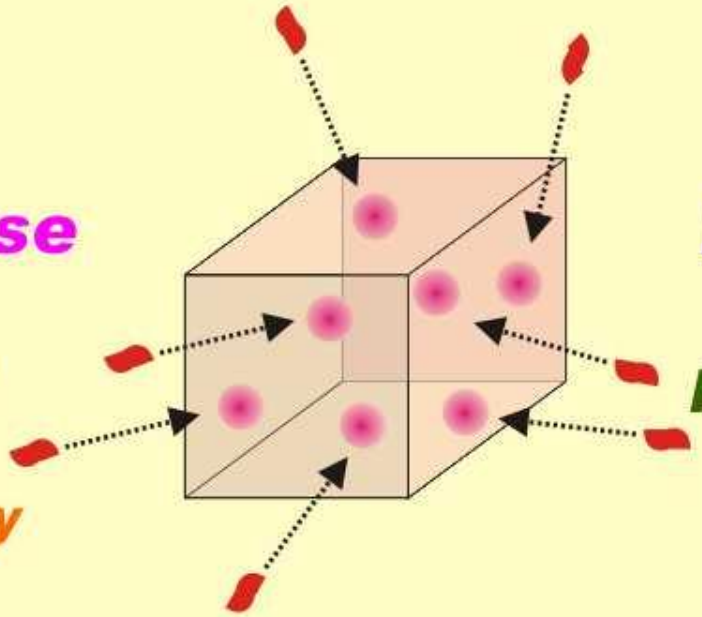


Image Noise

determined by

Number of Photons

per voxel

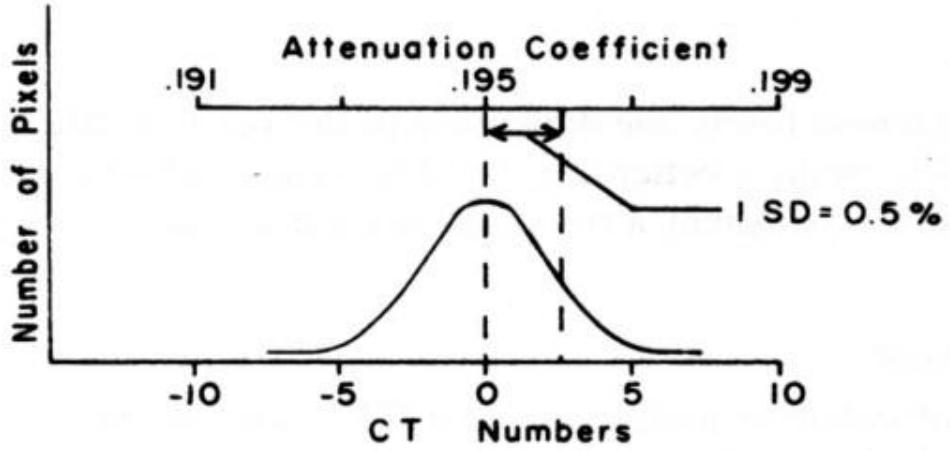
Dose is increased by increasing number of photons.

Noise is reduced by increasing number of photons.

Sprawls

CT NOISE MEASUREMENT

2	-2	-3	0	-6	-6	1	0
4	1	2	5	-1	1	5	3
2	-1	0	5	0	0	2	1
-1	-1	-2	0	0	1	0	0
1	1	-2	-1	1	-1	-4	-2
-2	2	-1	0	1	-1	-3	0
6	-3	2	1	-4	3	1	4
3	4	2	-4	-3	-1	-2	-5



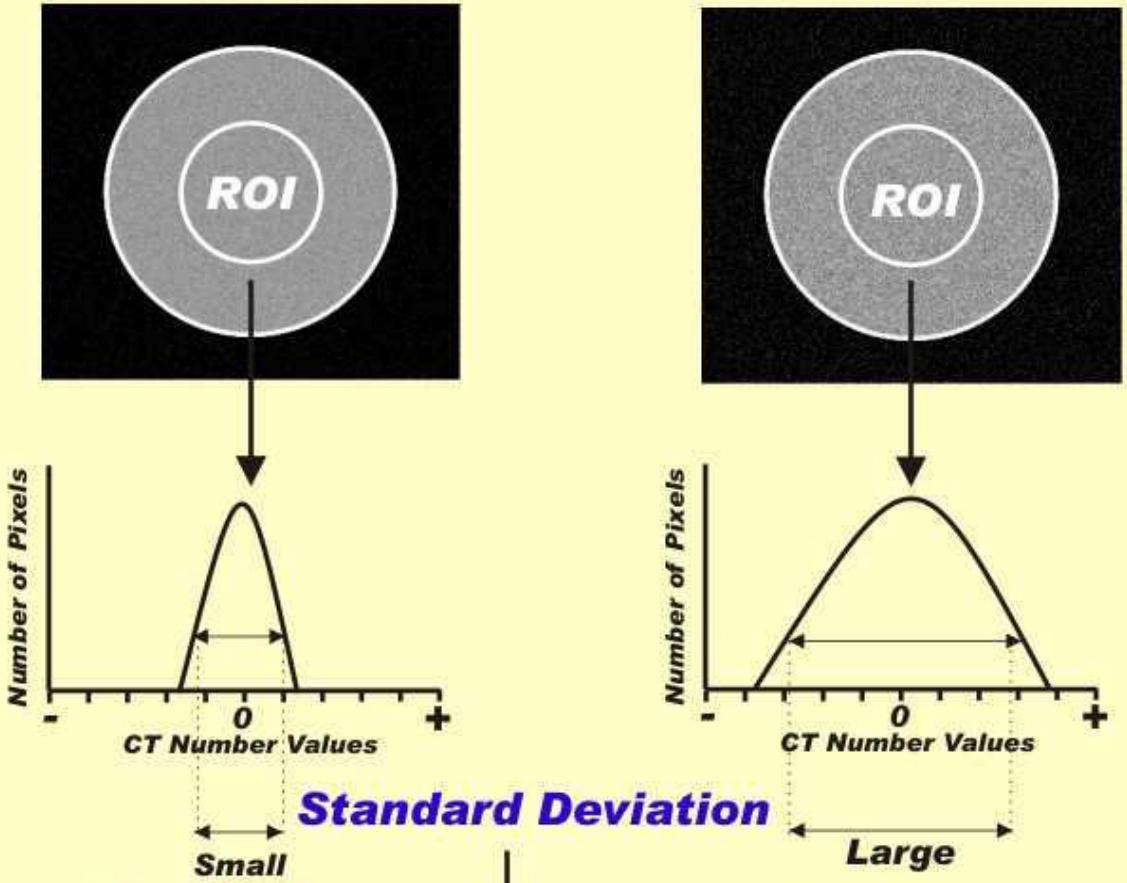
Sprawls

Measuring CT Image Noise

Images of Water

(CT Number = 0)

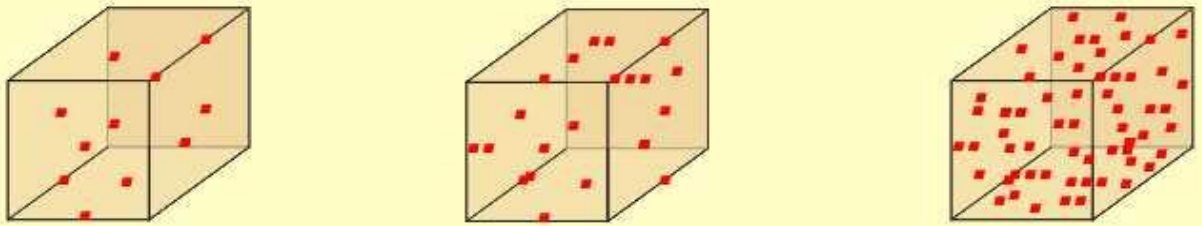
Distribution of CT Numbers within ROI



Sprawls

Decreasing Noise

Requires Increased Photons Absorbed Per Voxel



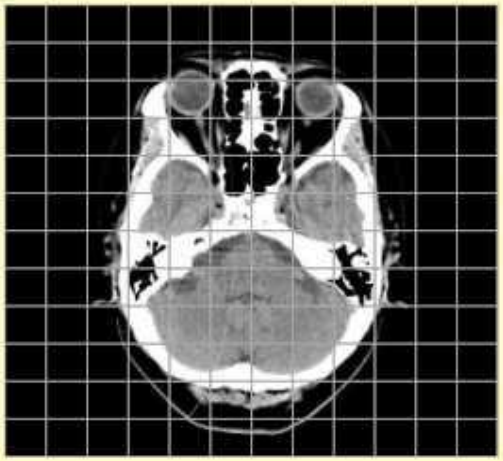
Produces Increasing Dose

Sprawls

Effect of Matrix Size on Image Noise

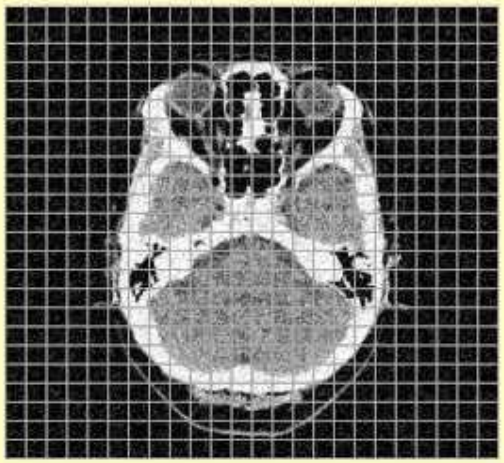
Small **Matrix** ***Large***

Large Voxels



Low Noise

Small Voxels

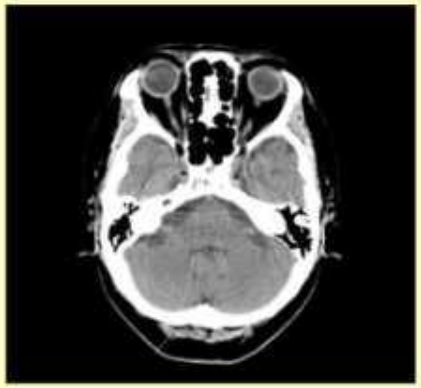


High Noise

The same radiation dose for both images.

Sprawls

Two Major Image Quality Goals



High Detail

Low Noise

Voxel Size

FOV | **Matrix** | **Slice Th.**

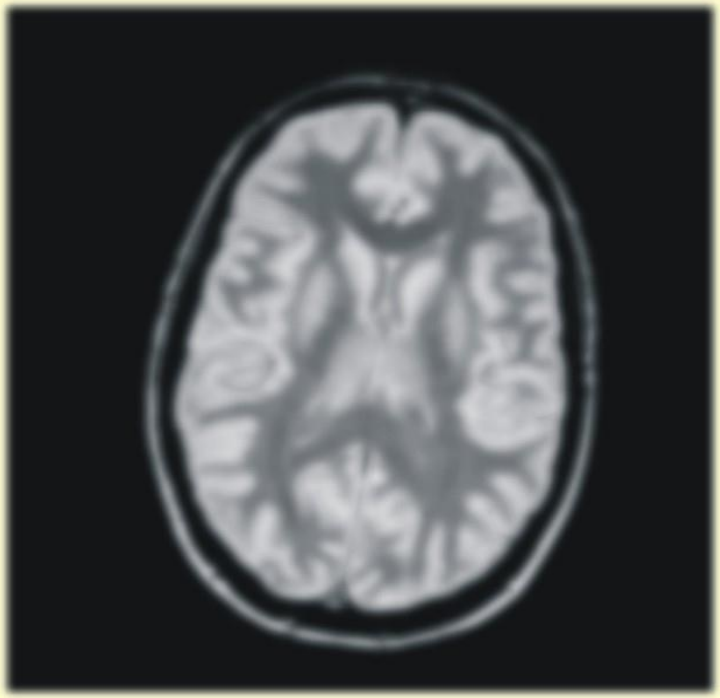
Protocol Factors

Sprawls

DETAIL
(BLURRING)

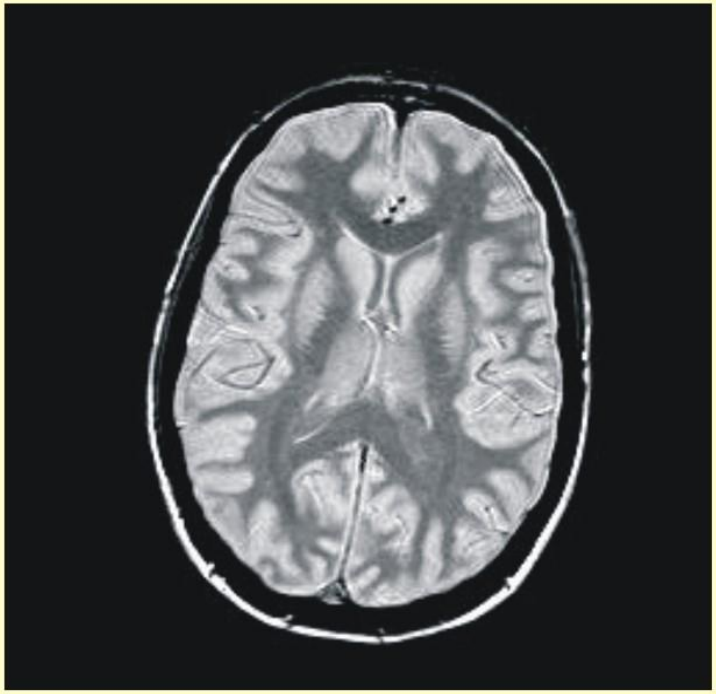
VISIBILITY OF DETAIL

LOW



HIGH

HIGH

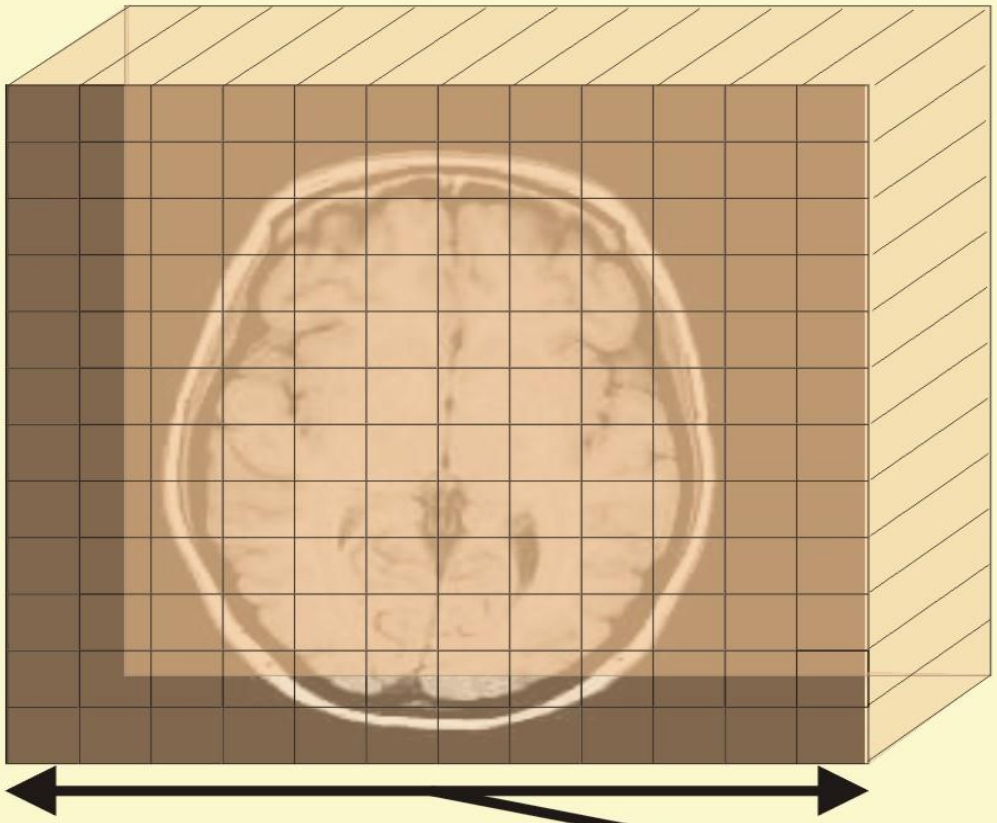


LOW

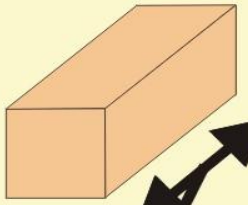
BLUR

Sprawls

IMAGE DETAIL



VOXEL SIZE



Matrix

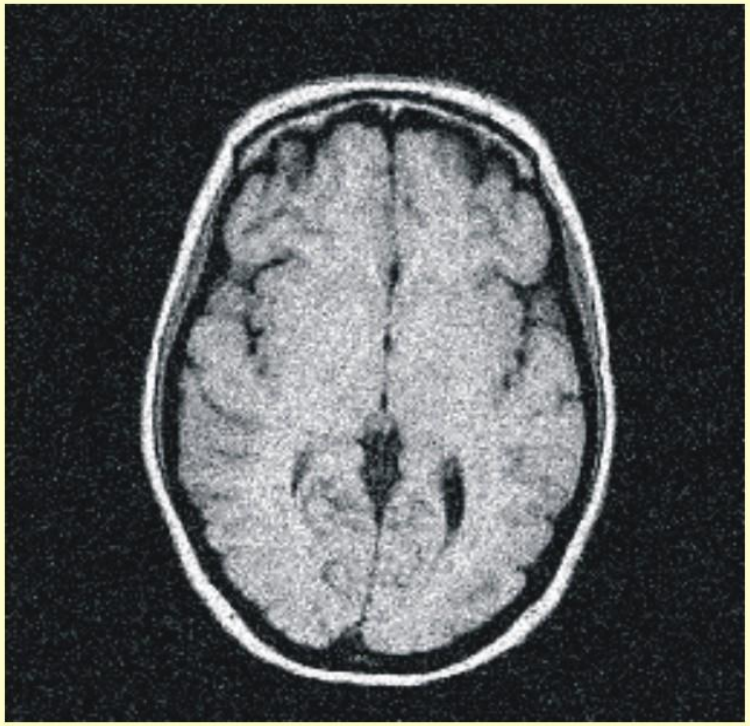
FOV

Thickness

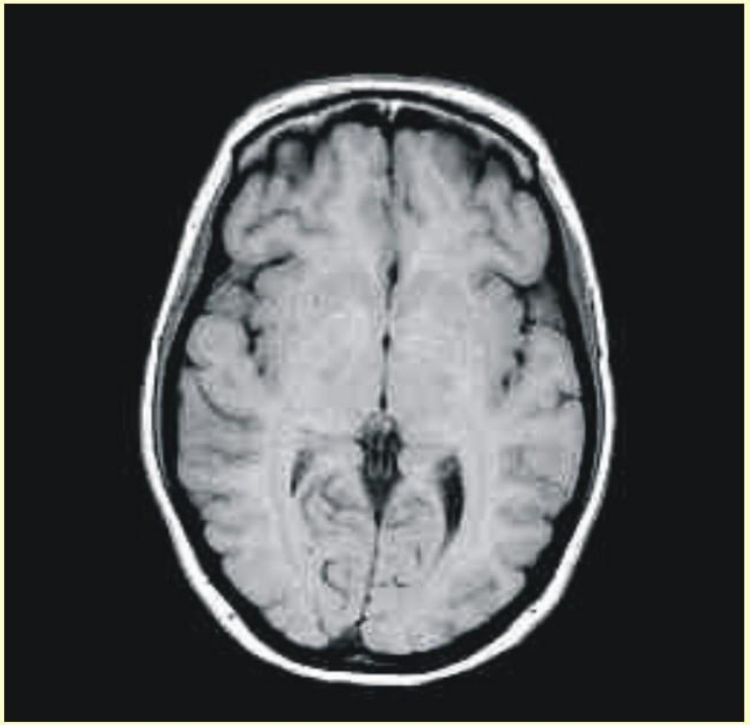
Sprawls

NOISE

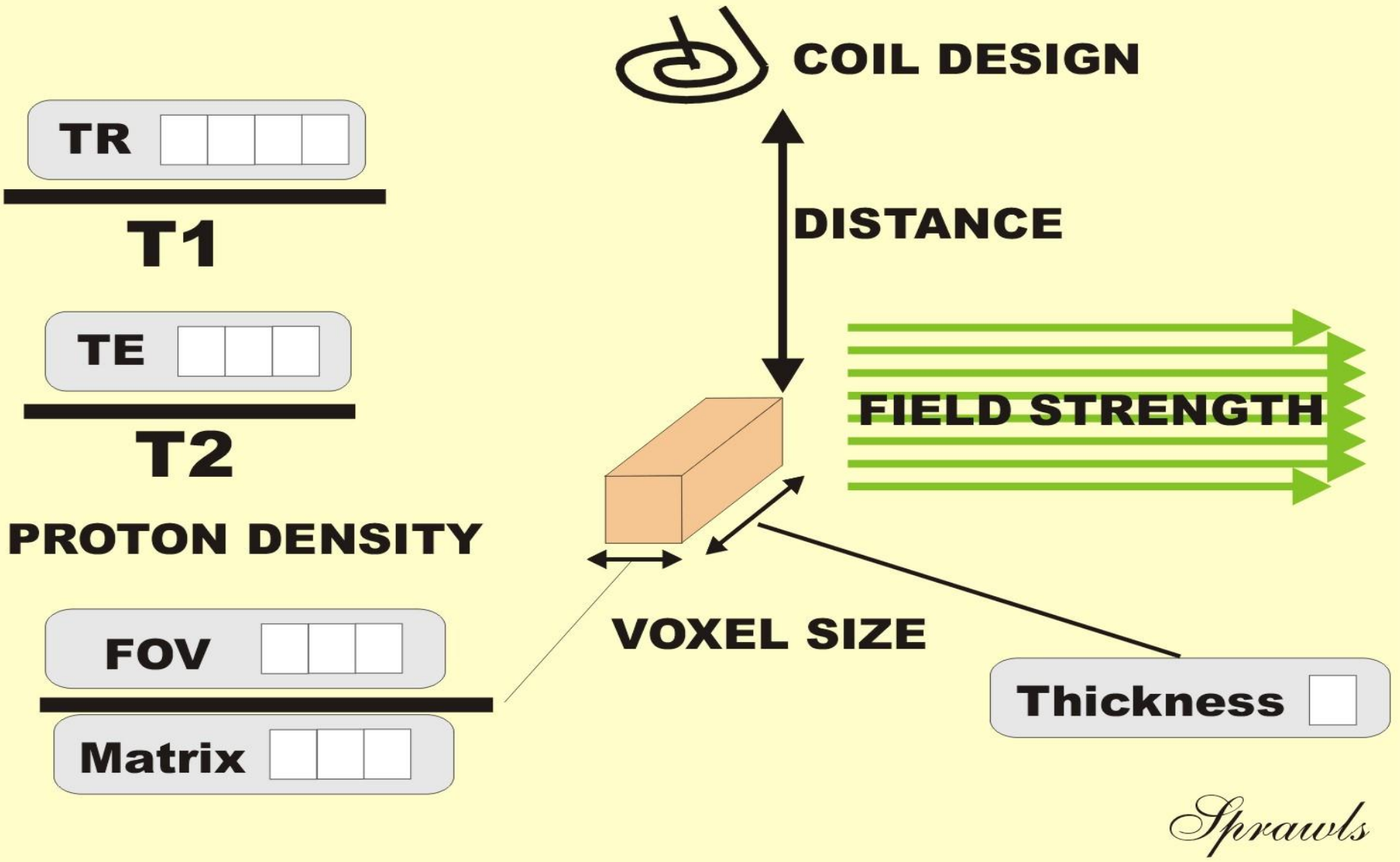
HIGH NOISE



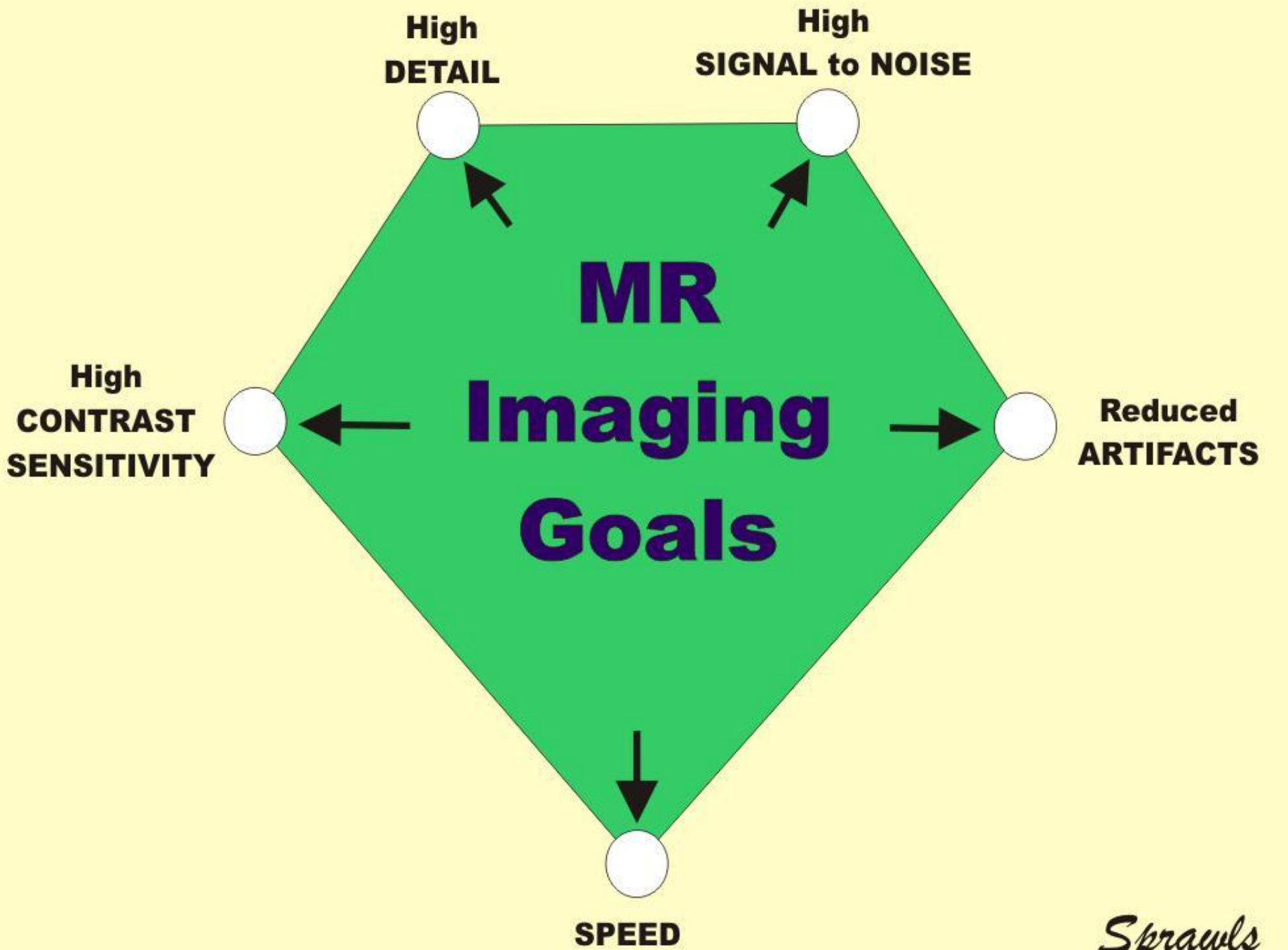
LOW NOISE

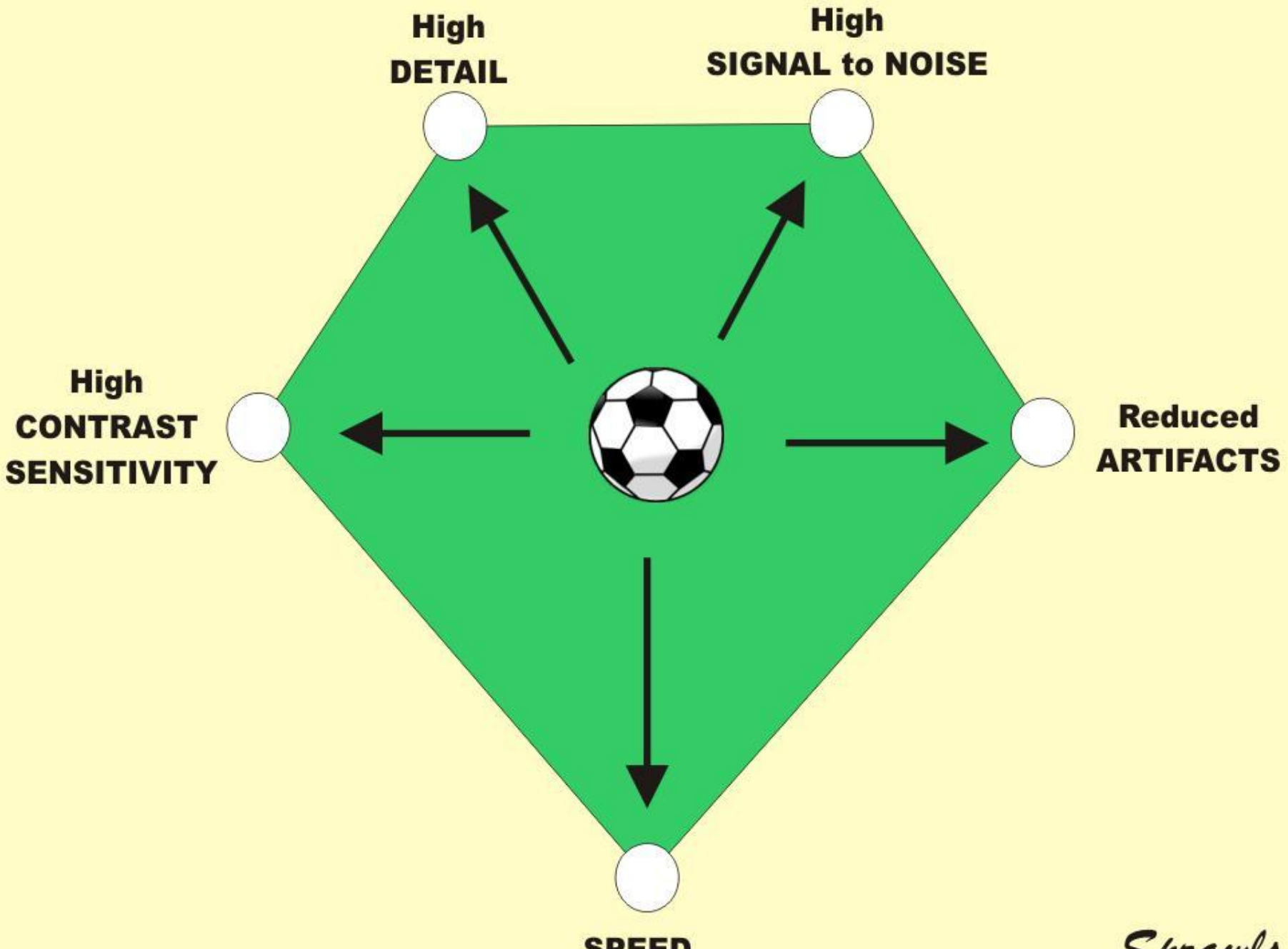


SIGNAL STRENGTH



Sprawls


High
DETAIL
High
SIGNAL to NOISE
MR
Imaging
Goals
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls


High
DETAIL
High
SIGNAL to NOISE
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

High
DETAIL

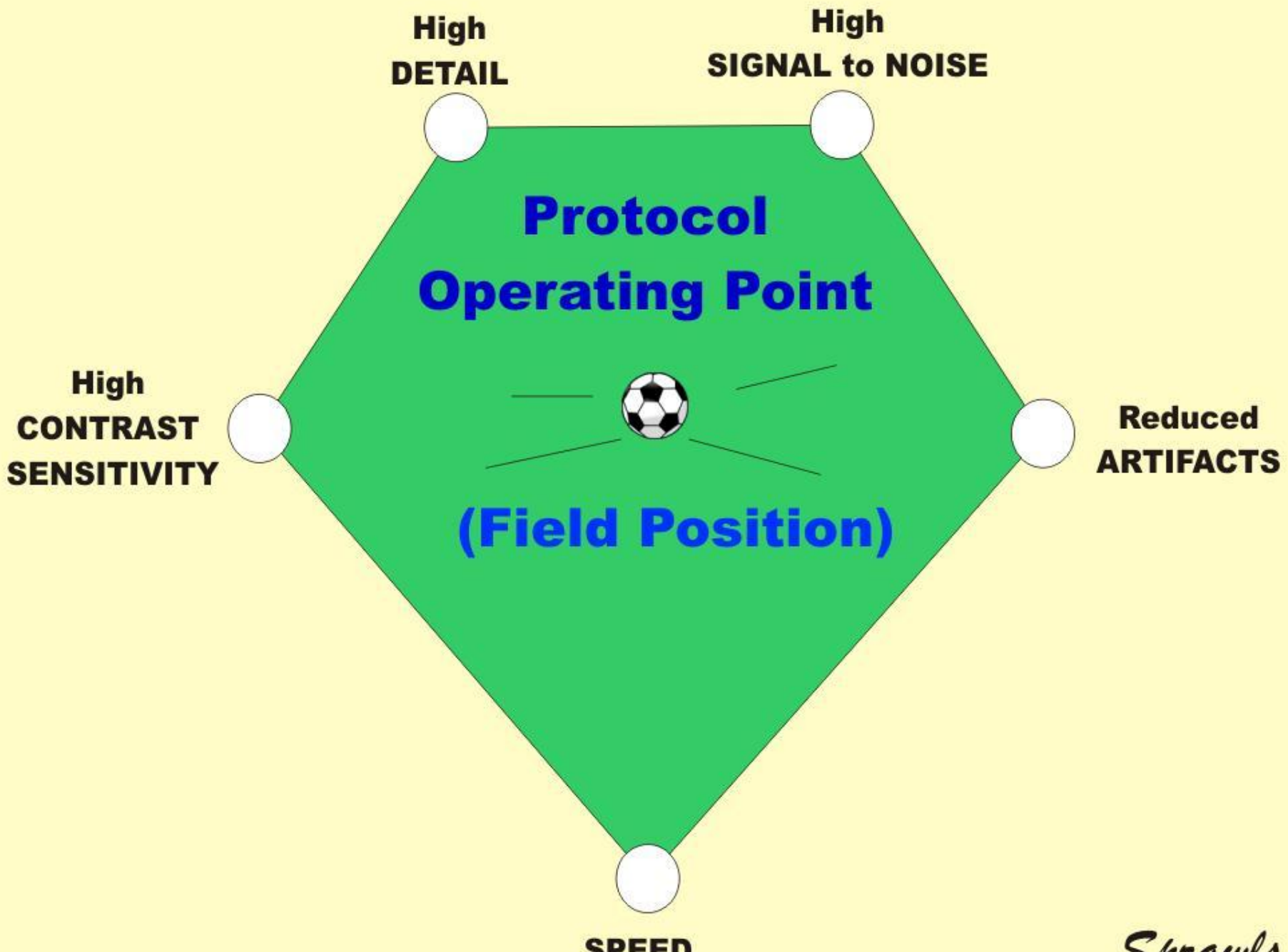
High
SIGNAL to NOISE

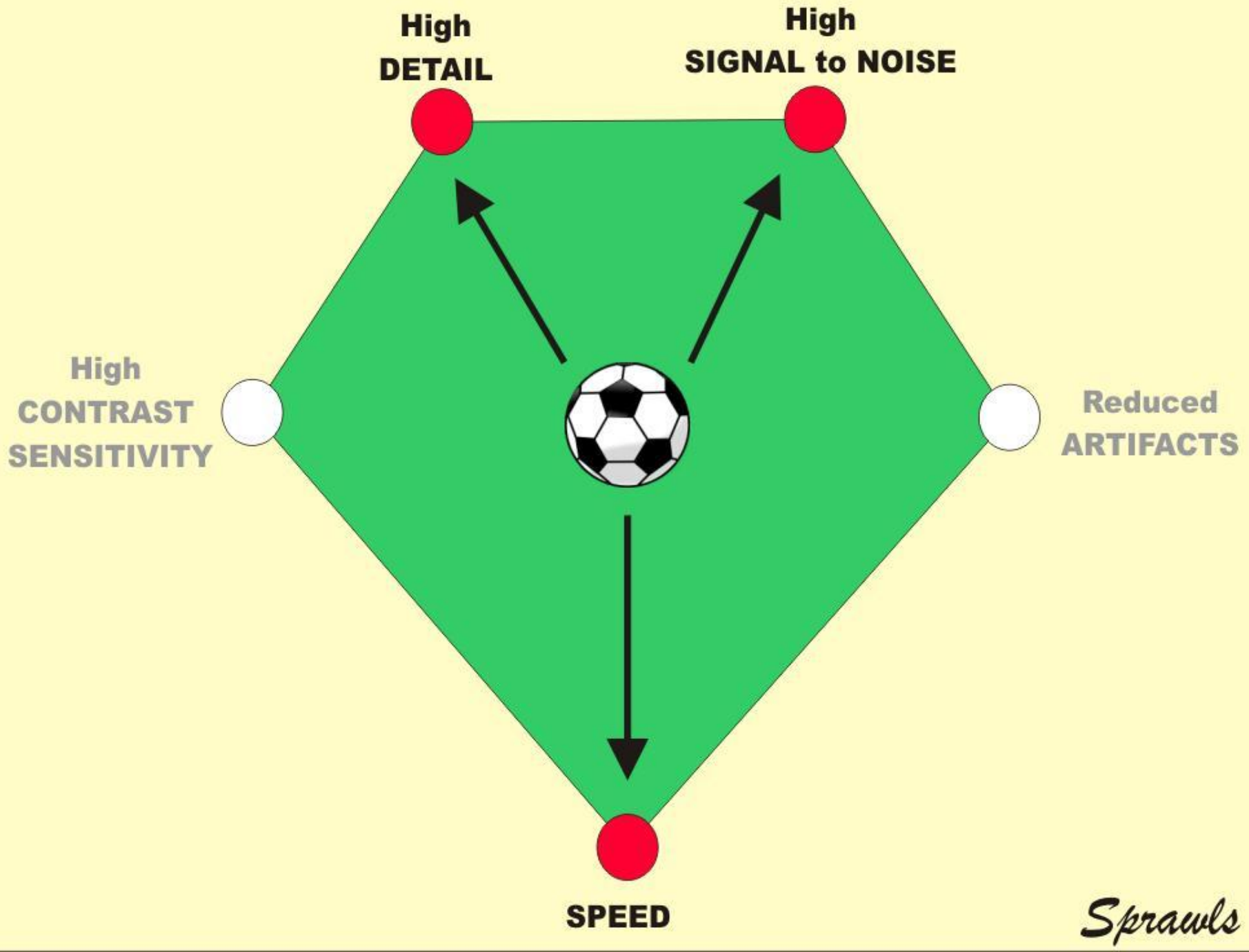
High
CONTRAST
SENSITIVITY

Reduced
ARTIFACTS

SPEED

Sprawls

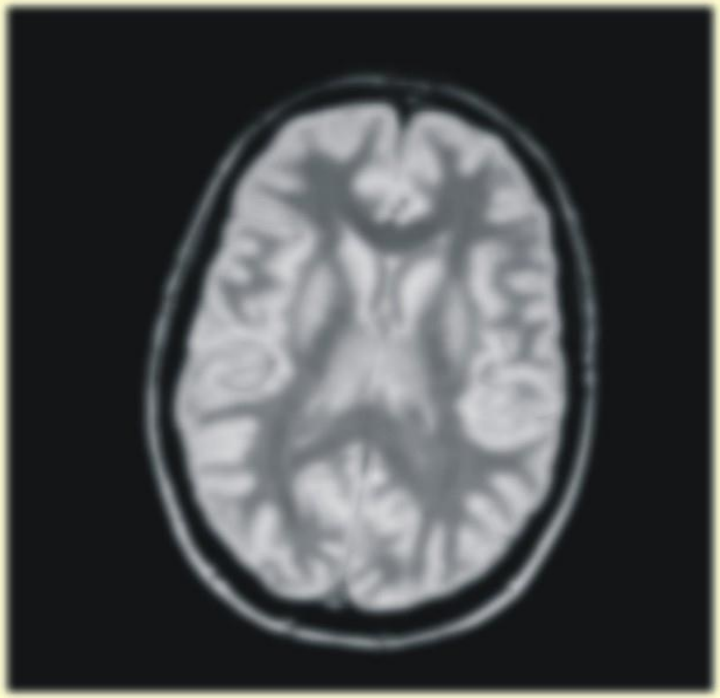

High
DETAIL
High
SIGNAL to NOISE
Protocol
Operating Point
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
(Field Position)
SPEED
Sprawls


High
DETAIL
High
SIGNAL to NOISE
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

DETAIL
(BLURRING)

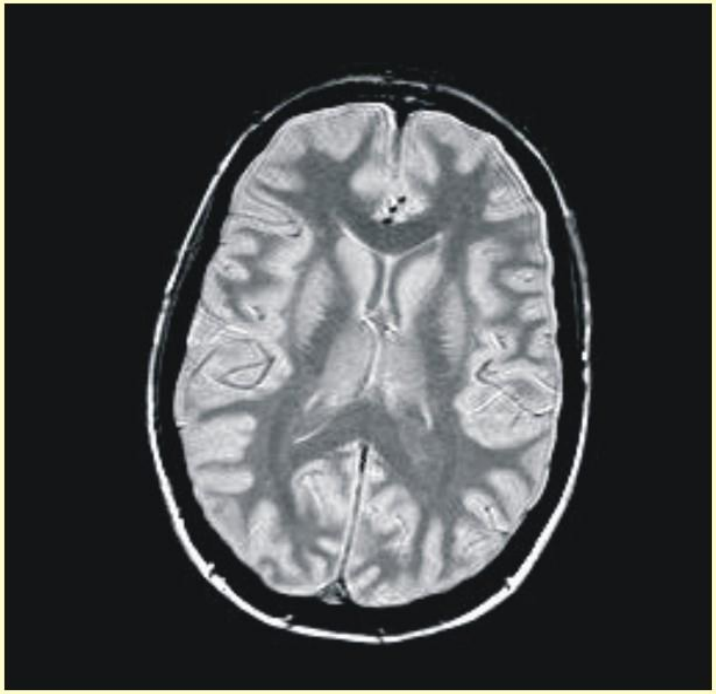
VISIBILITY OF DETAIL

LOW



HIGH

HIGH

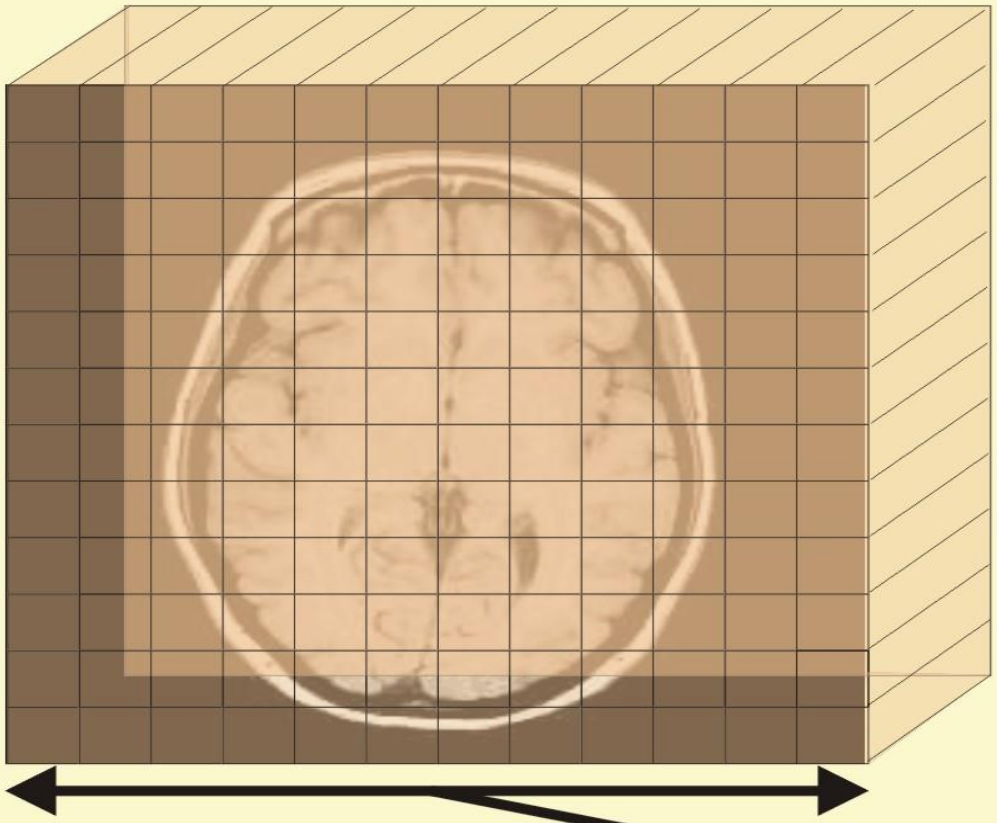


LOW

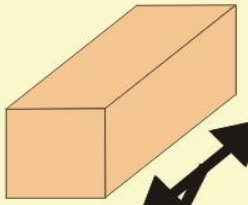
BLUR

Sprawls

IMAGE DETAIL



VOXEL SIZE



Matrix

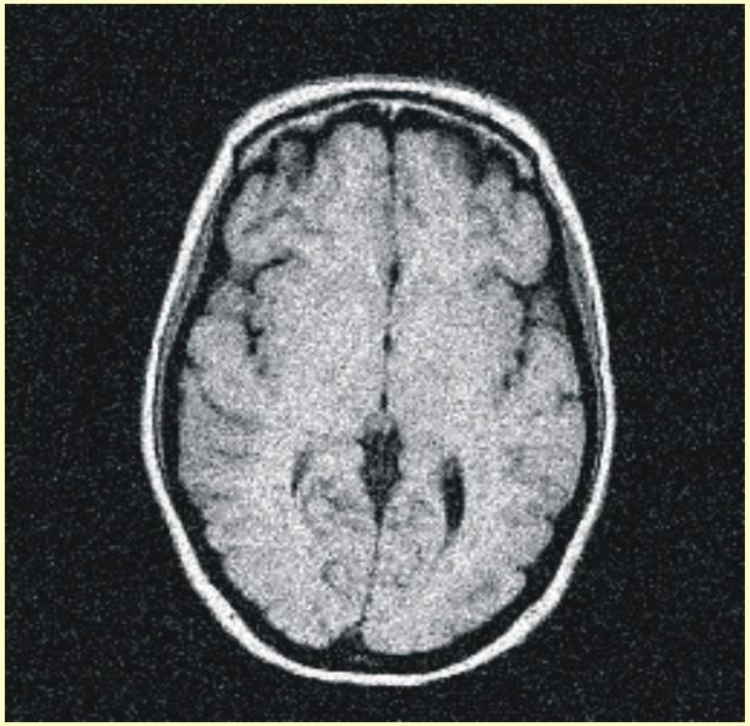
FOV

Thickness

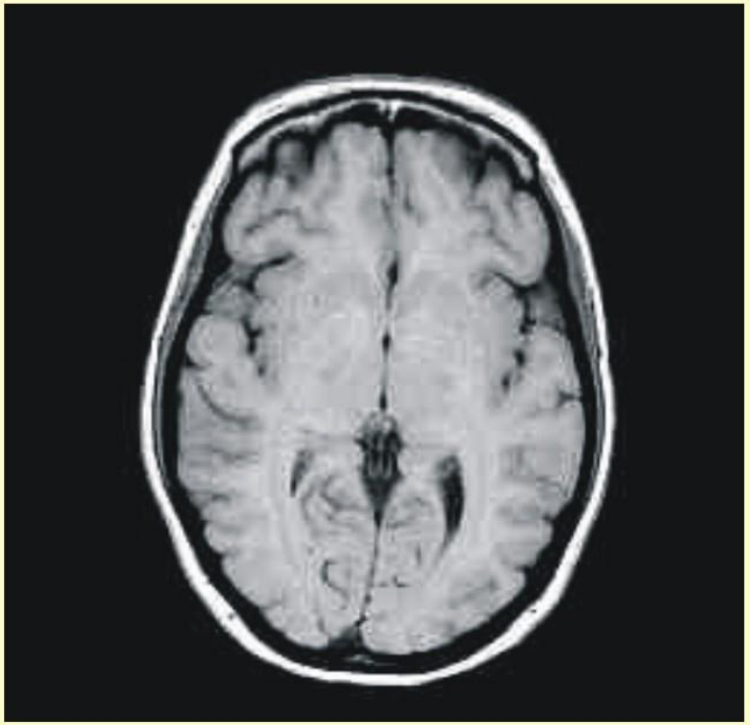
Sprawls

NOISE

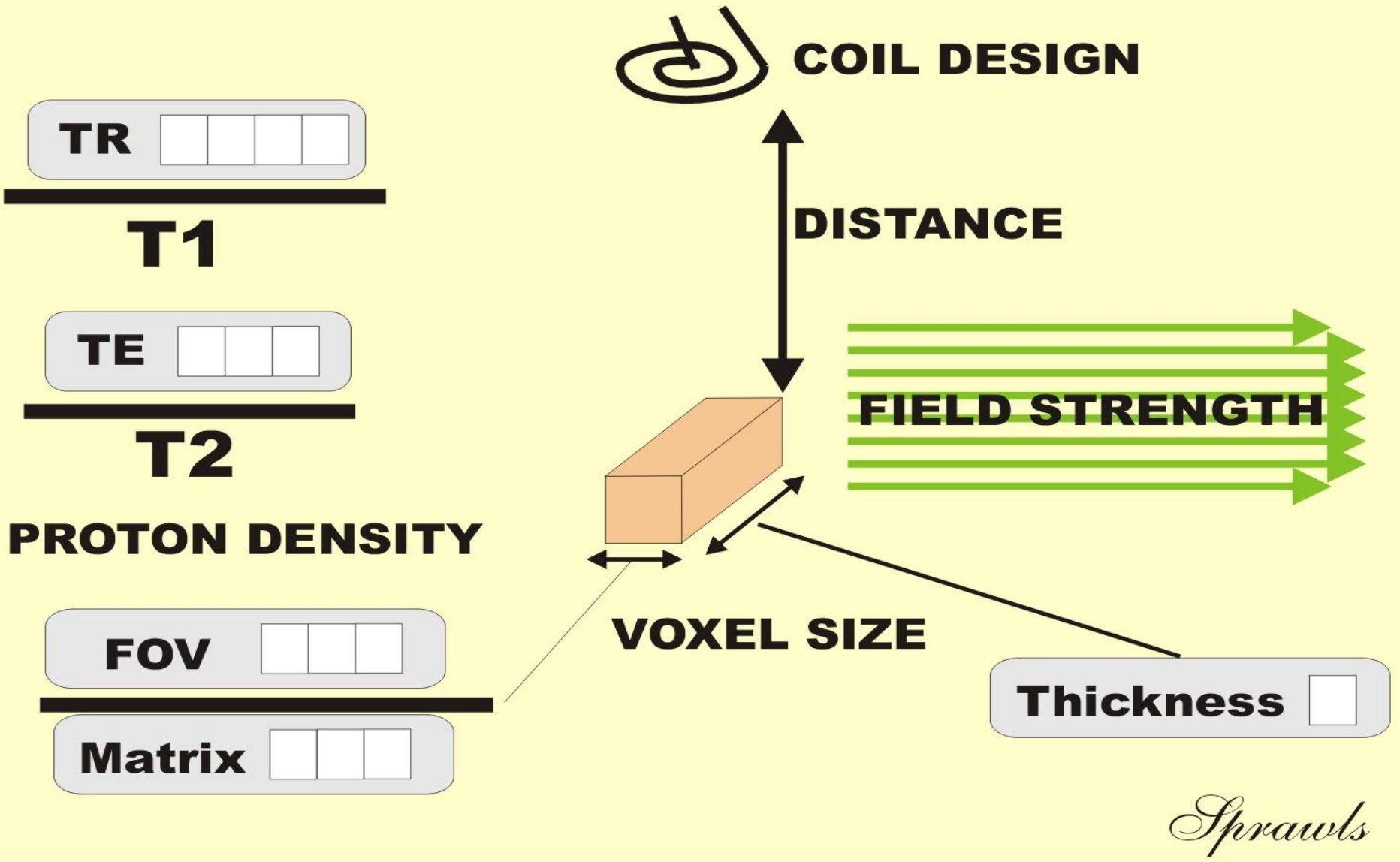
HIGH NOISE



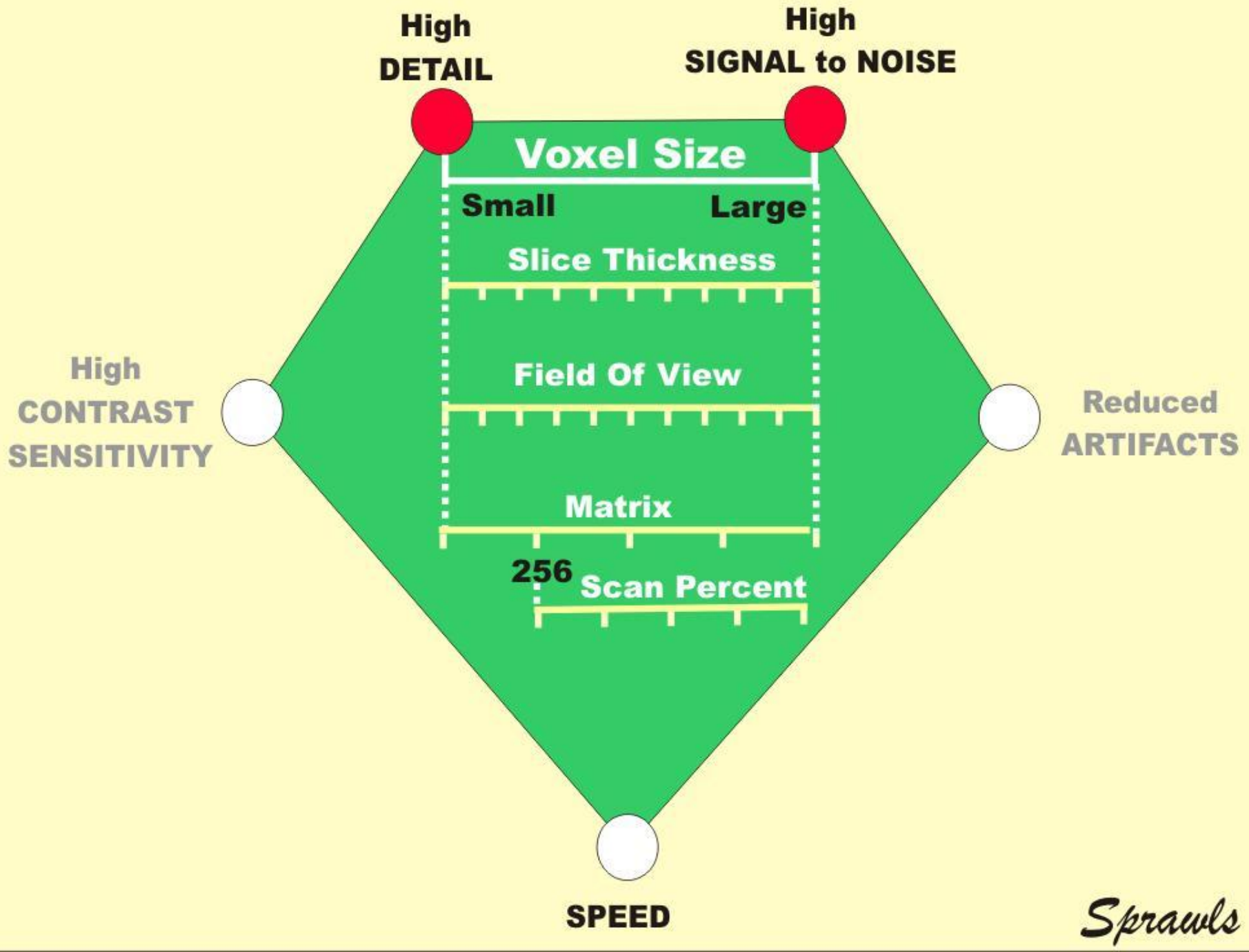
LOW NOISE



SIGNAL STRENGTH

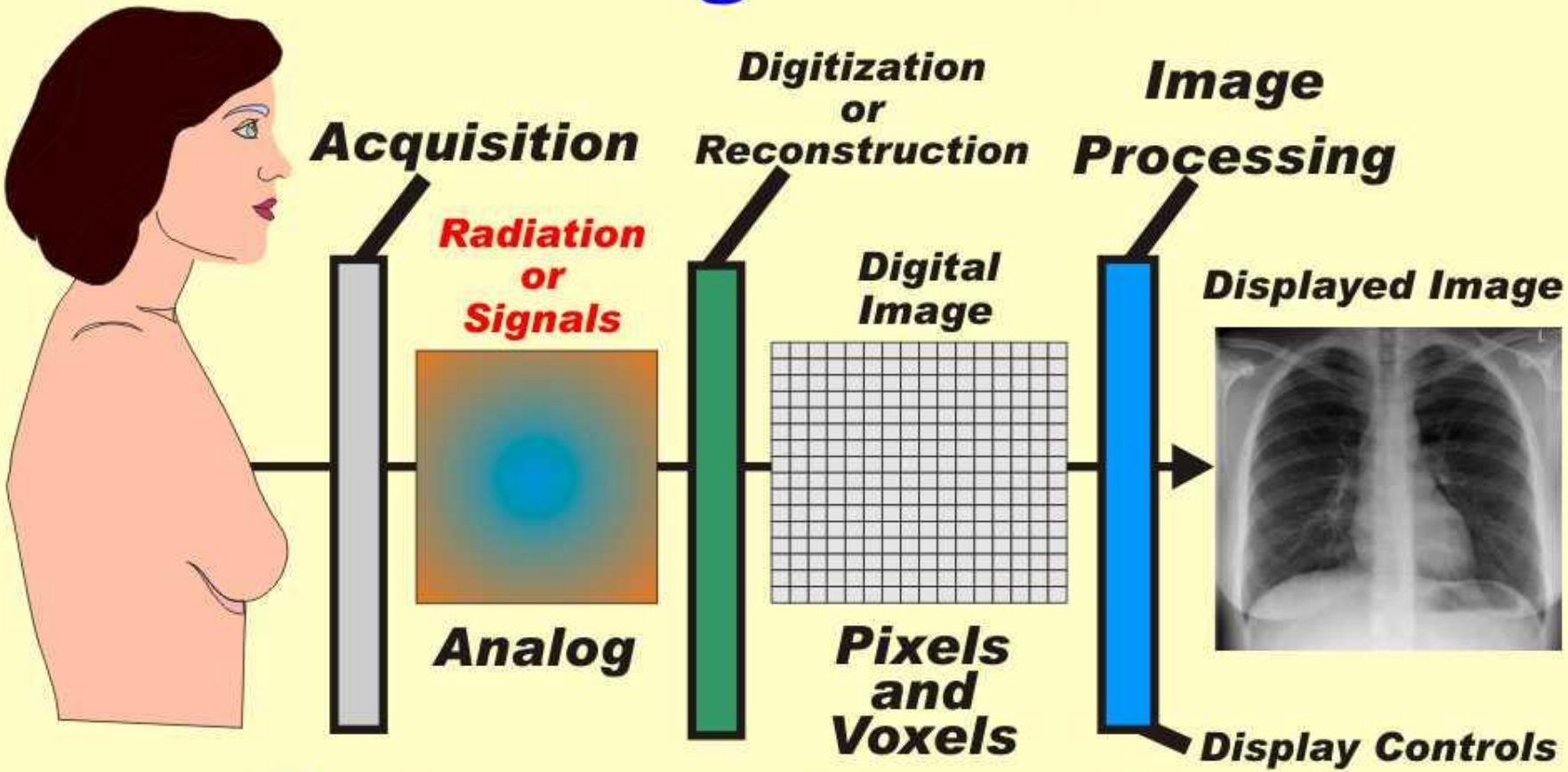


Sprawls


High
DETAIL
High
SIGNAL to NOISE
Voxel Size
Small
Large
Slice Thickness
Field Of View
Matrix
256
Scan Percent
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

The Medical Imaging Process

Image Noise



Source **Modified**

Sprawls

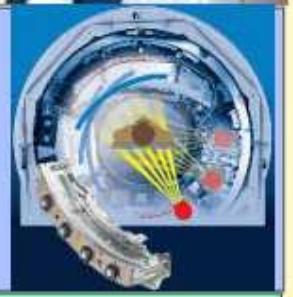
Computed Tomography

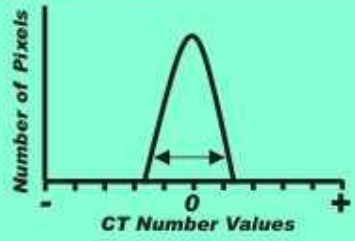
Image Characteristics and Quality

Radiation Dose

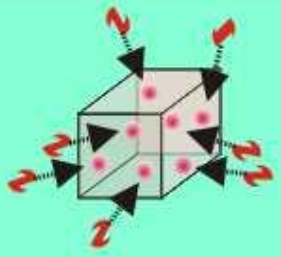
Imaging Protocols

Technology





Science



Sprawls

Clinically Focused Physics Education

Classroom

Clinical Conference

Small Group

"Flying Solo"

Highly Efficient

For General Physics and Related Topics

Highly Effective

Clinically Rich Learning Activities

Visuals **Images** **Online Modules**

Resources and References

Sprawls

Effective Medical Imaging Physics Learning ...In The Clinic

The Real World **Motivating** **Interactive** **Collaborative**

The Physicist Provides:
Learning Modules & Collaboration

Sprawls

Medical Image Quality and Dose Optimization in the Digital Era: Clinically Focused Issues

Perry Sprawls, Ph.D.

To follow on ipad

. http://www.sprawls.org/ipad