# Clinical MR Image Quality Assessment and Optimization

Perry Sprawls, Ph.D.

**Review at:** www.sprawls.org/ipad

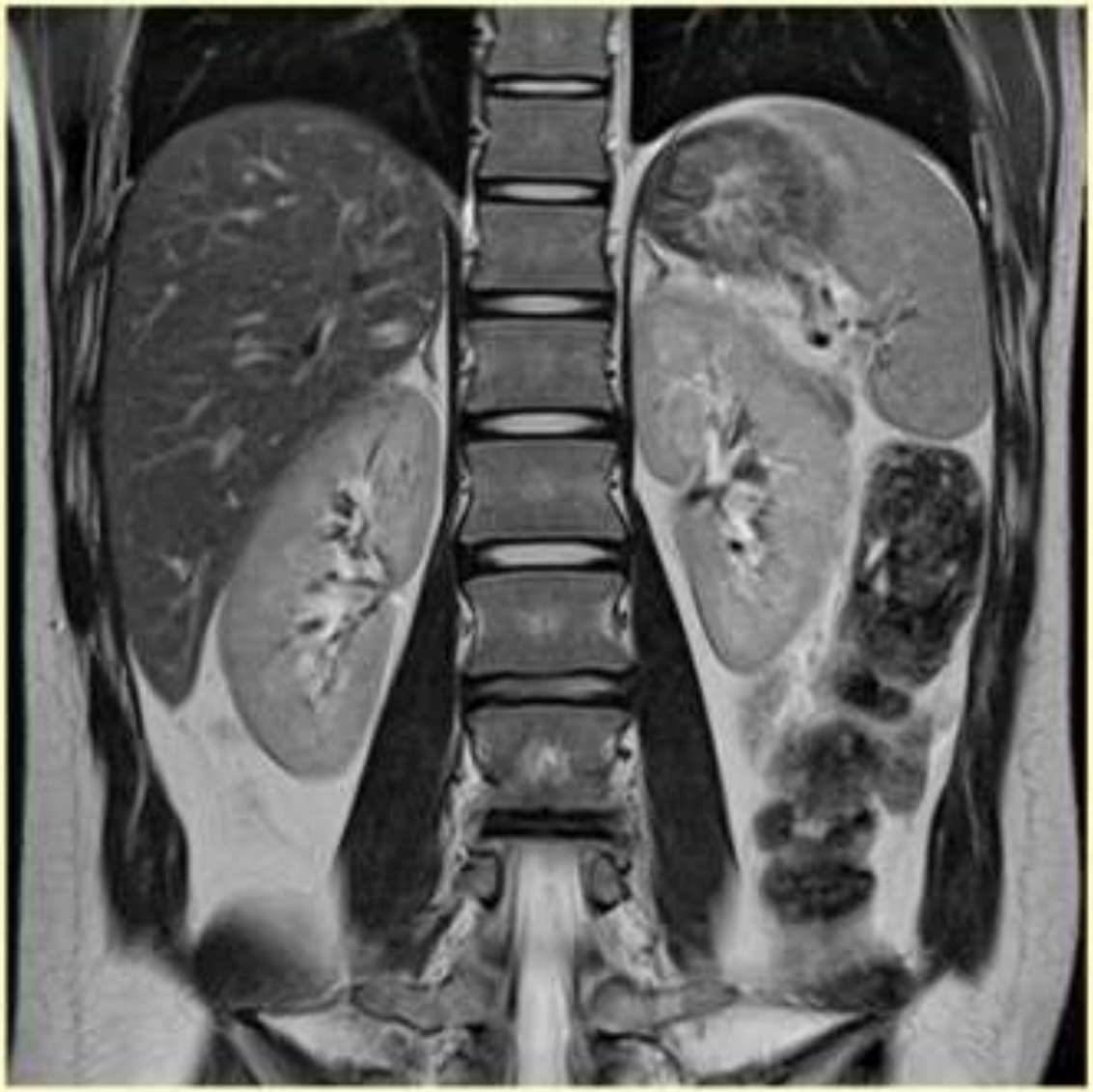
**Reference :** www.sprawls.org/mripmt

# Questions For You


What do you think about the quality of this image?
Which image characteristic is the problem?
How can you change and improve the image?
Why do we not go for maximum image quality?
What is optimization all about?

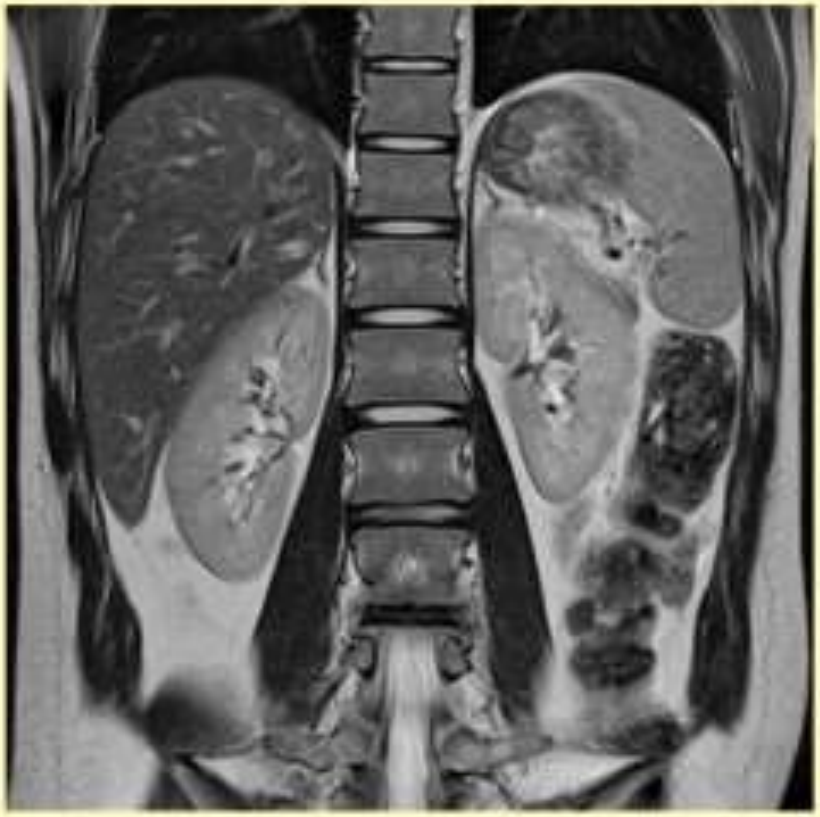
Sprawls

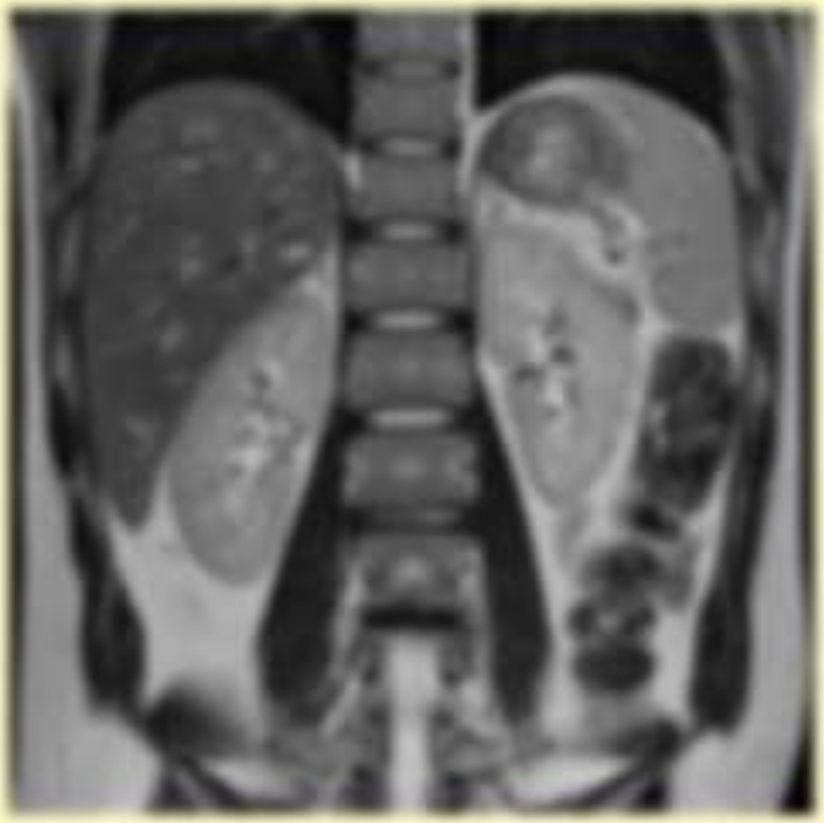
# What do you think about the quality of this image?



Sprawls

What do you think about the quality of this image?

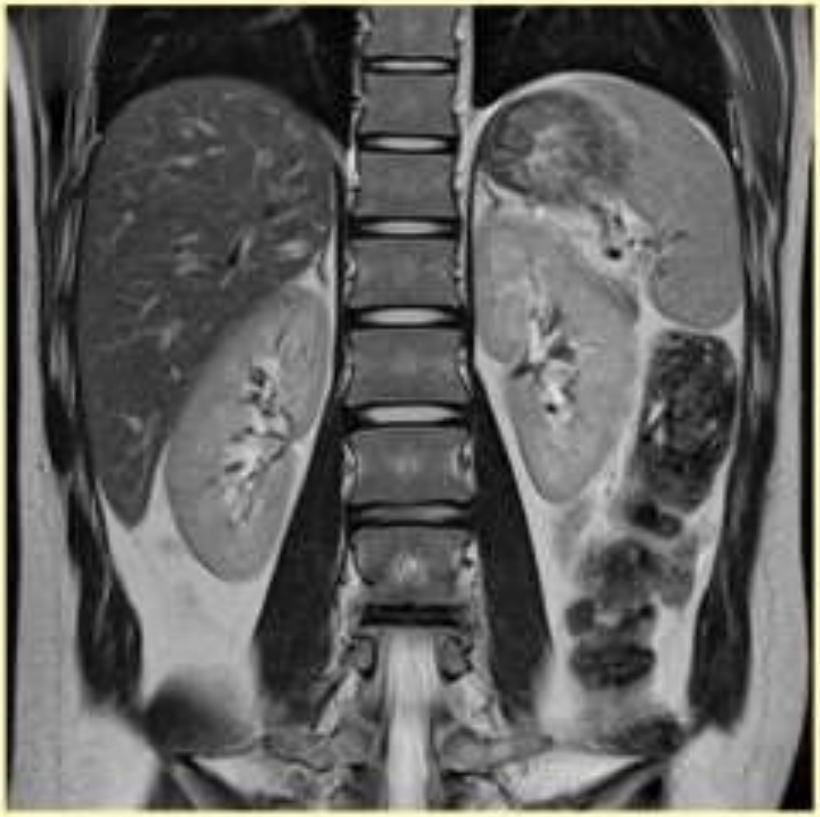


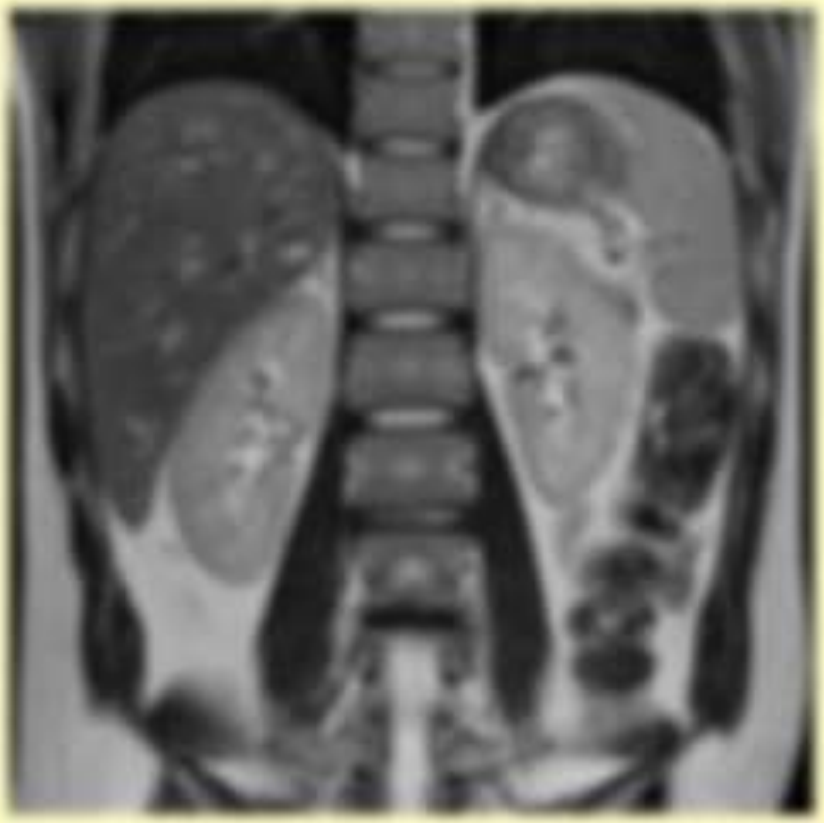


Which image characteristic is the problem?

Sprawls

What do you think about the quality of this image?





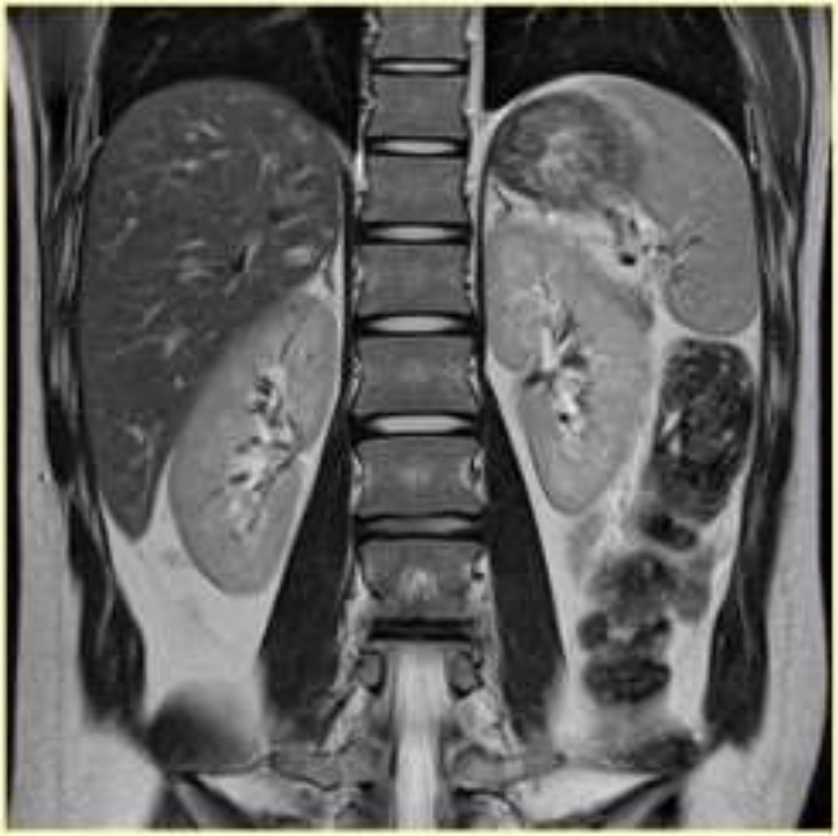
Which image characteristic is the problem?

# Detail

**(Sometimes called resolution)**

Sprawls

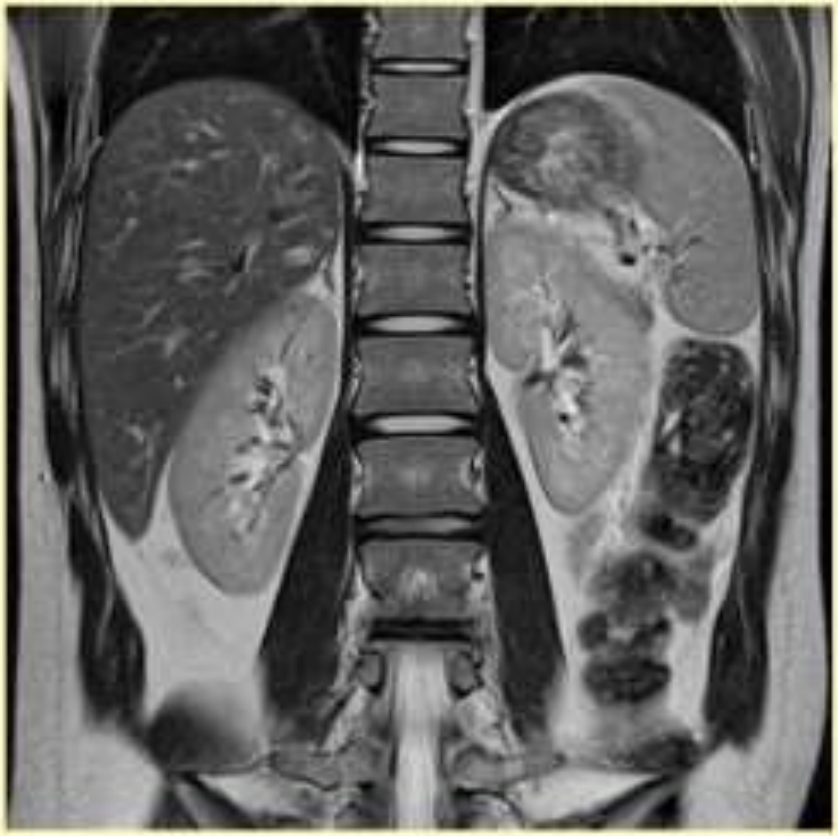
What do you think about the quality of this image?



Which image characteristic is the problem?

Sprawls

What do you think about the quality of this image?

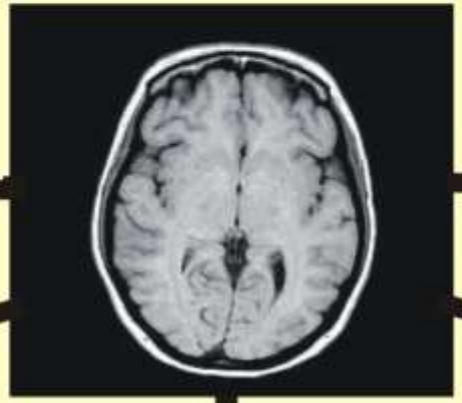


Which image characteristic is the problem?

# Noise

Sprawls

# MAGNETIC RESONANCE IMAGE QUALITY CHARACTERISTICS



SPATIAL

ARTIFACTS

DETAIL (BLURRING)

CONTRAST SENSITIVITY

NOISE

## IMAGING PROTOCOL

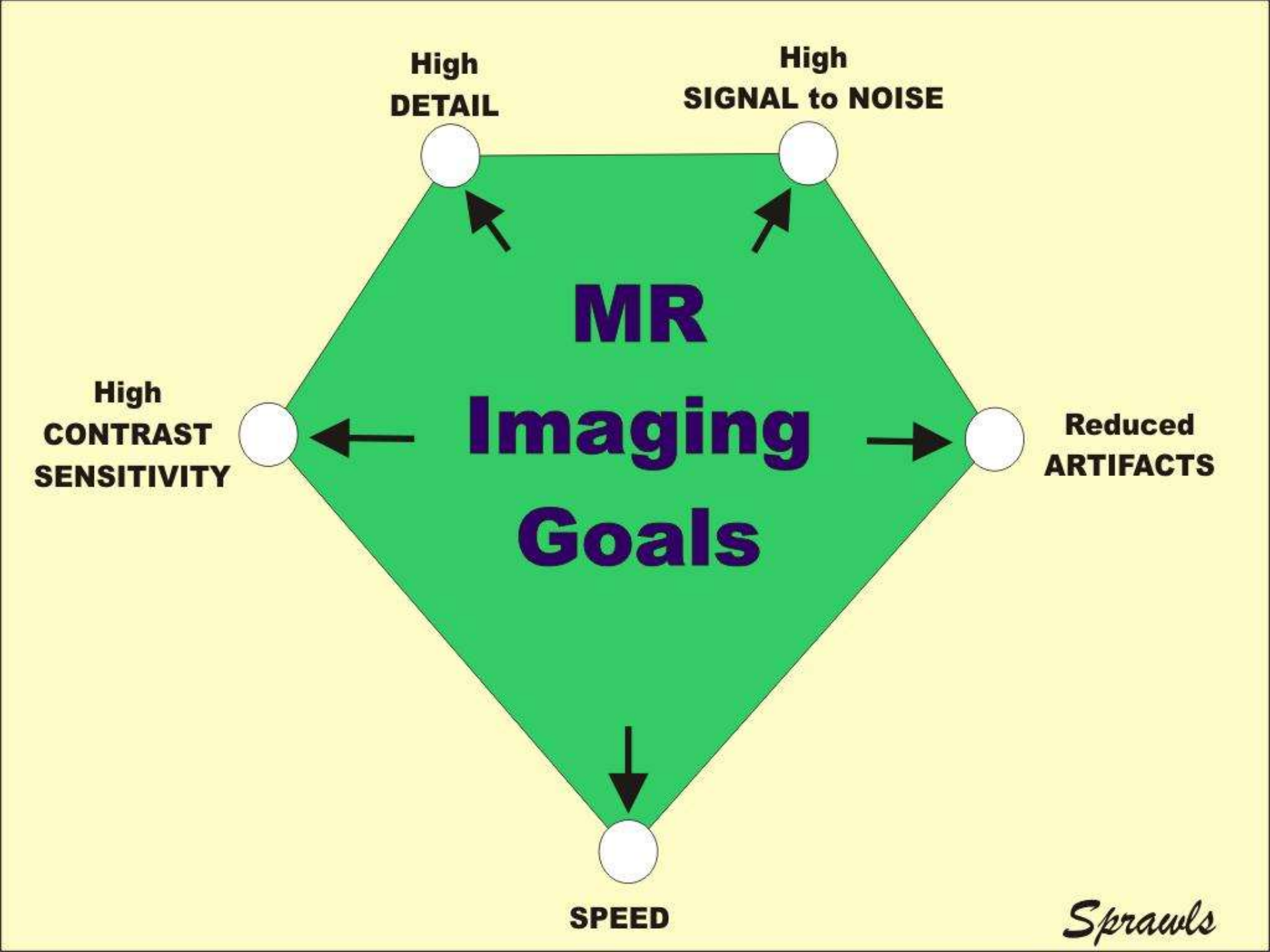
TR

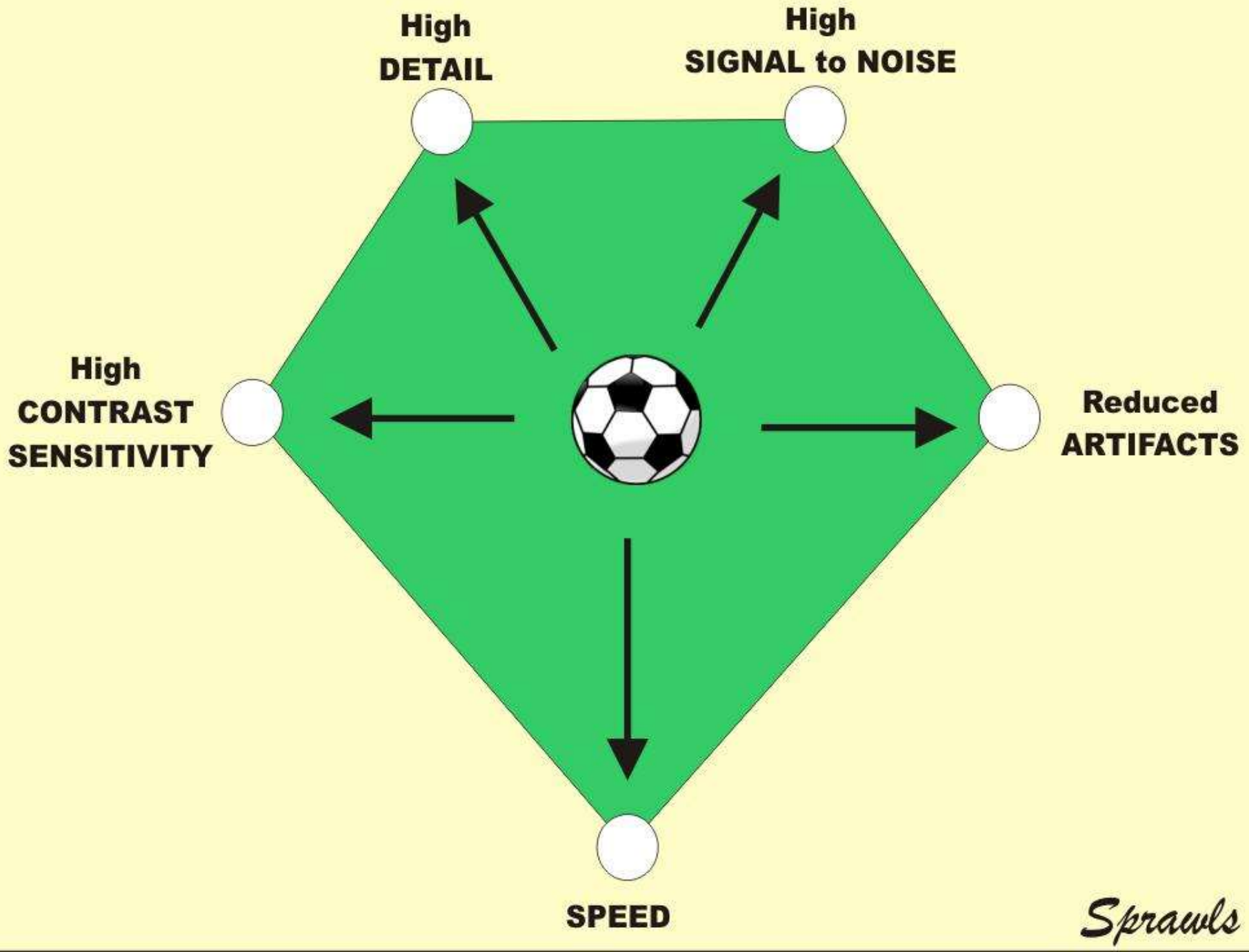
TE

Matrix

## FACTORS

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

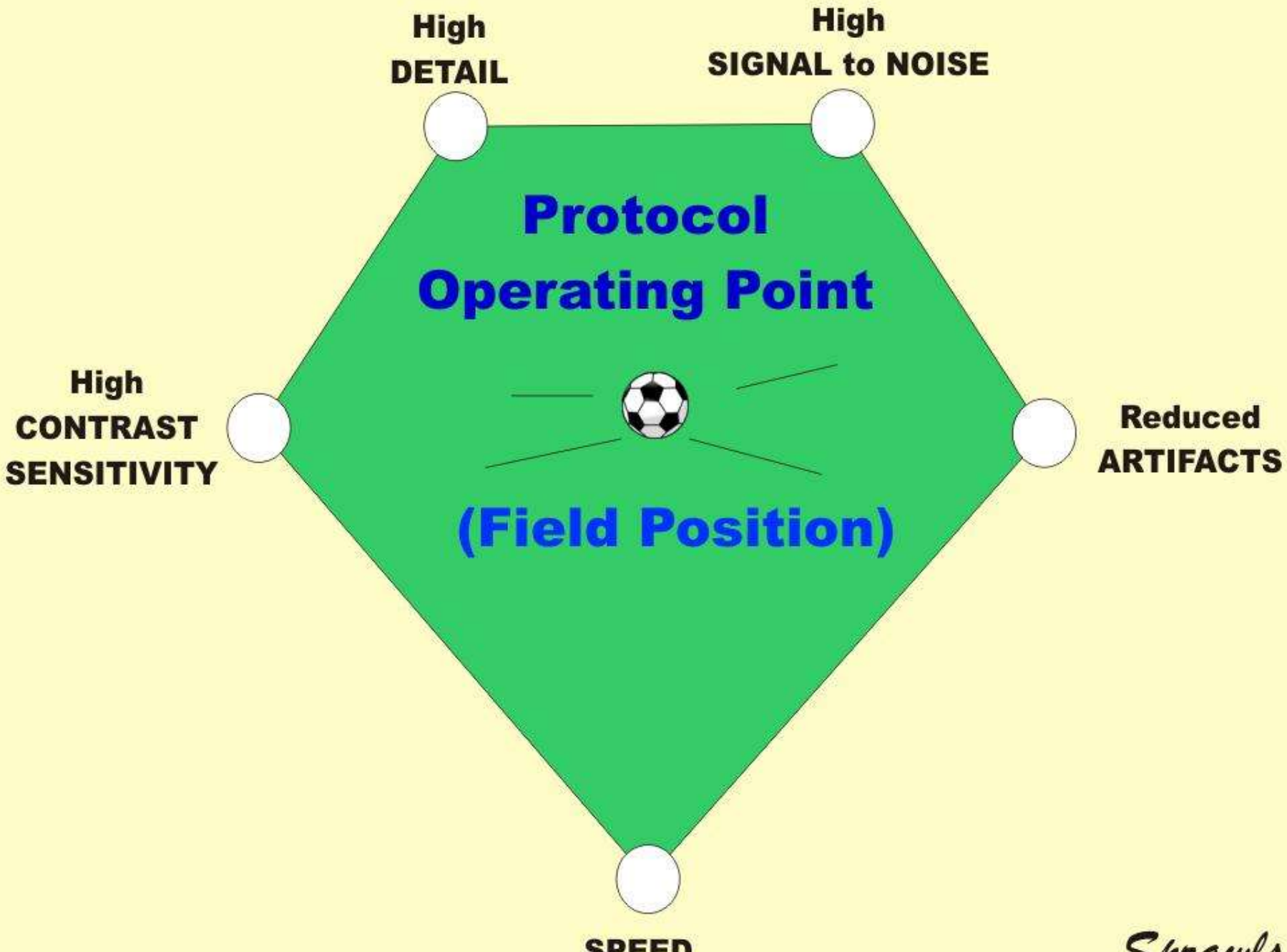
High
SIGNAL to NOISE

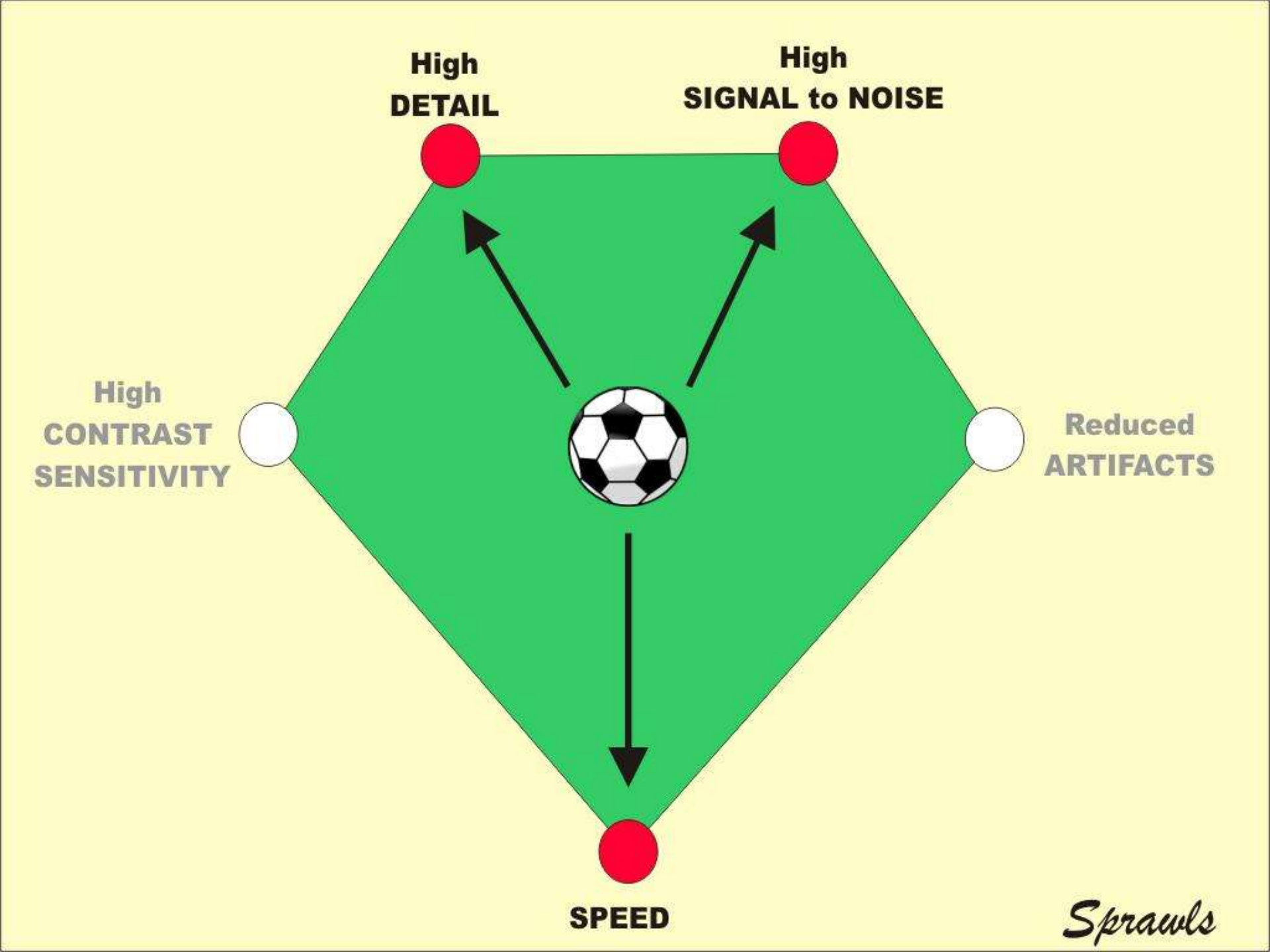
High
CONTRAST
SENSITIVITY

Reduced
ARTIFACTS

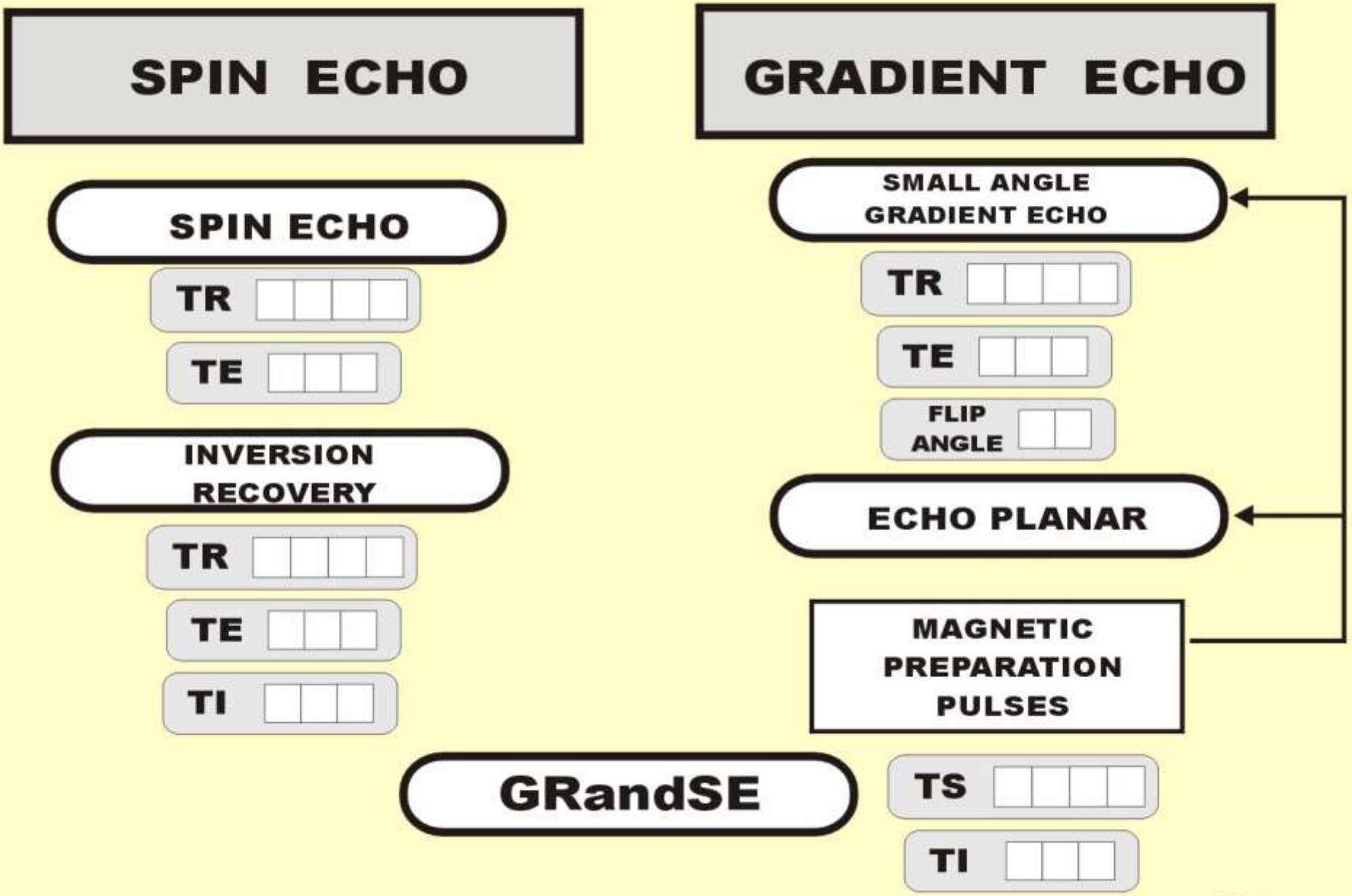
SPEED

Sprawls


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

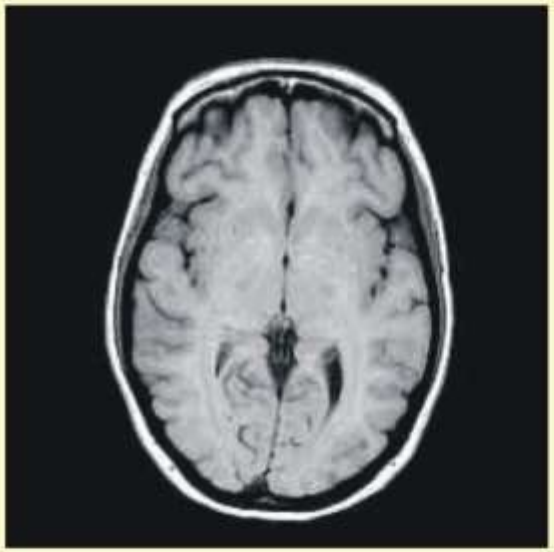

High
DETAIL
High
SIGNAL to NOISE
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

# IMAGING METHODS

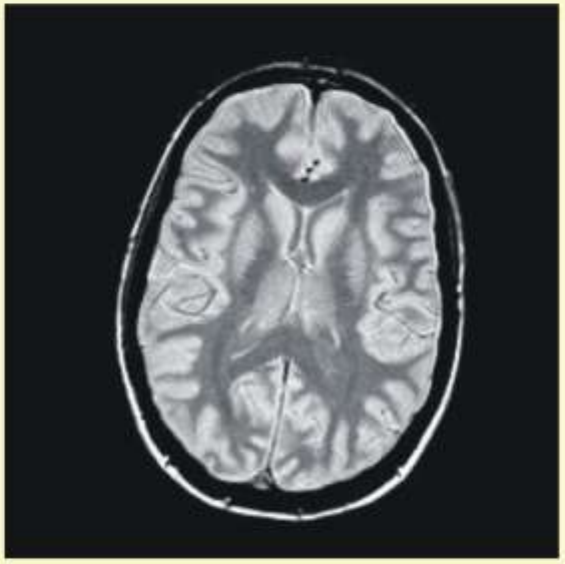


# MAGNETIC RESONANCE IMAGE

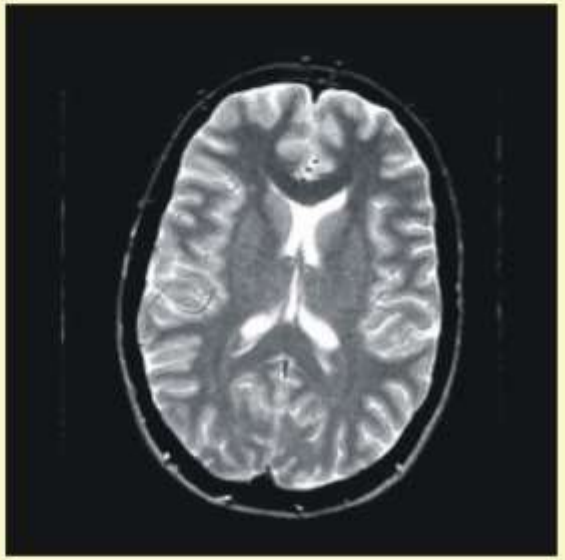
## ( WHAT DO YOU SEE? )



T1



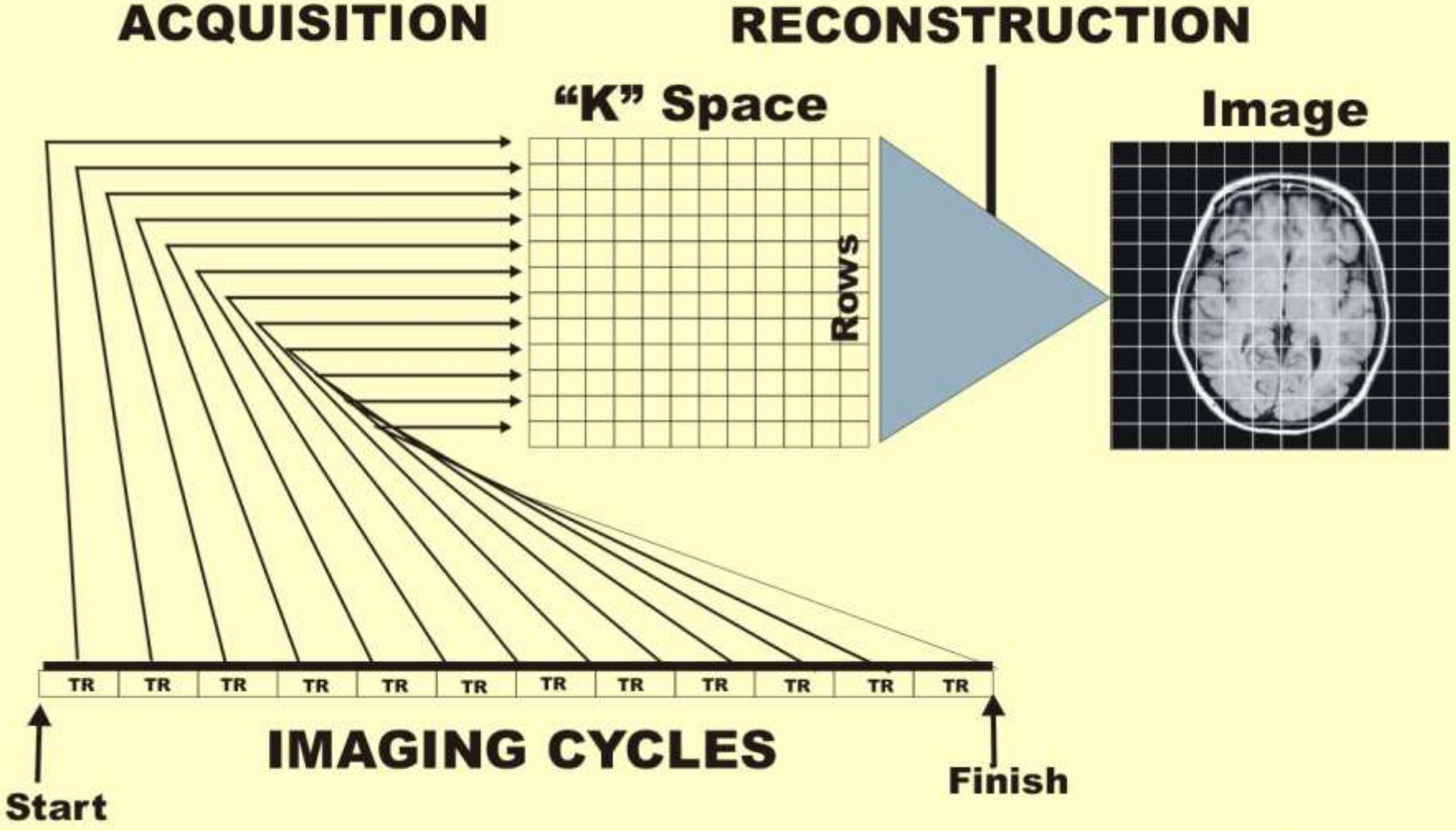
PROTON
DENSITY



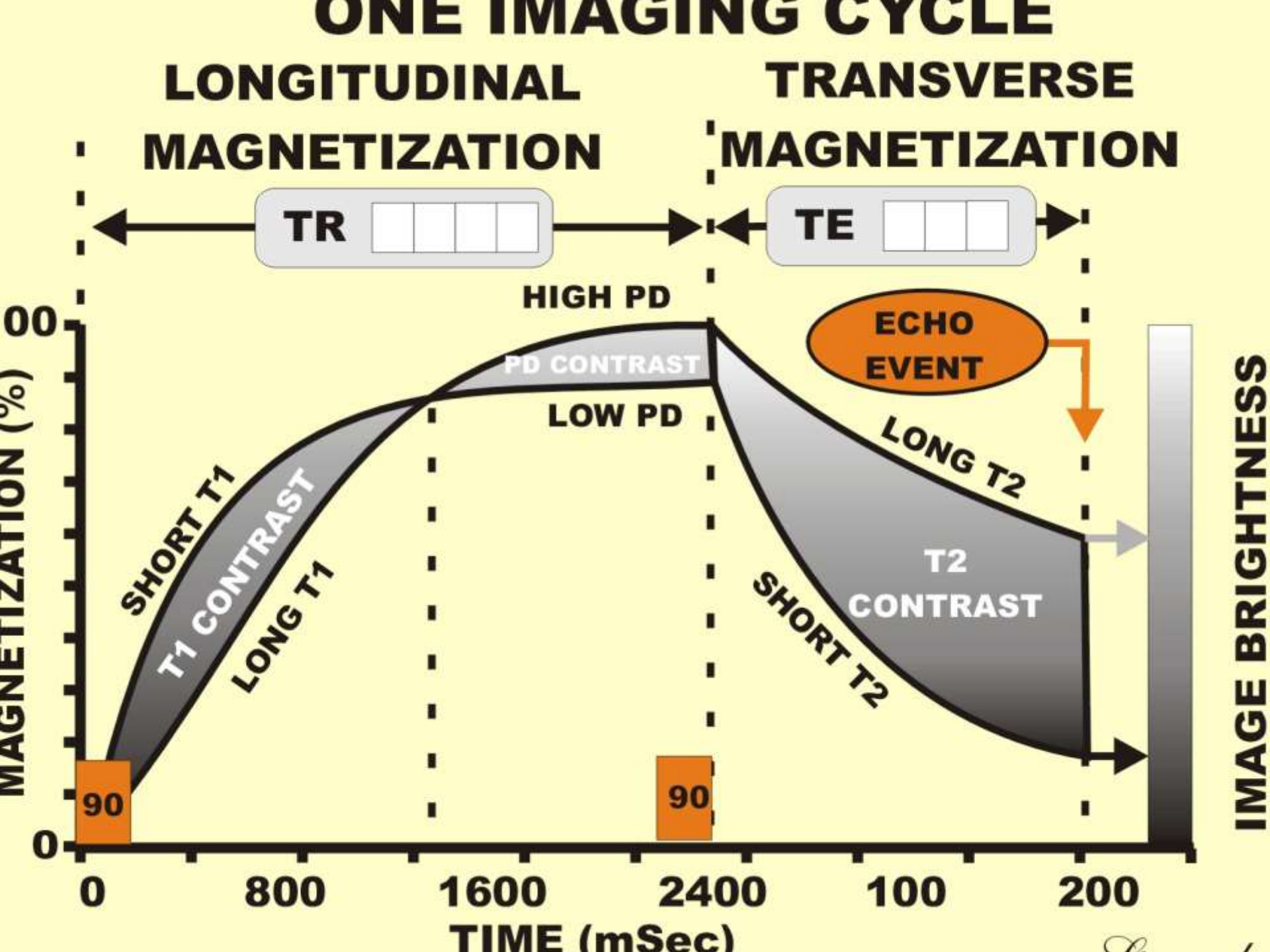
T2

## TISSUE CHARACTERISTICS

# THE MR IMAGING PROCESS




Strawls


ONE IMAGING CYCLE
LONGITUDINAL MAGNETIZATION
TRANSVERSE MAGNETIZATION
TR
TE
HIGH PD
PD CONTRAST
LOW PD
ECHO EVENT
SHORT T1
T1 CONTRAST
LONG T1
LONG T2
T2 CONTRAST
SHORT T2
90
90
00
0
MAGNETIZATION (%)
IMAGE BRIGHTNESS
0
800
1600
2400
100
200
TIME (mSec)

# T1 IMAGE

FAT

WHITE

GRAY

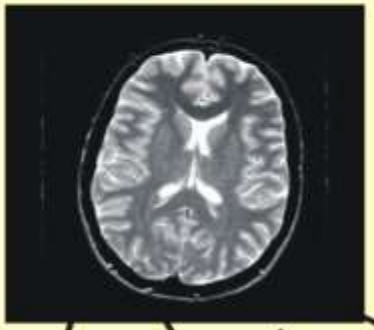
FLUID

SHORT 200 400 600 800 1000 LONG

TISSUE T1 VALUES (msec)

Sprawls

# T2 IMAGE



FAT

WHITE

GRAY

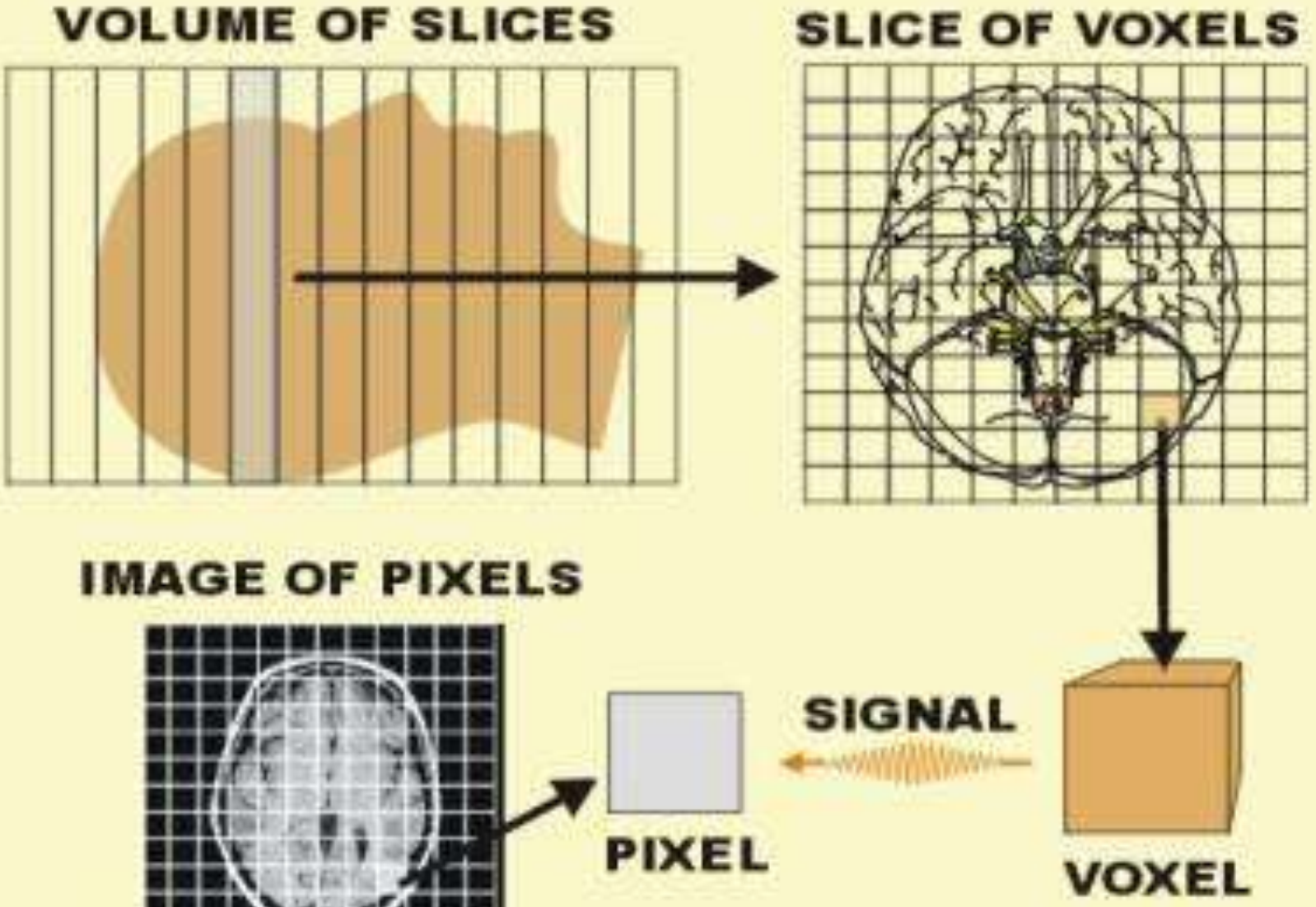
FLUID

SHORT 40 60 80 100 100 LONG

TISSUE T2 VALUES (msec)

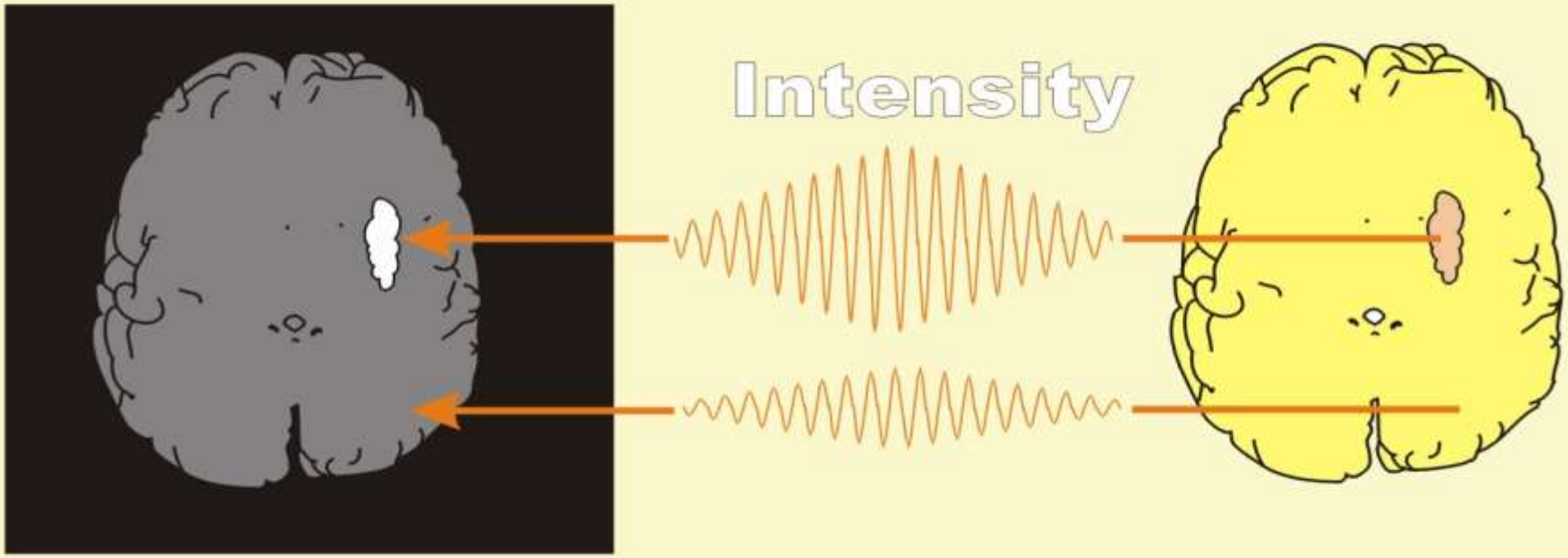
Sprawls

# SPATIAL CHARACTERISTICS



# MAGNETIC RESONANCE IMAGE

## ( WHAT DO YOU SEE? )



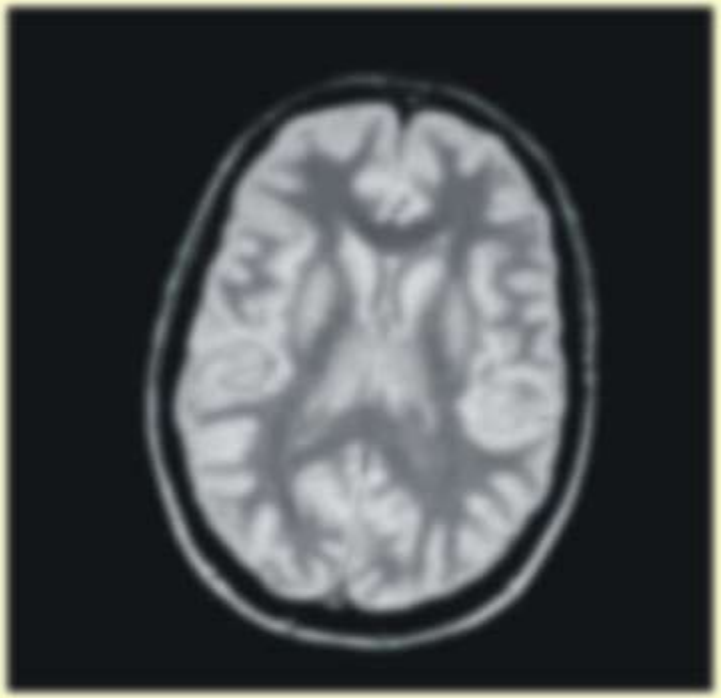

## RADIO FREQUENCY SIGNALS

Sprawls

DETAIL
(BLURRING)

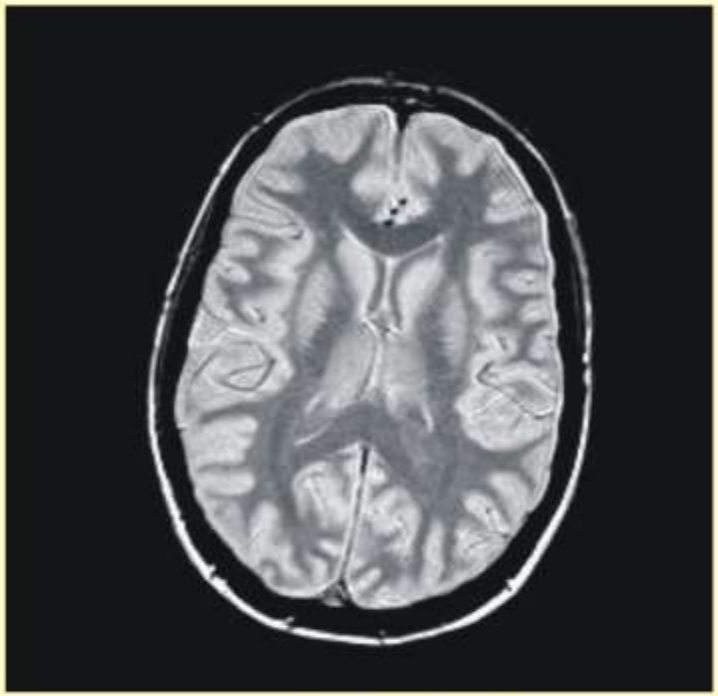
# VISIBILITY OF DETAIL

LOW



HIGH

HIGH

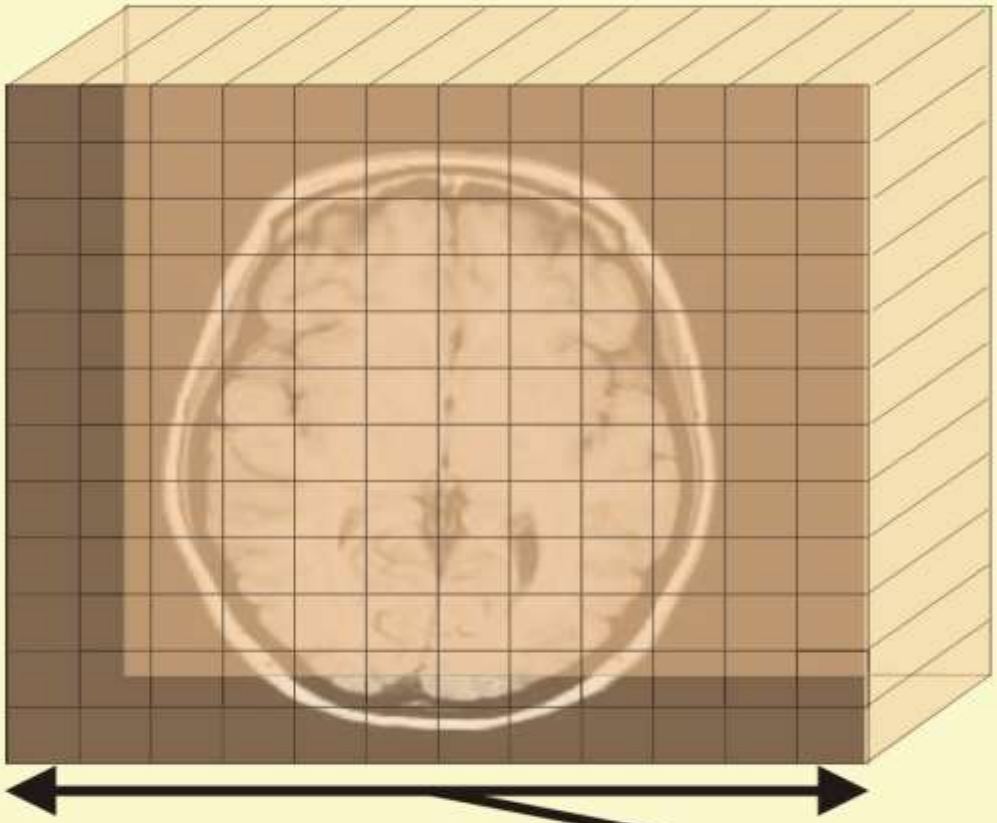


LOW

BLUR

Sprawls

# IMAGE DETAIL



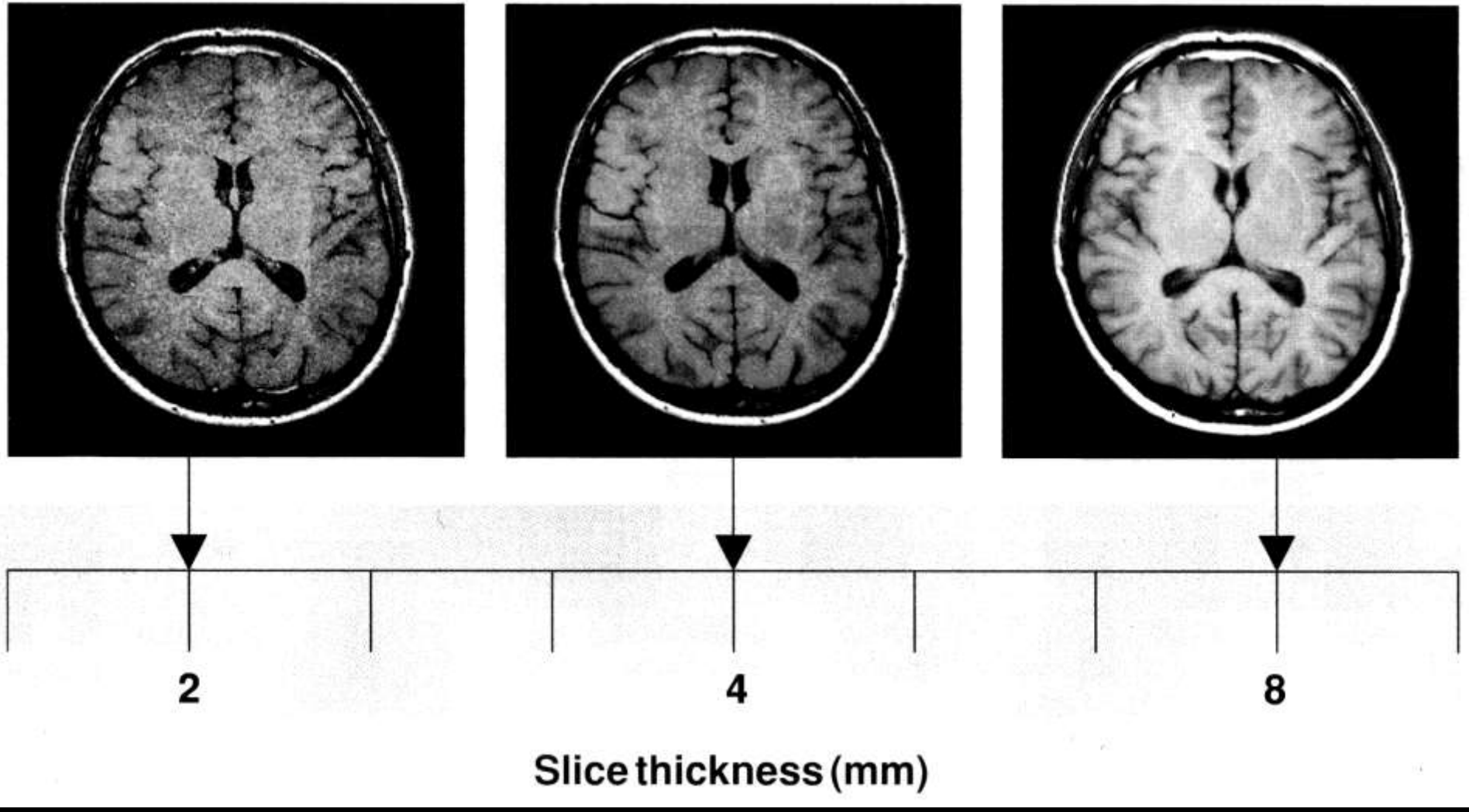
VOXEL SIZE

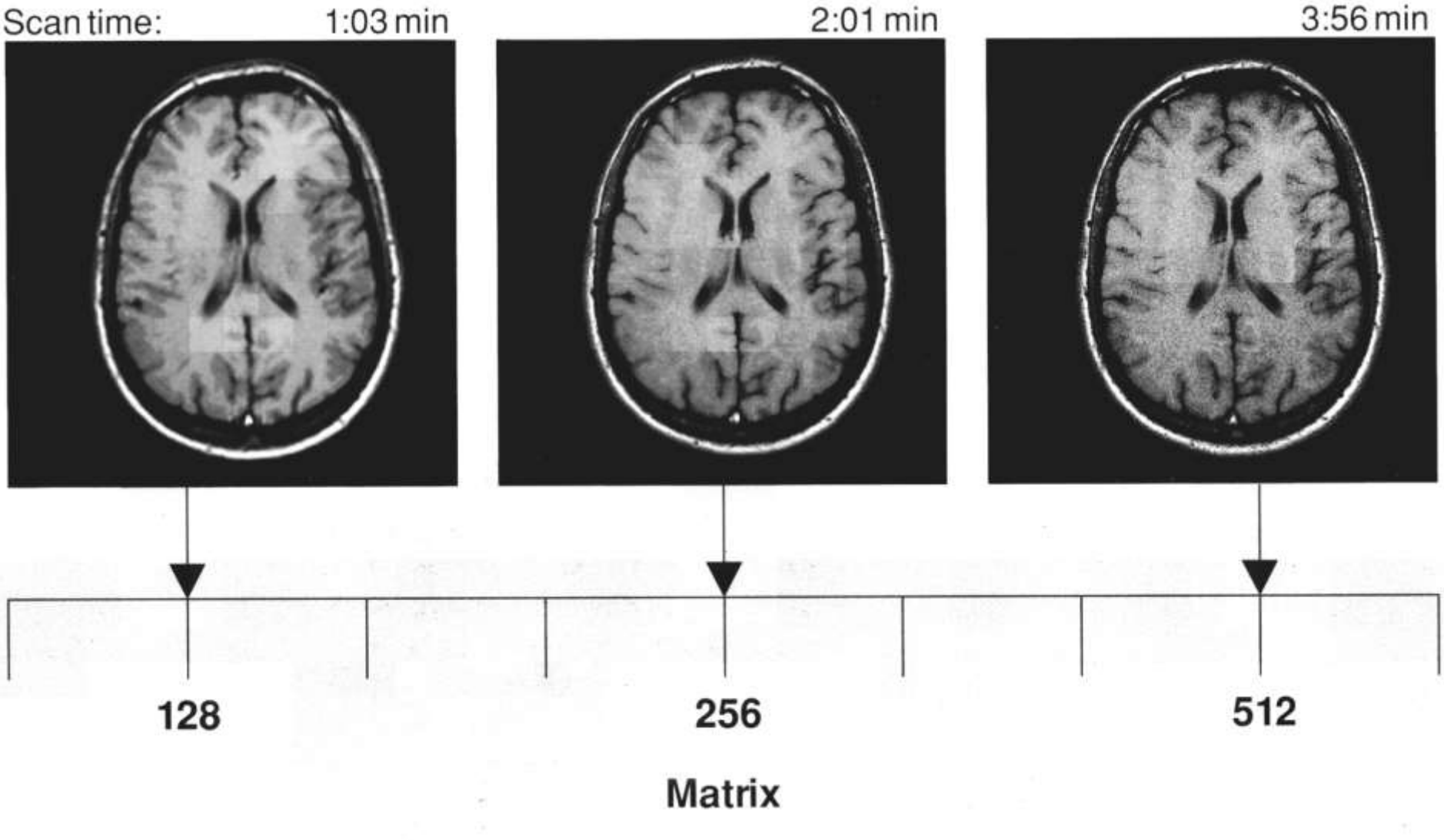
Matrix

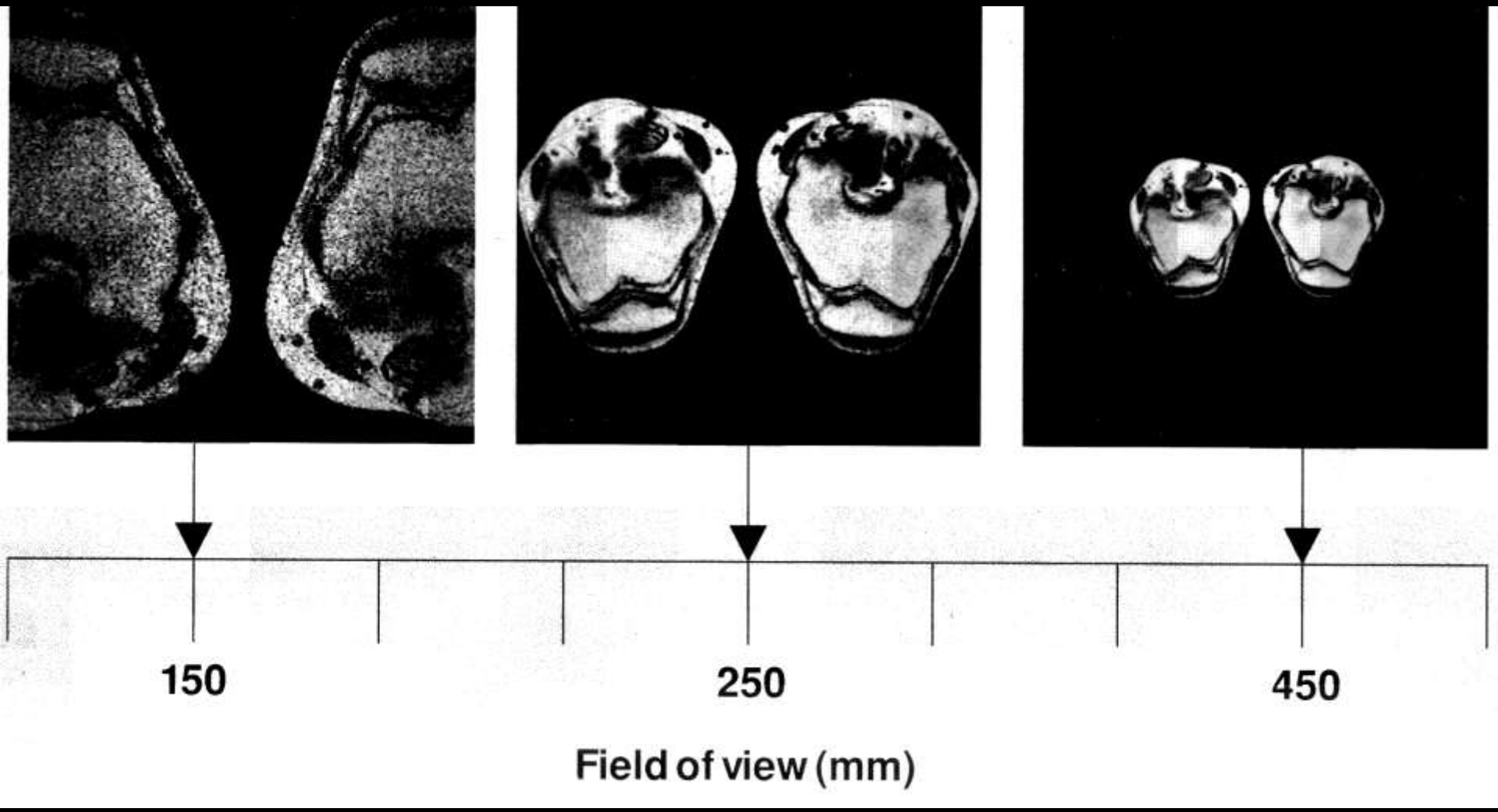
FOV

Thickness

Sprawls


2
4
8
Slice thickness (mm)

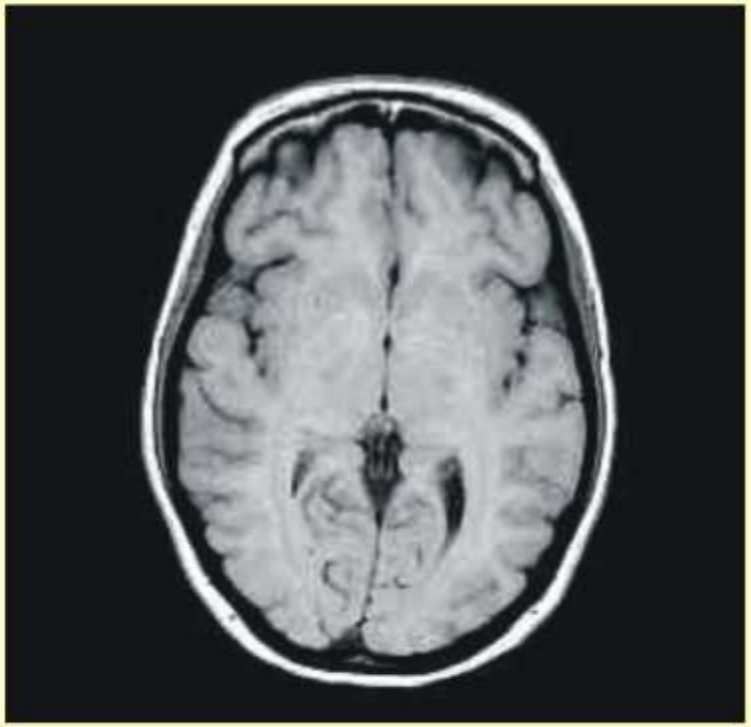

Scan time:
1:03 min
2:01 min
3:56 min
128
256
512
Matrix


150
250
450
Field of view (mm)

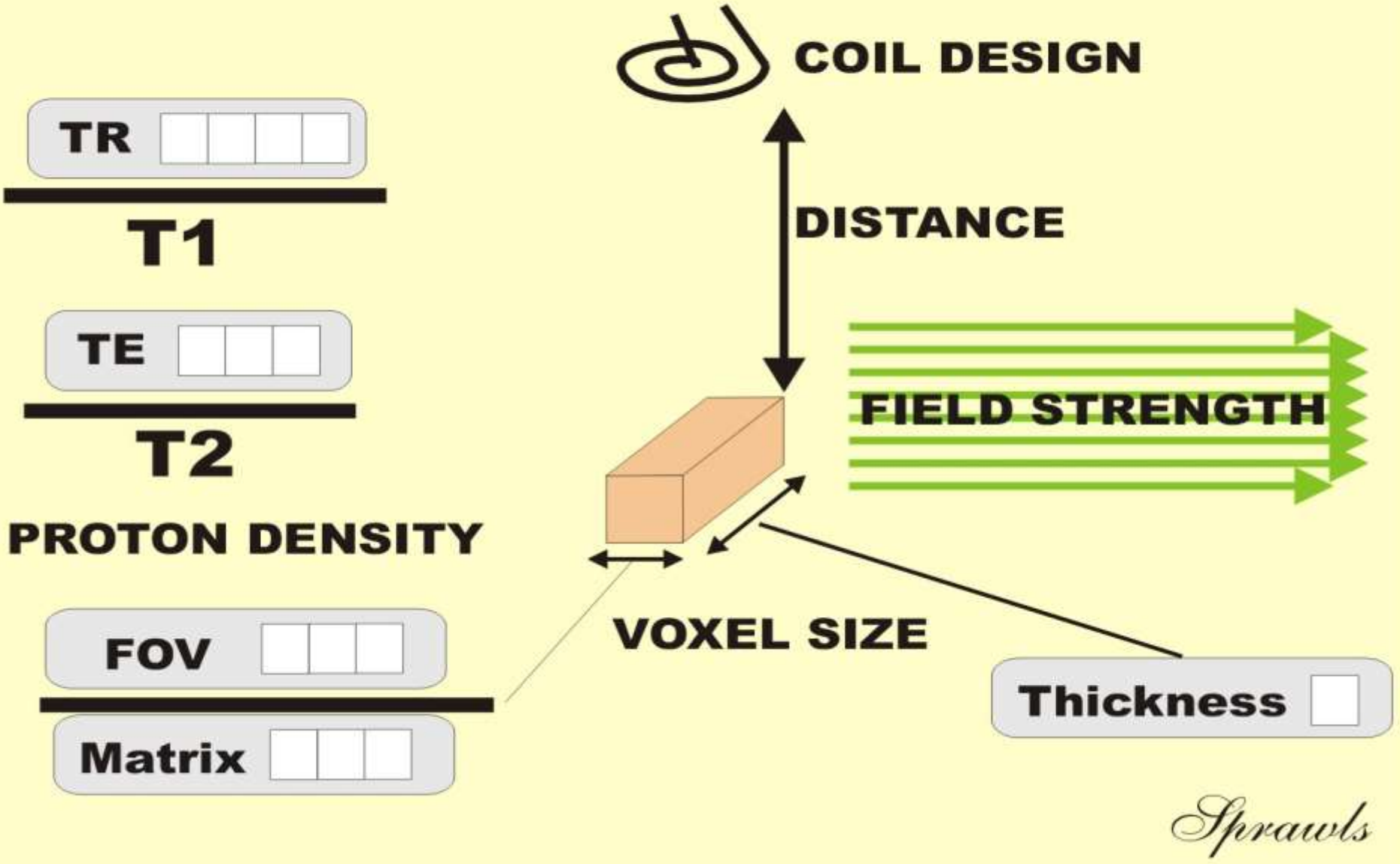
# NOISE

## HIGH NOISE

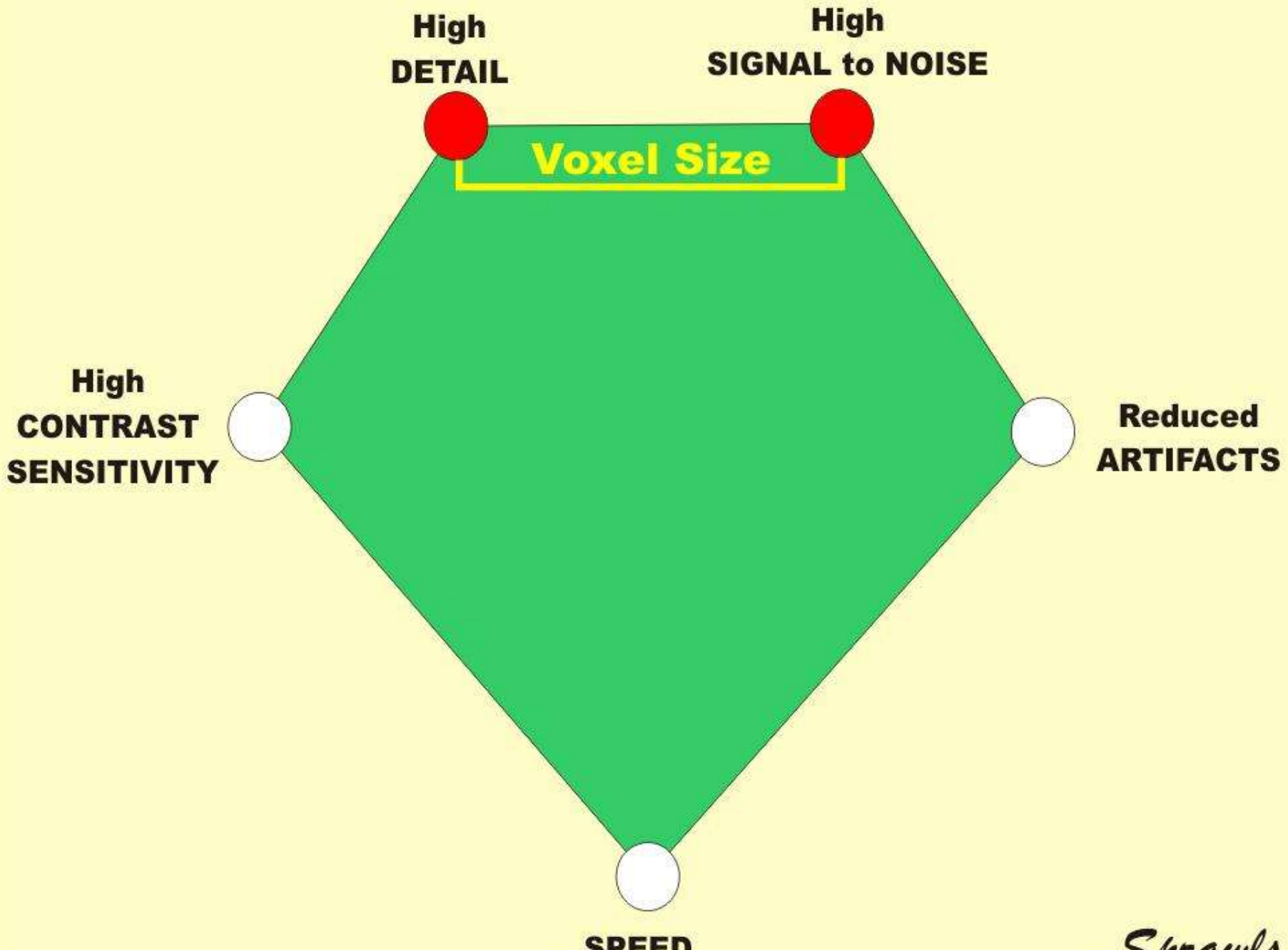
## LOW NOISE

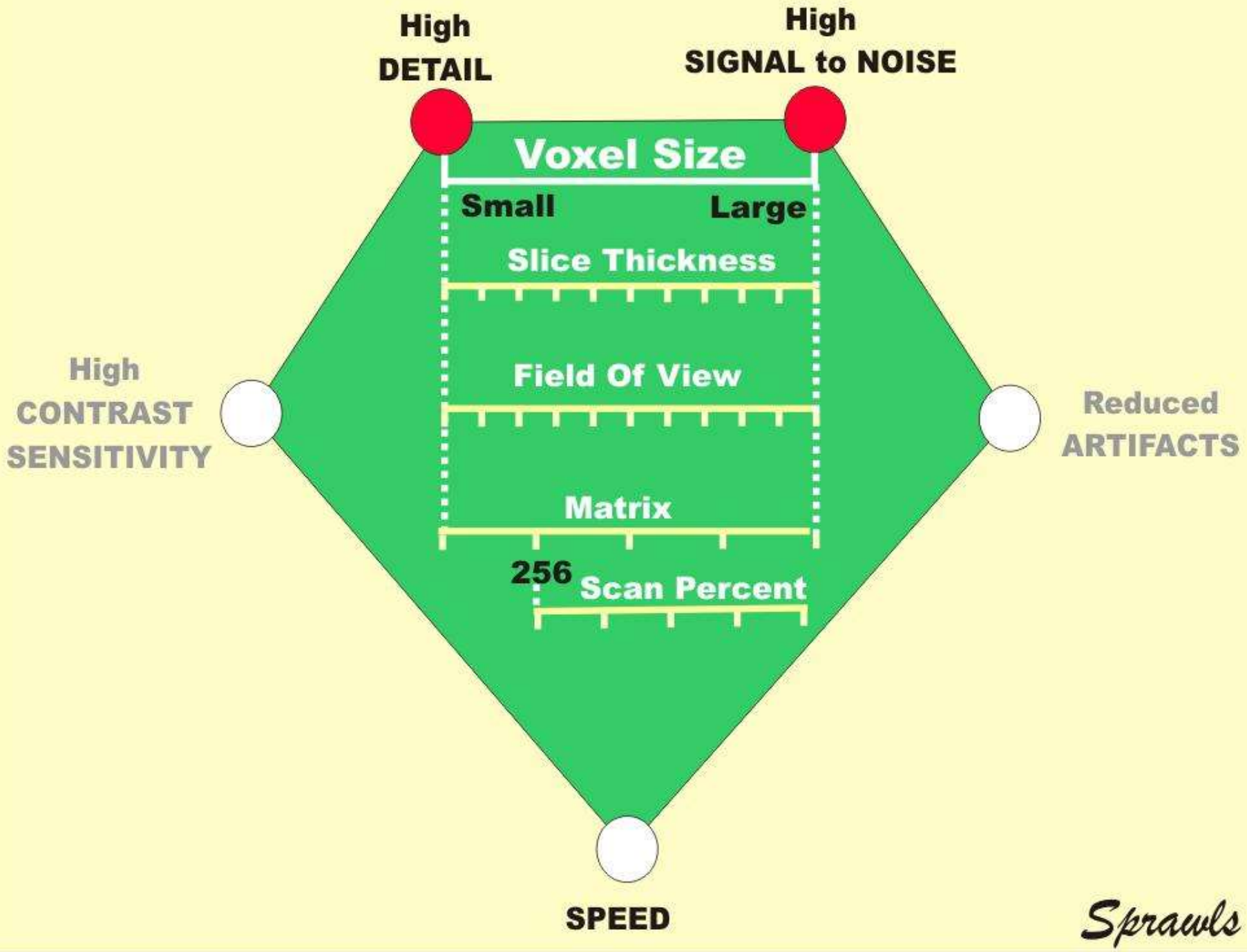


# SIGNAL STRENGTH




Sprawls


High
DETAIL
High
SIGNAL to NOISE
Voxel Size
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
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

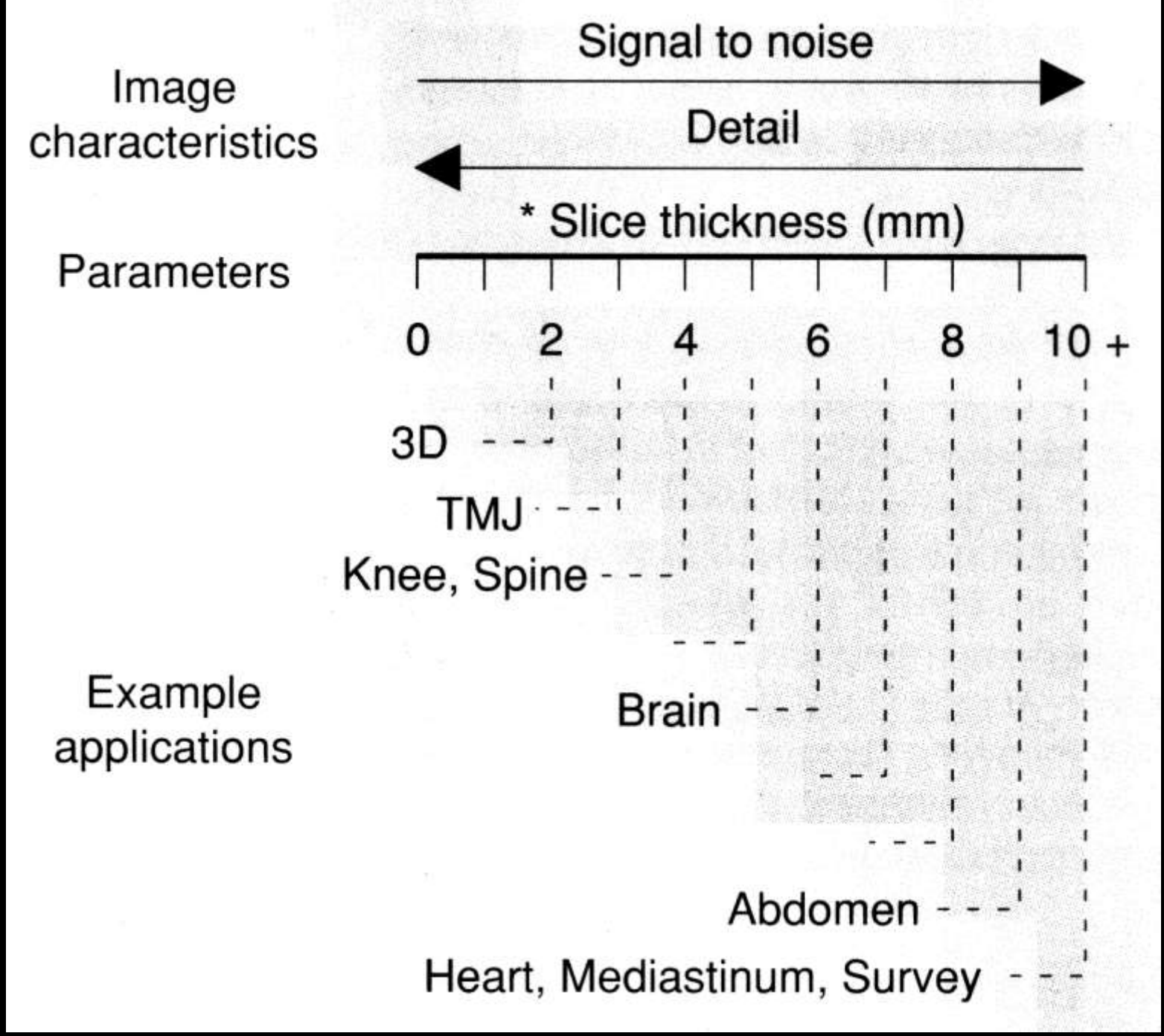


Image characteristics
Signal to noise
Detail
Parameters
* Slice thickness (mm)
0
2
4
6
8
10 +
3D
TMJ
Knee, Spine
Example applications
Brain
Abdomen
Heart, Mediastinum, Survey

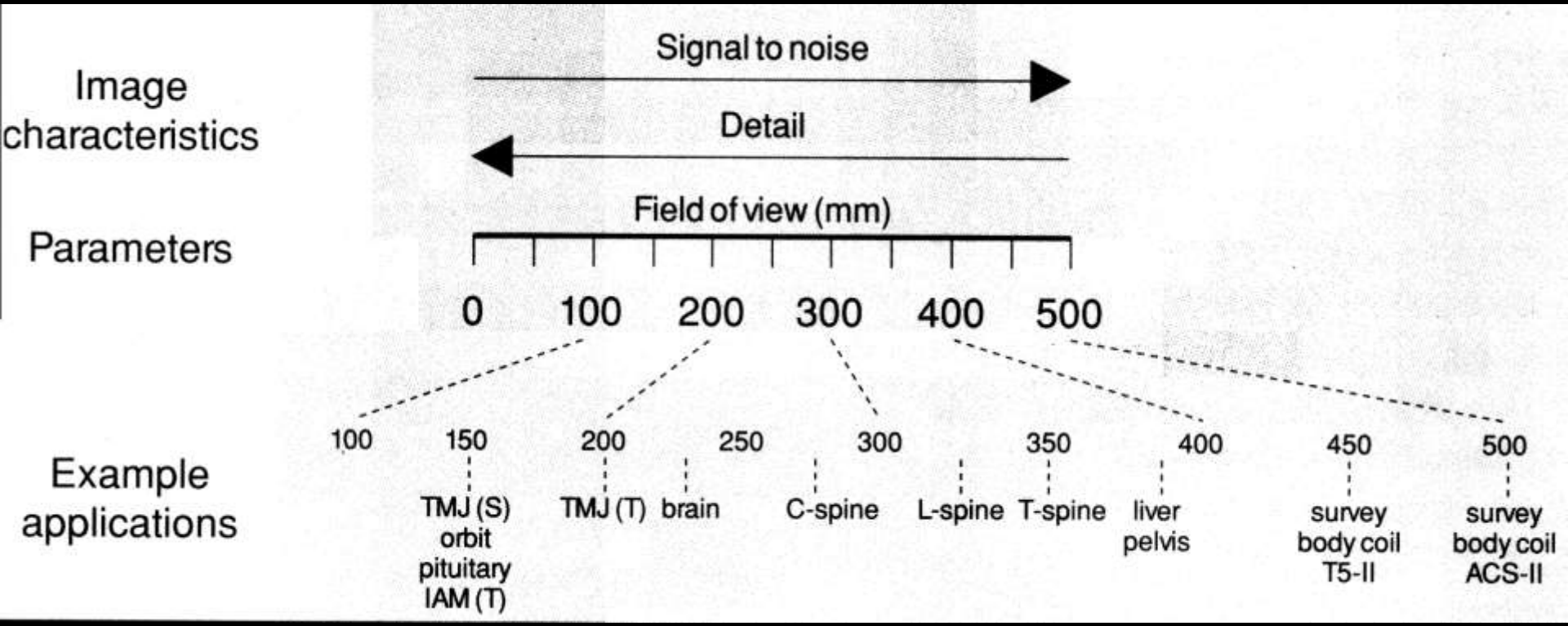
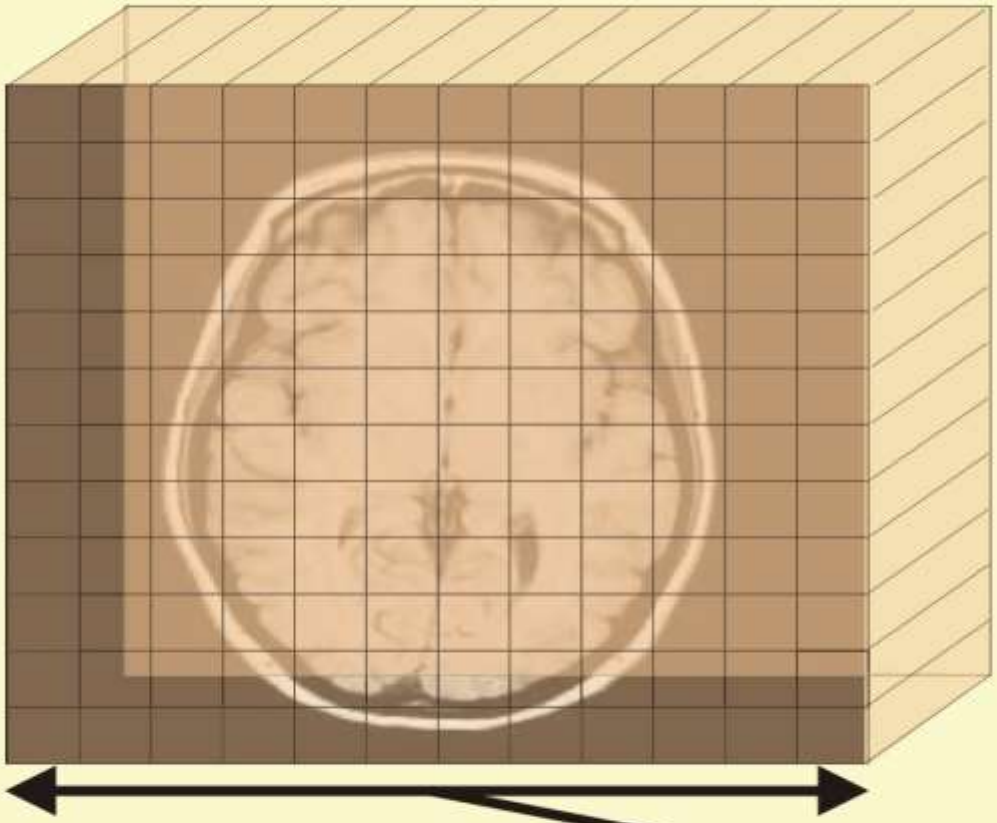


Image characteristics
Signal to noise
Detail
Parameters
Field of view (mm)
0
100
200
300
400
500
Example applications
100
150
TMJ (S)
orbit
pituitary
IAM (T)
200
TMJ (T)
250
brain
300
C-spine
350
L-spine
T-spine
400
liver
pelvis
450
survey
body coil
T5-II
500
survey
body coil
ACS-II

# IMAGE DETAIL



VOXEL SIZE

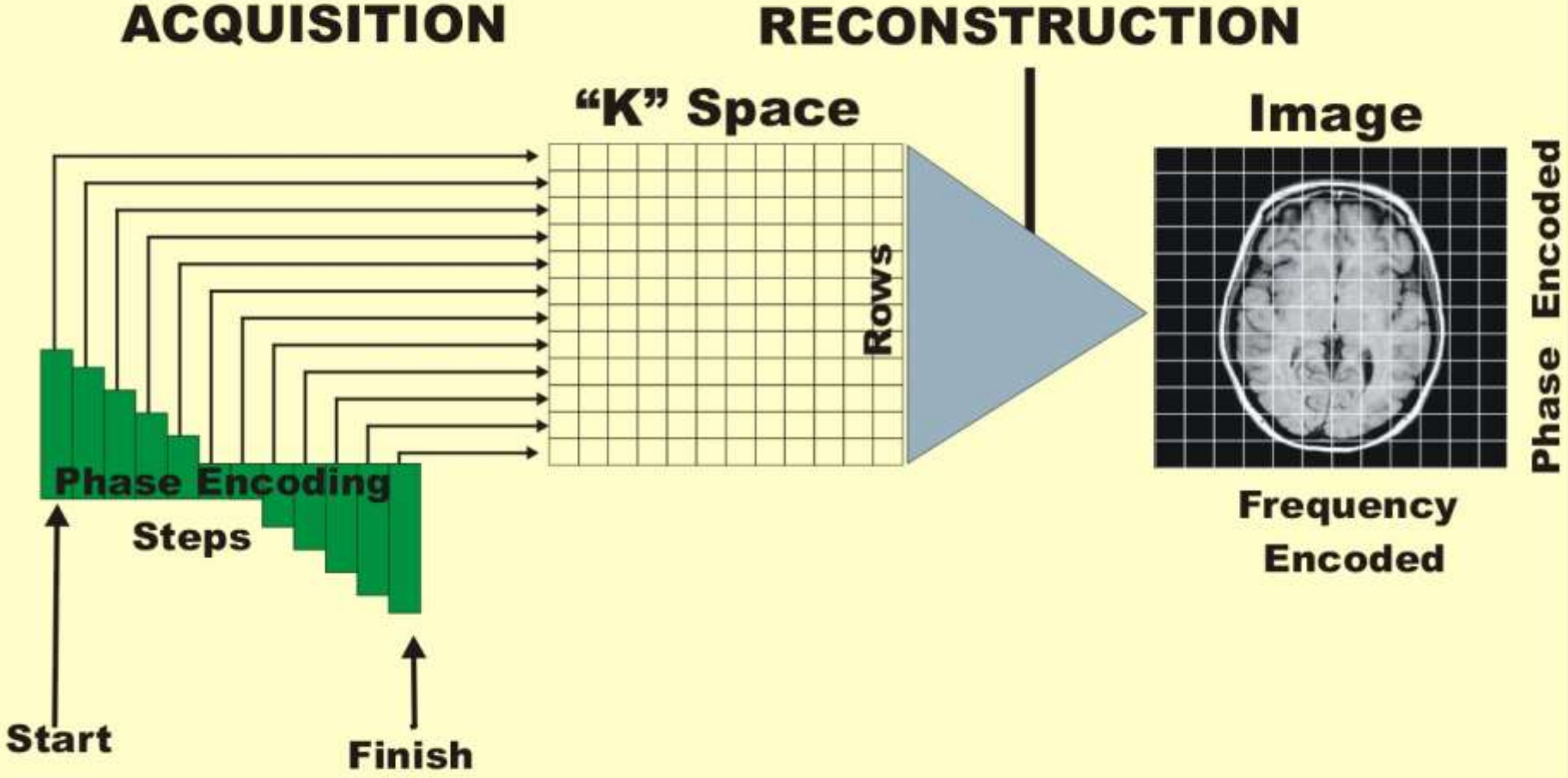
Matrix

FOV

Thickness

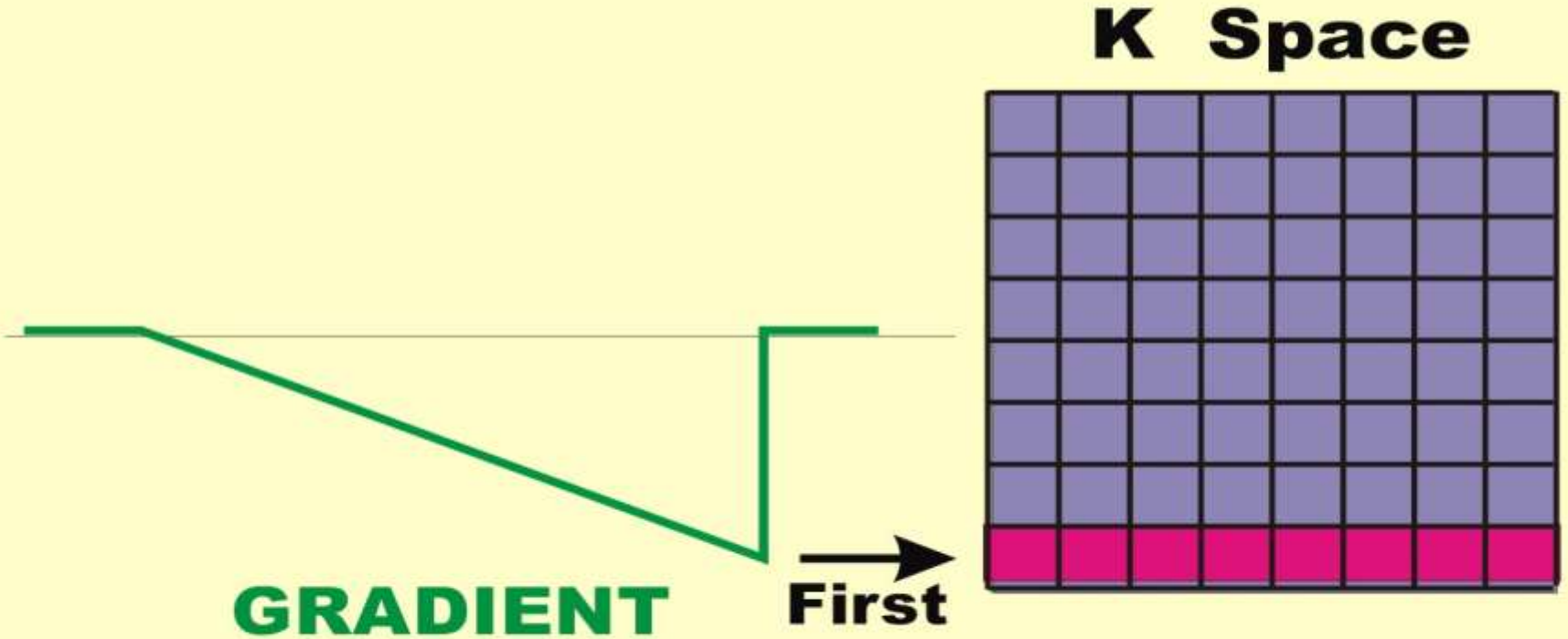
Sprawls

# THE MR IMAGING PROCESS



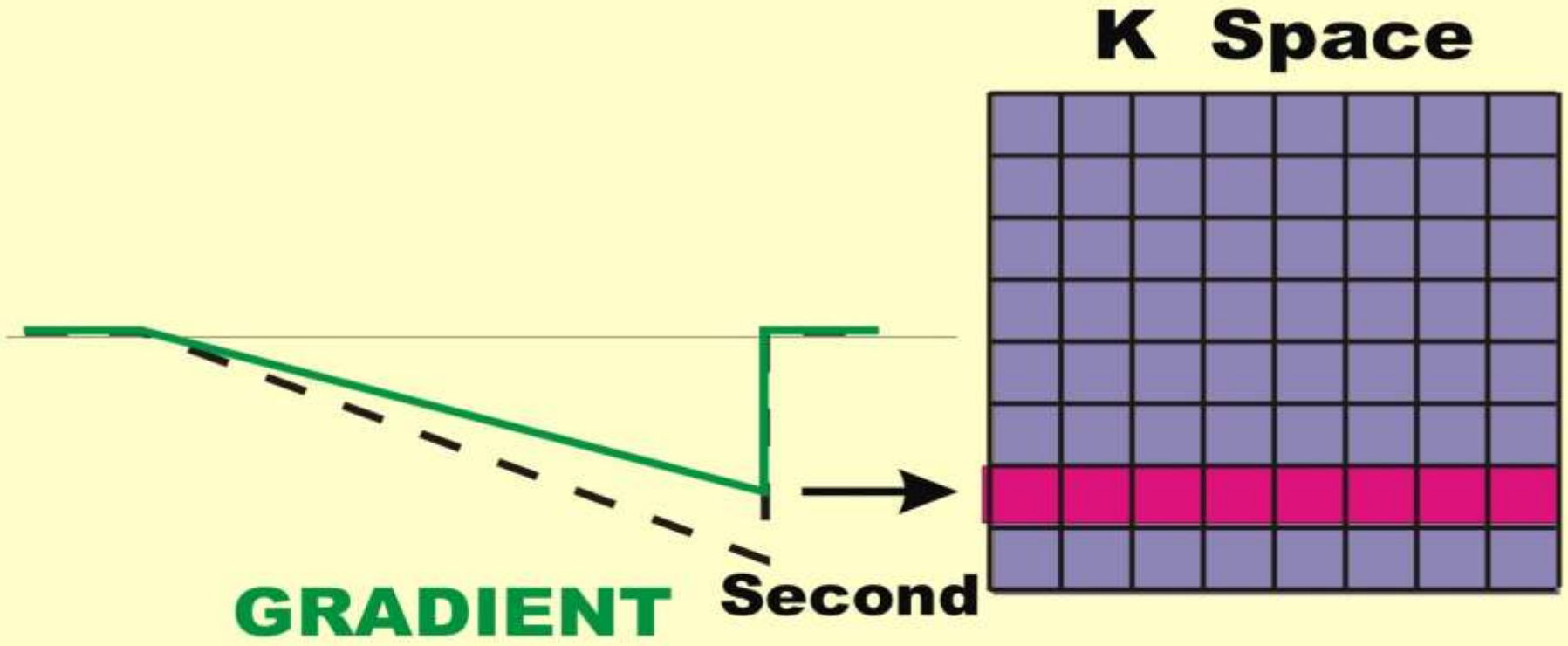

Strawls

# PHASE-ENCODING STEPS



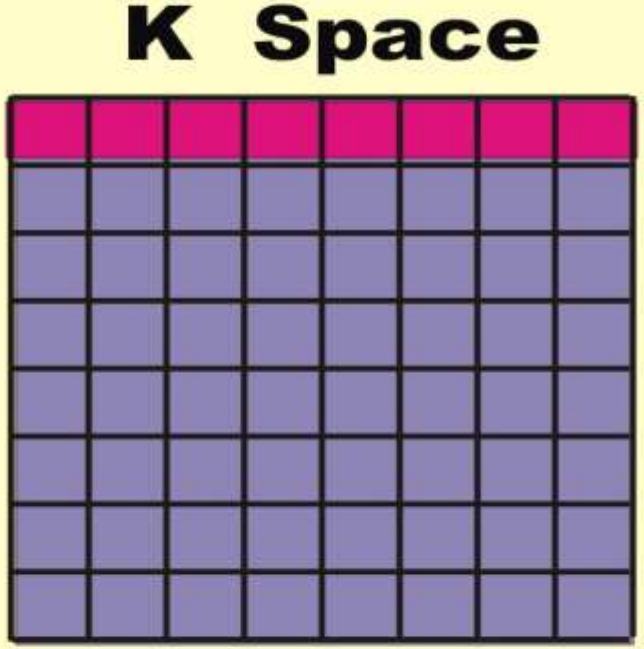

Sprawls

# PHASE-ENCODING STEPS




Sprawls

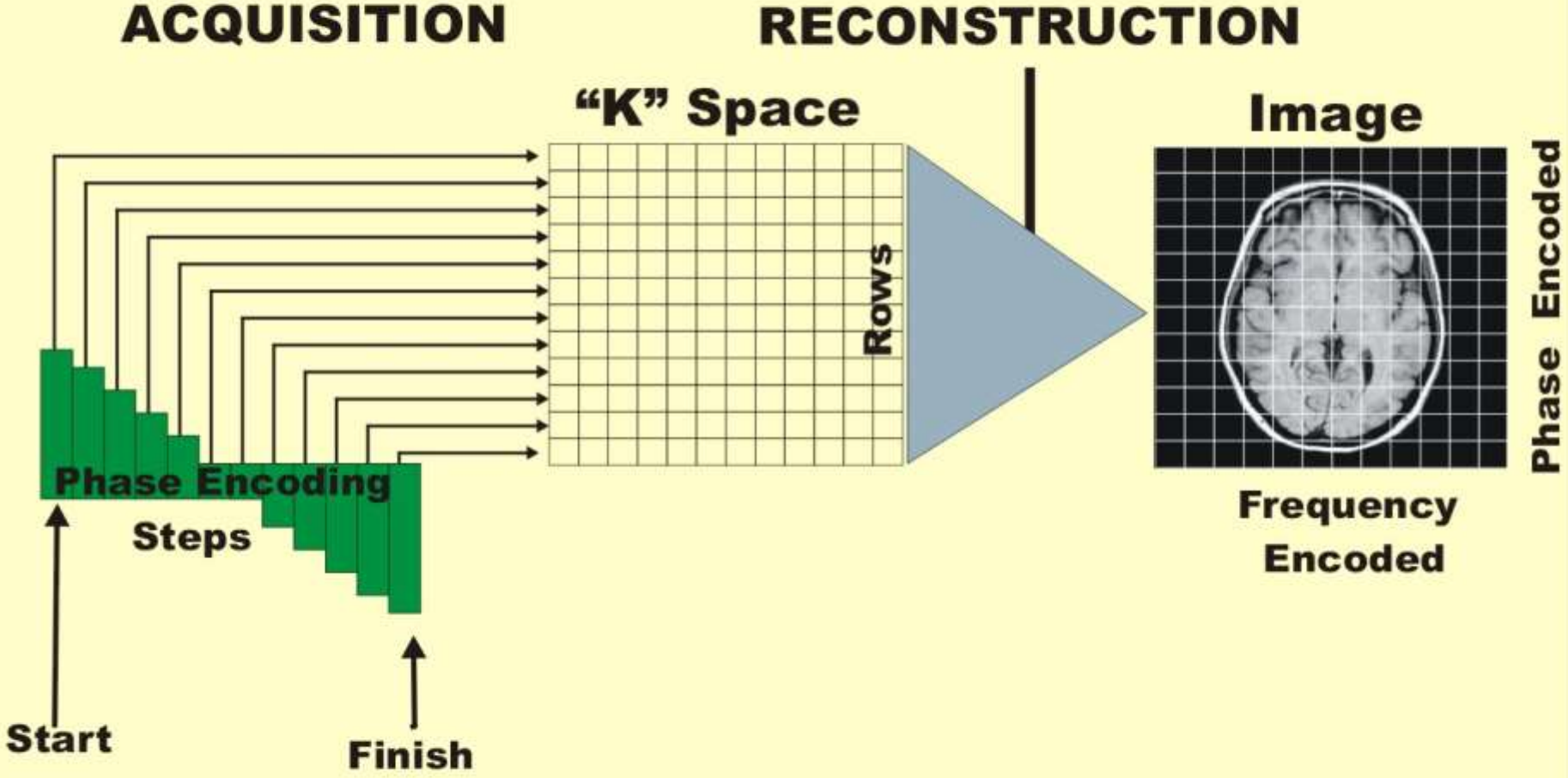
# PHASE-ENCODING STEPS

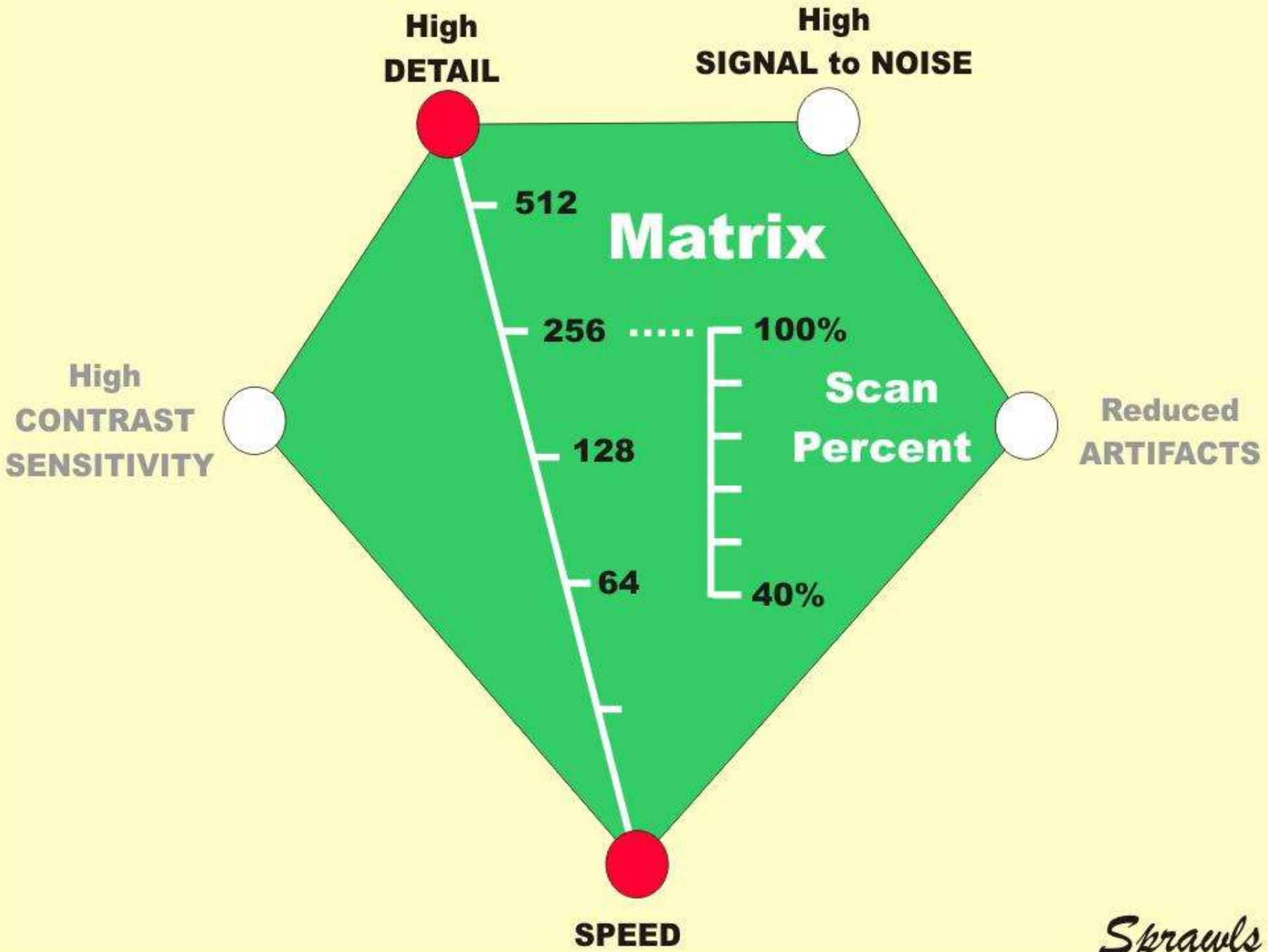

GRADIENT

Sprawls

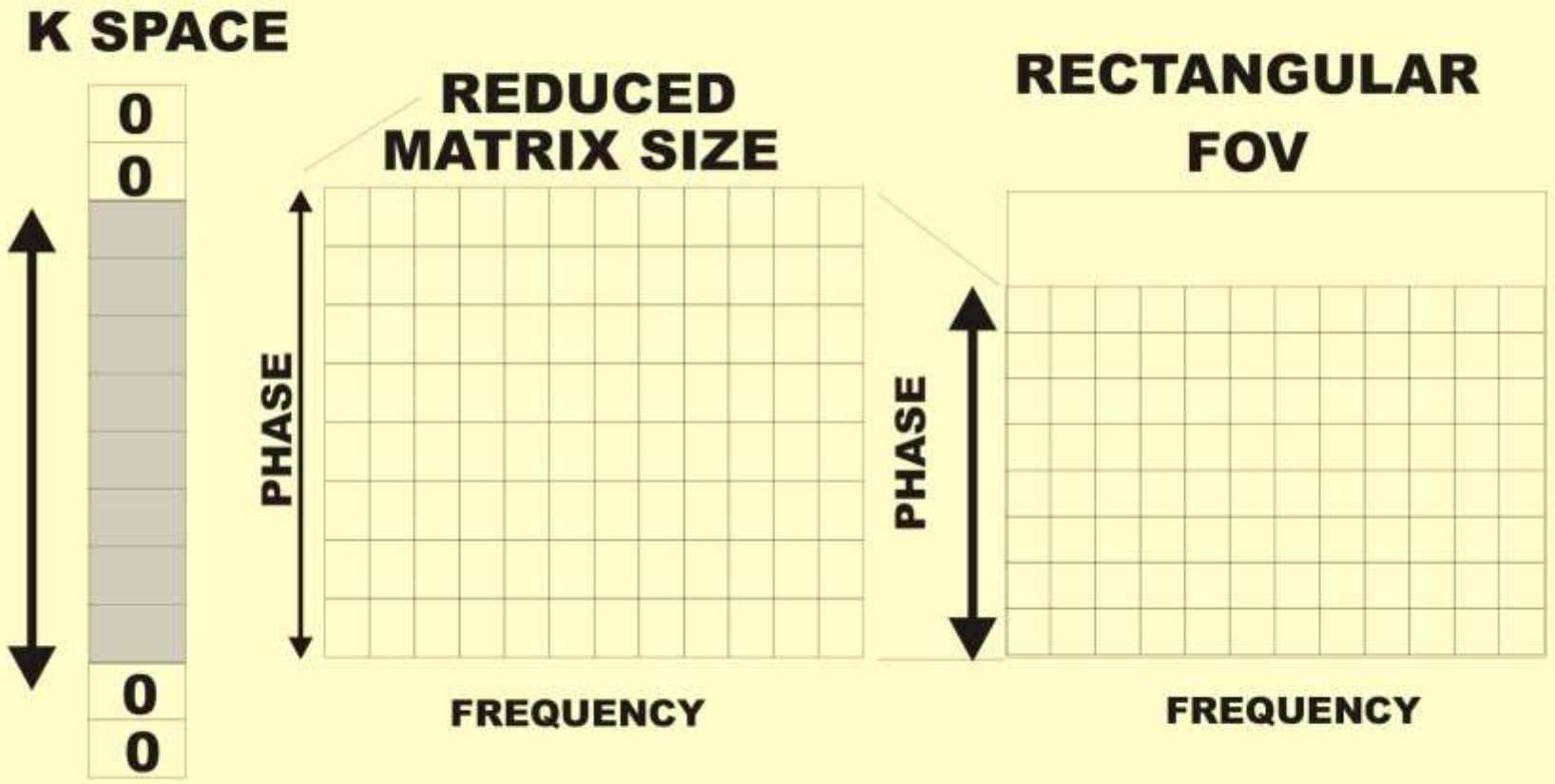
# THE MR IMAGING PROCESS



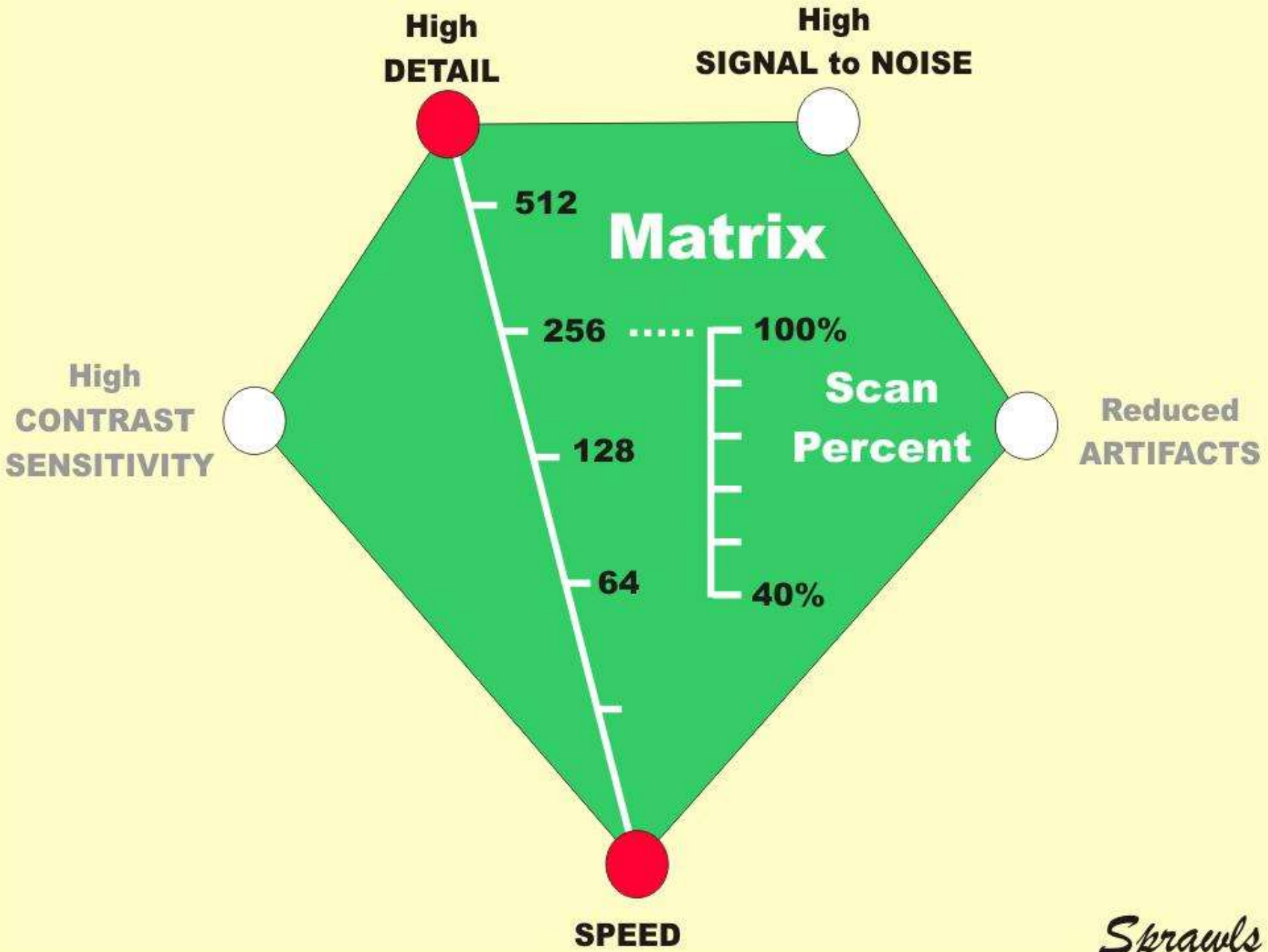

Strawls


High
DETAIL
High
SIGNAL to NOISE
512
Matrix
256
100%
Scan
Percent
128
64
40%
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

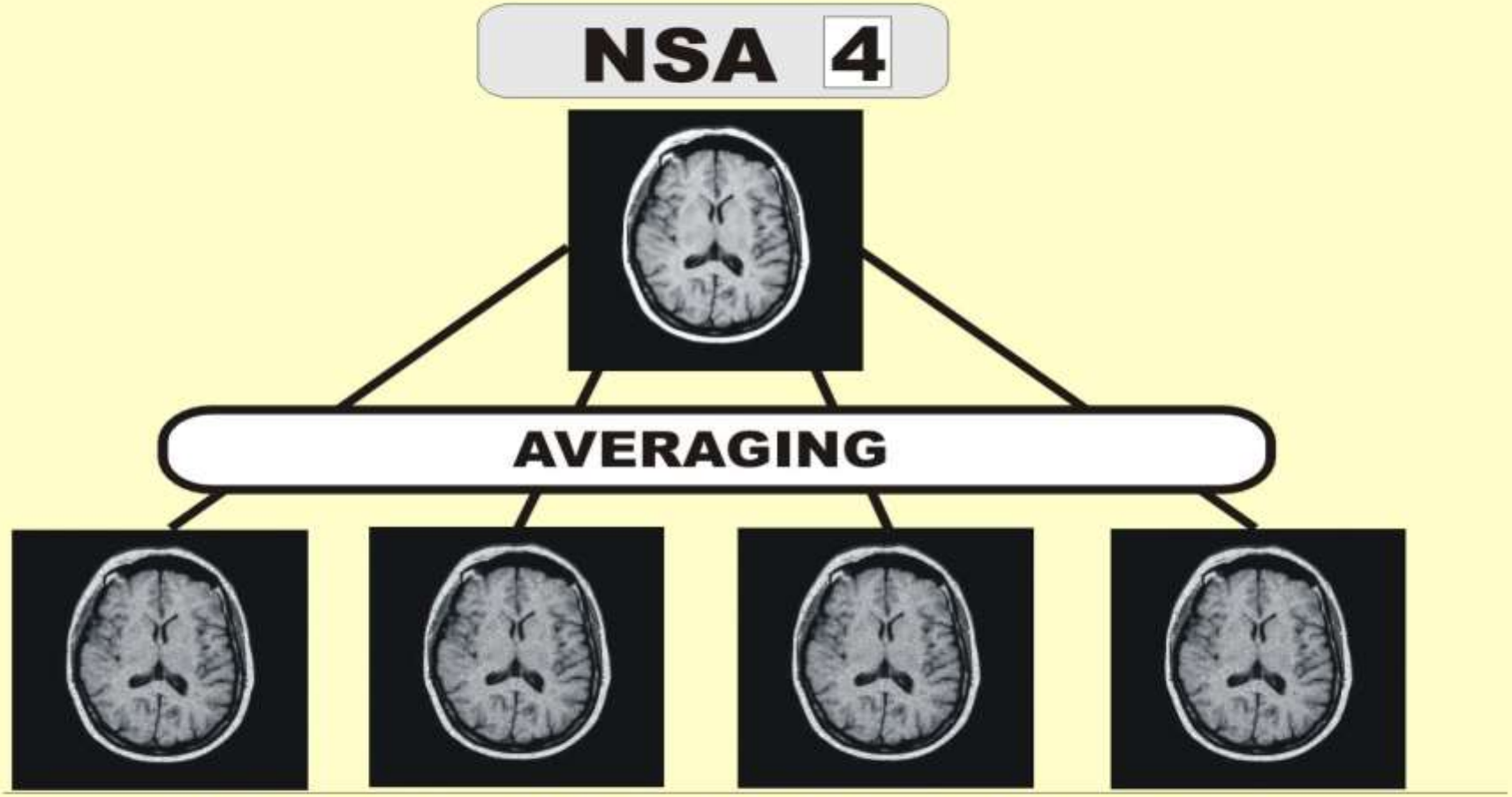
# REDUCED ACQUISITION




Sprawls


High
DETAIL
High
SIGNAL to NOISE
512
Matrix
256
100%
Scan
Percent
128
64
40%
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
SPEED
Sprawls

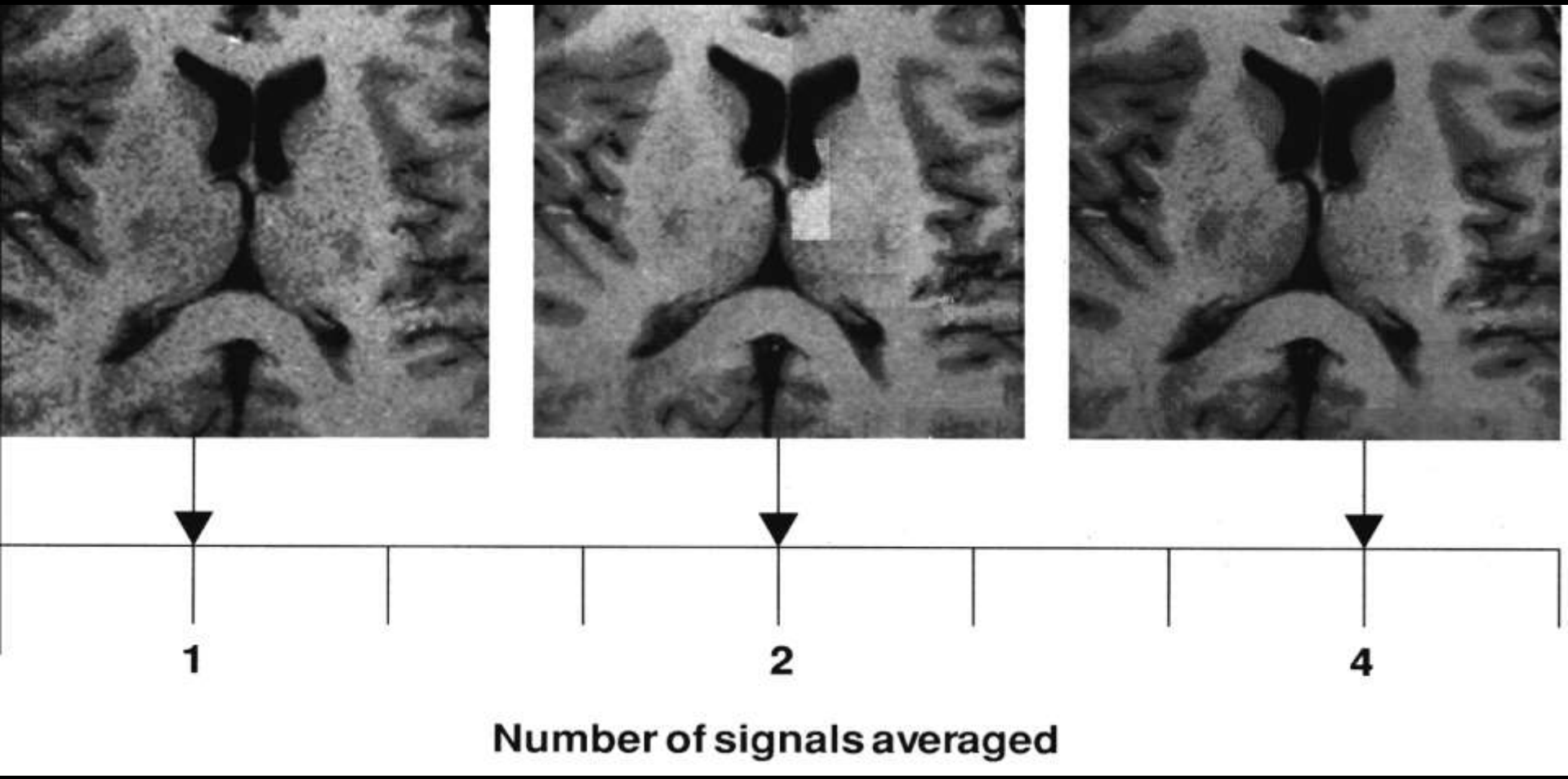
# THE EFFECT OF AVERAGING

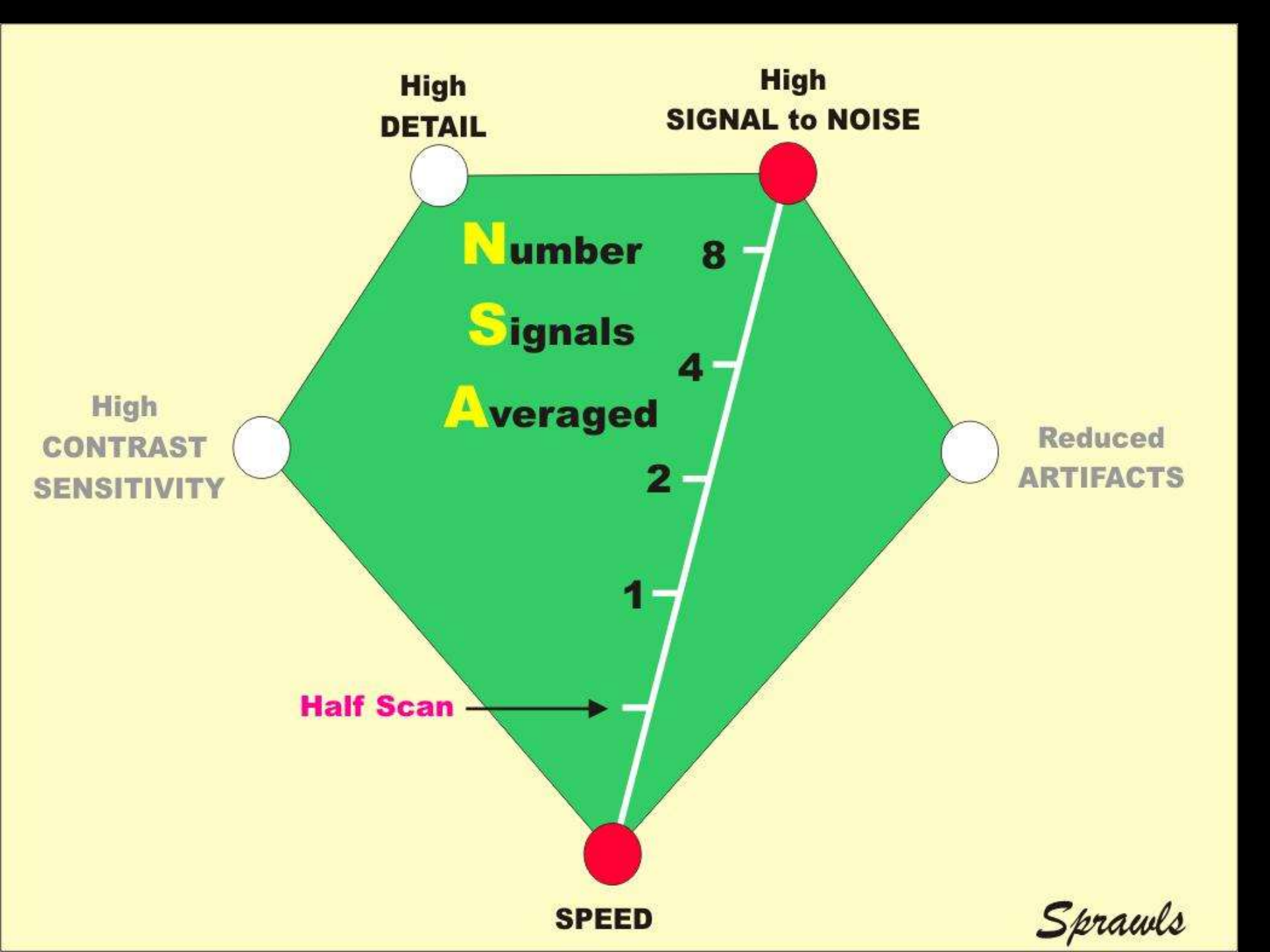



IMAGES FROM FOUR ACQUISITIONS

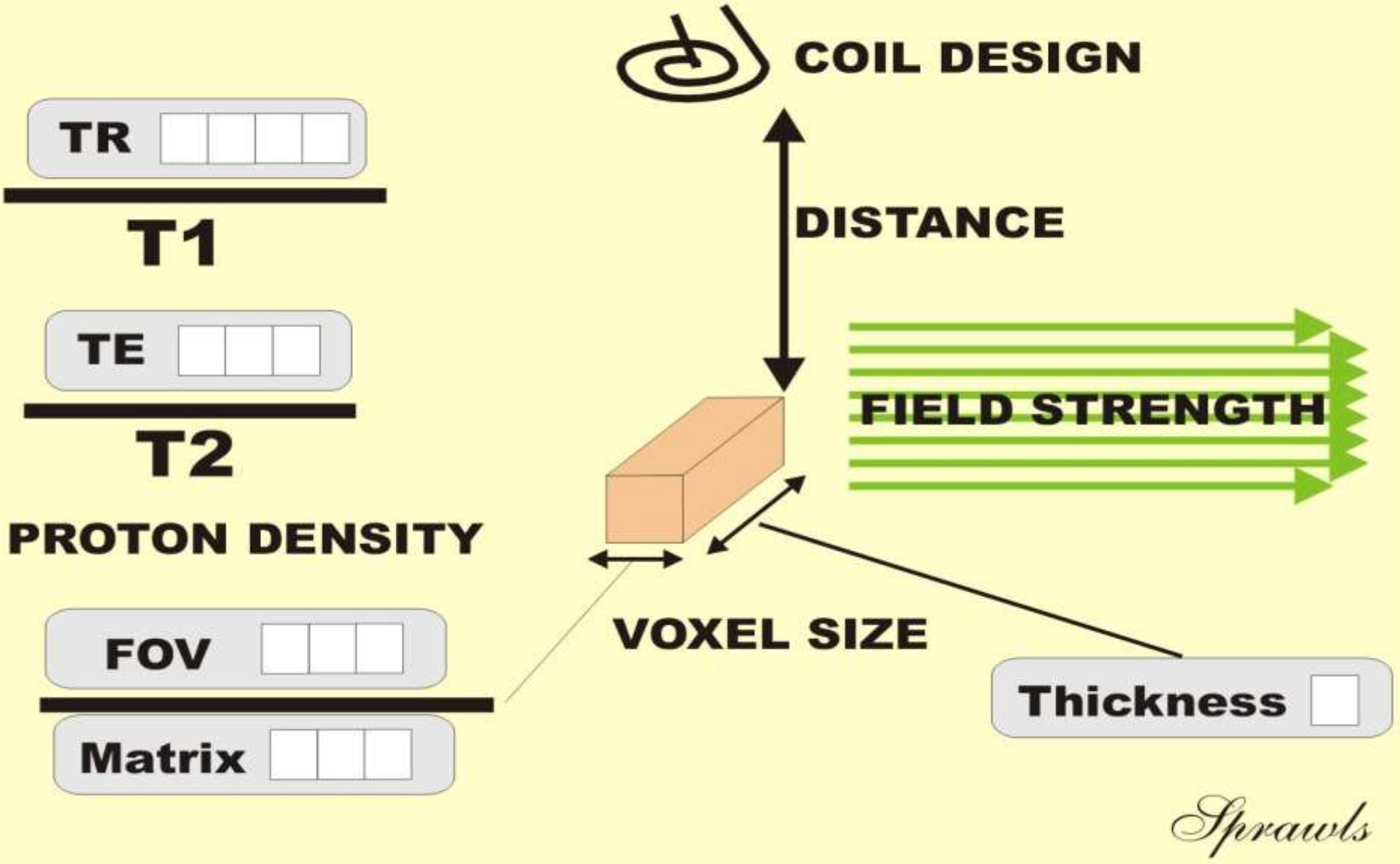
Sprawls

# AVERAGING



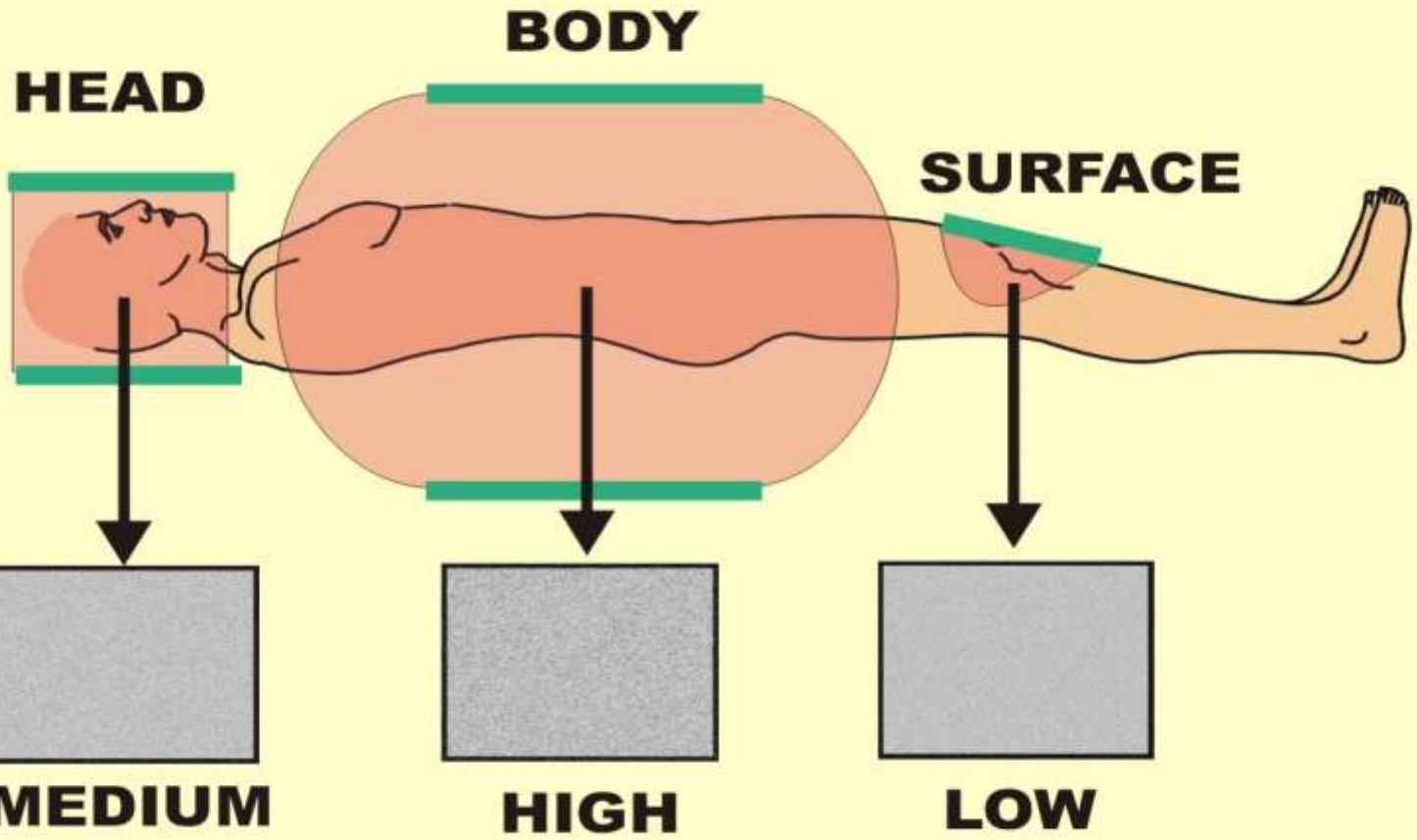

High
DETAIL
High
SIGNAL to NOISE
Number
Signals
Averaged
8
4
2
1
High
CONTRAST
SENSITIVITY
Reduced
ARTIFACTS
Half Scan
SPEED
Sprawls

# SIGNAL STRENGTH




Sprawls

# RADIO FREQUENCY COILS



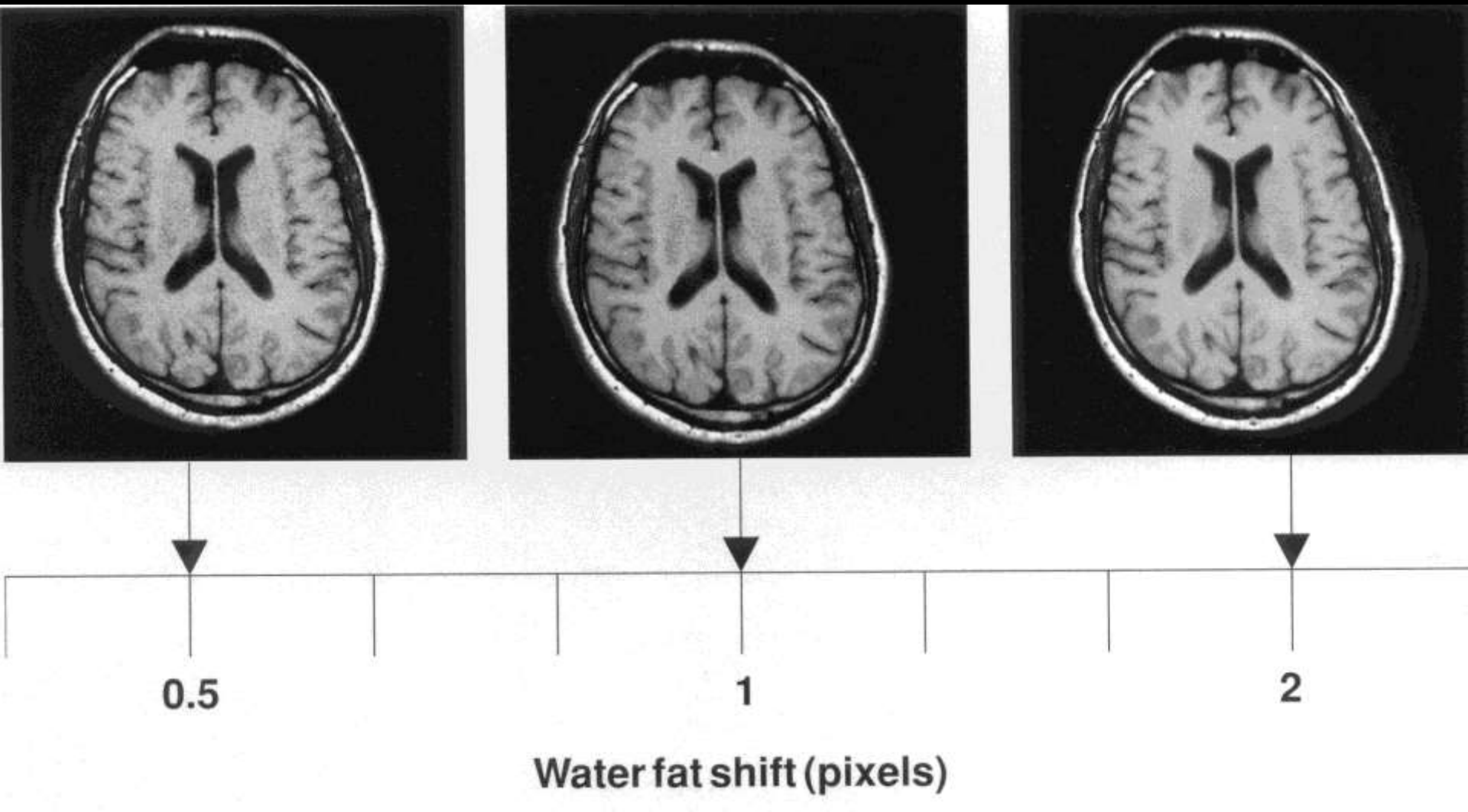

## NOISE RECEIVED FROM BODY

Sprawls

# BANDWIDTH

LARGE (WIDE)

SMALL (NARROW)



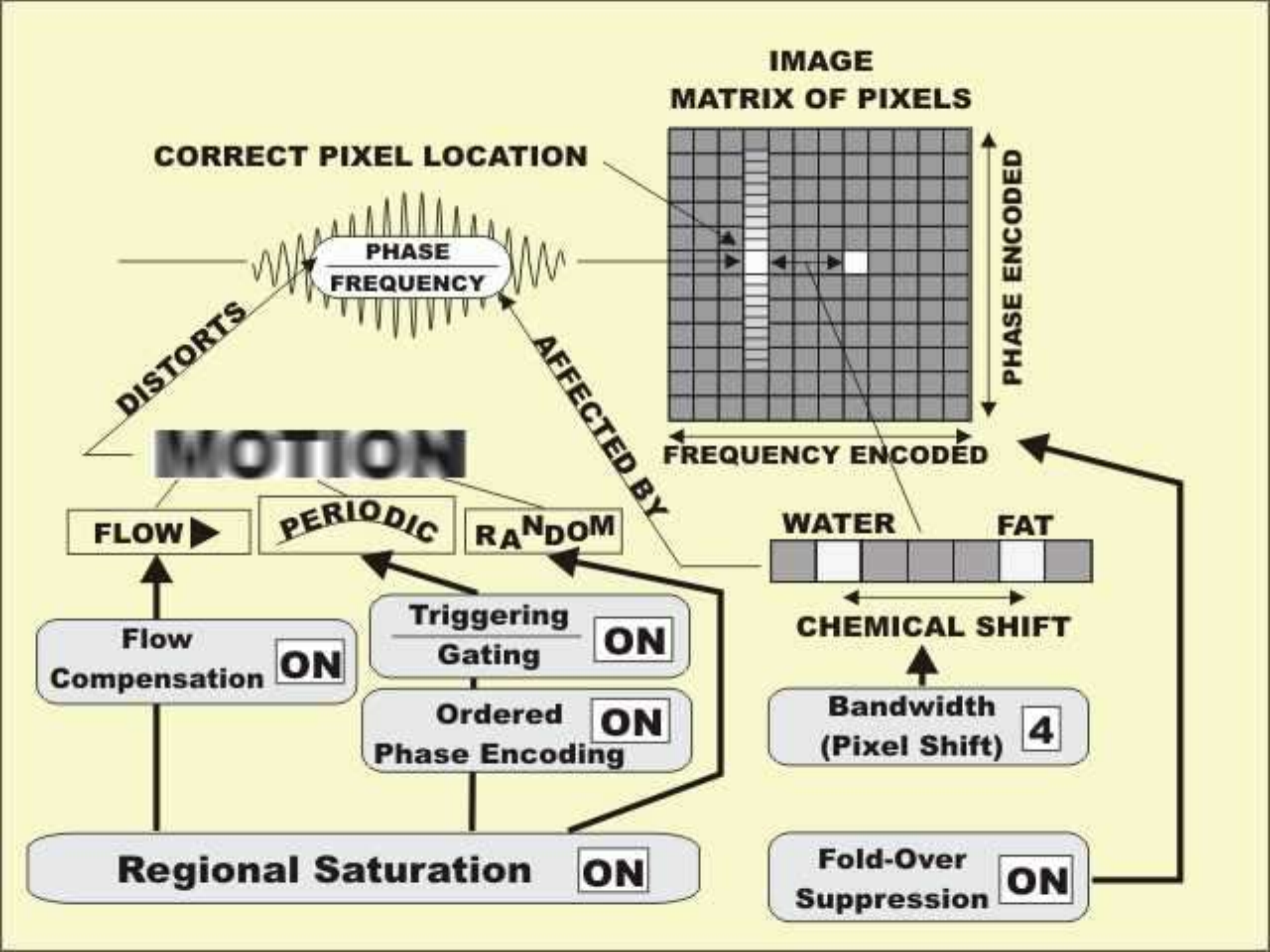


IMAGE
MATRIX OF PIXELS
CORRECT PIXEL LOCATION
PHASE
FREQUENCY
DISTORTS
AFFECTED BY
PHASE ENCODED
FREQUENCY ENCODED
MOTION
FLOW
PERIODIC
RANDOM
WATER
FAT
CHEMICAL SHIFT
Flow
Compensation
ON
Triggering
Gating
ON
Ordered
Phase Encoding
ON
Bandwidth
(Pixel Shift)
4
Regional Saturation
ON
Fold-Over
Suppression
ON

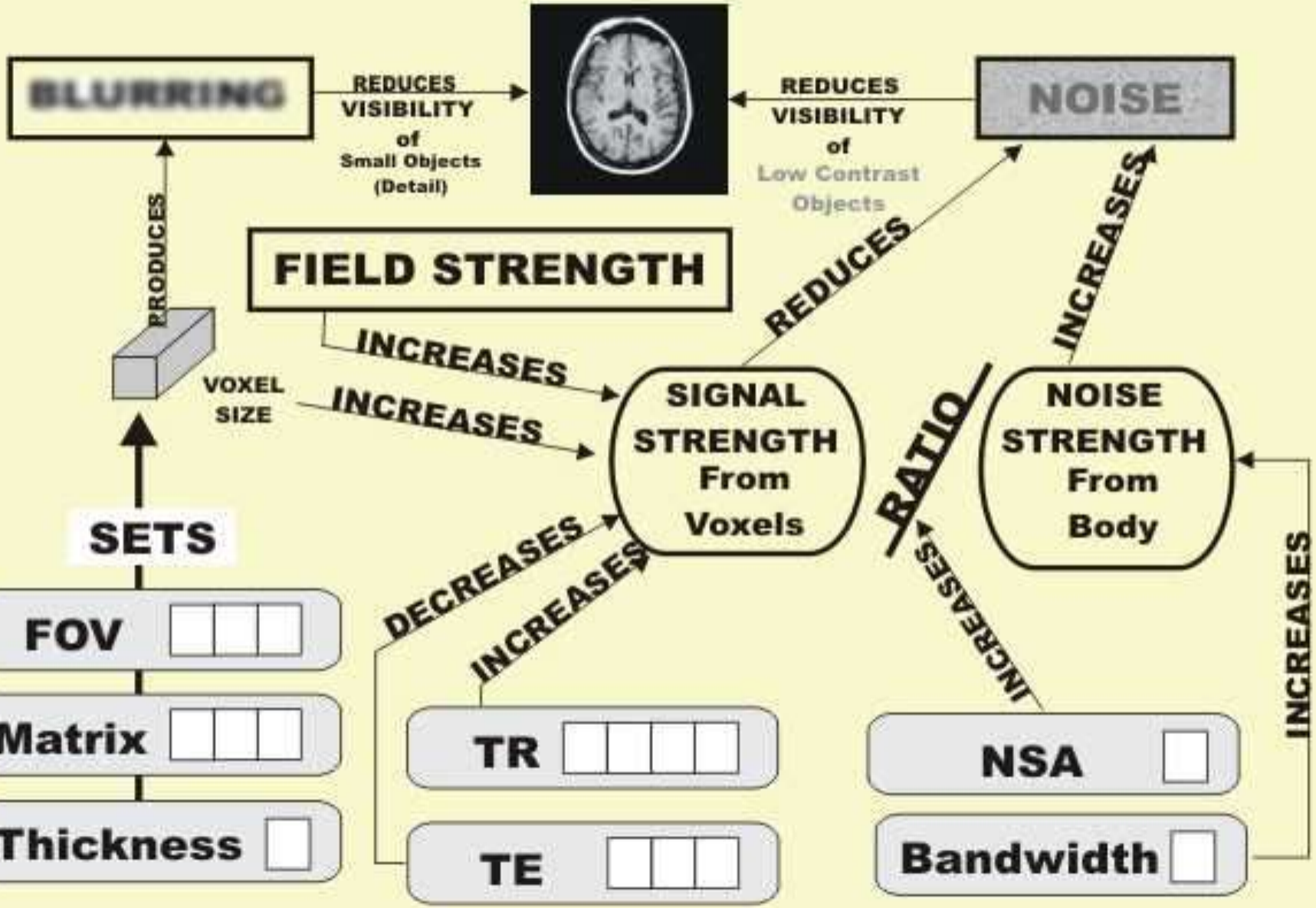
# PROTOCOL FACTORS AFFECTING

## IMAGE DETAIL

- Slice Thickness
- Matrix Size
- FOV

## IMAGE NOISE

- Slice Thickness
- Matrix Size
- FOV
- Coil Selection
- Averaging
- Bandwidth
- TR and TE
- Field Strength


BLURRING
REDUCES VISIBILITY of Small Objects (Detail)
REDUCES VISIBILITY of Low Contrast Objects
NOISE
PRODUCES
FIELD STRENGTH
INCREASES
REDUCES
INCREASES
VOXEL SIZE
INCREASES
SIGNAL STRENGTH From Voxels
RATIO
NOISE STRENGTH From Body
SETS
DECREASES
INCREASES
INCREASES
FOV
Matrix
Thickness
TR
TE
NSA
Bandwidth
INCREASES

# Clinical MR Image Quality Assessment and Optimization

Perry Sprawls, Ph.D.

**Review at:** www.sprawls.org/ipad

**Reference :** www.sprawls.org/mripmt