Effective
Medical Imaging Physics Education

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Sprawls Educational Foundation
http://www.sprawls.org

Website for this Presentation

http://www.sprawls.org/clinphys

To follow on iPad go to
http://www.sprawls.org/ipad

Clinical Medicine

Imaging

Radiation Therapy

Physics

The Foundation Science

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Effective and Safe Clinical Procedures

Imaging

Radiation Therapy

Require an extensive knowledge of Applied Physics and The Associated Technology

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Who needs a knowledge of Physics applied to clinical imaging?

Radiologists, Residents and Fellows

Technologists

Medical Physicists

Each provides unique challenges and opportunities.

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Physics Learning Objectives for Radiologists

Image Physical Characteristics

- **Identify**
- **Relationship to Visibility** → **Anatomy and Pathology**
- **Evaluate**
- **Control and Optimize** → **Risk**

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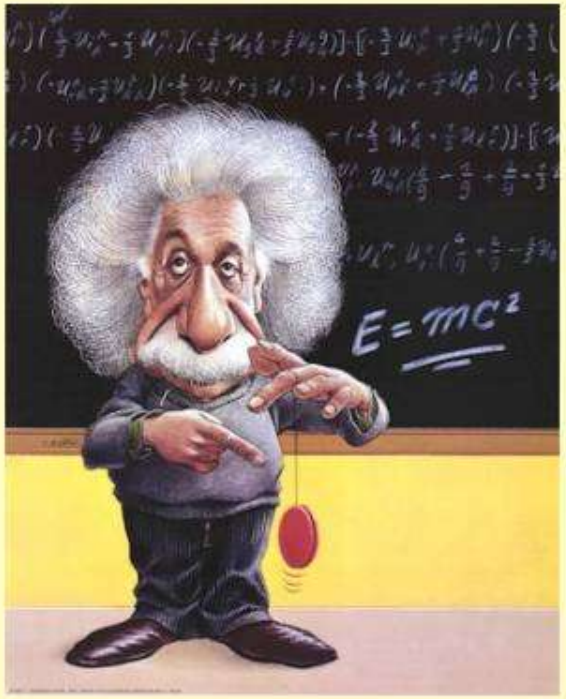
The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.



Be EFFICIENT in our teaching

Challenges Opportunities

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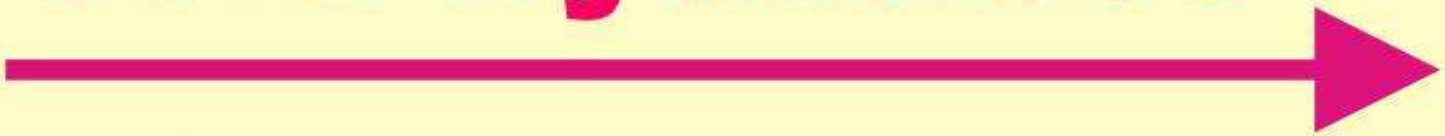
Five Dynamics



“ It’s a new ball game!”

Capability & Complexity
Geographic Dispersion
Learning & Teaching Knowledge
Expanding Educational Resources
Increased Connectivity

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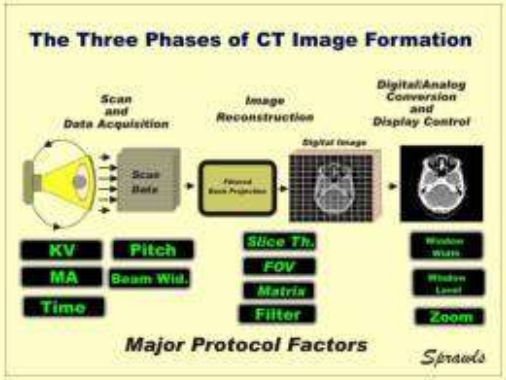
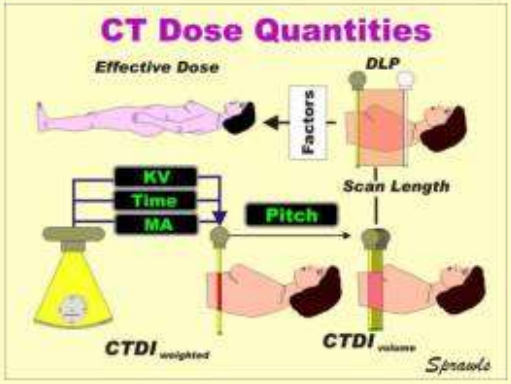
Capability & Complexity

(Computed Tomography)





Years

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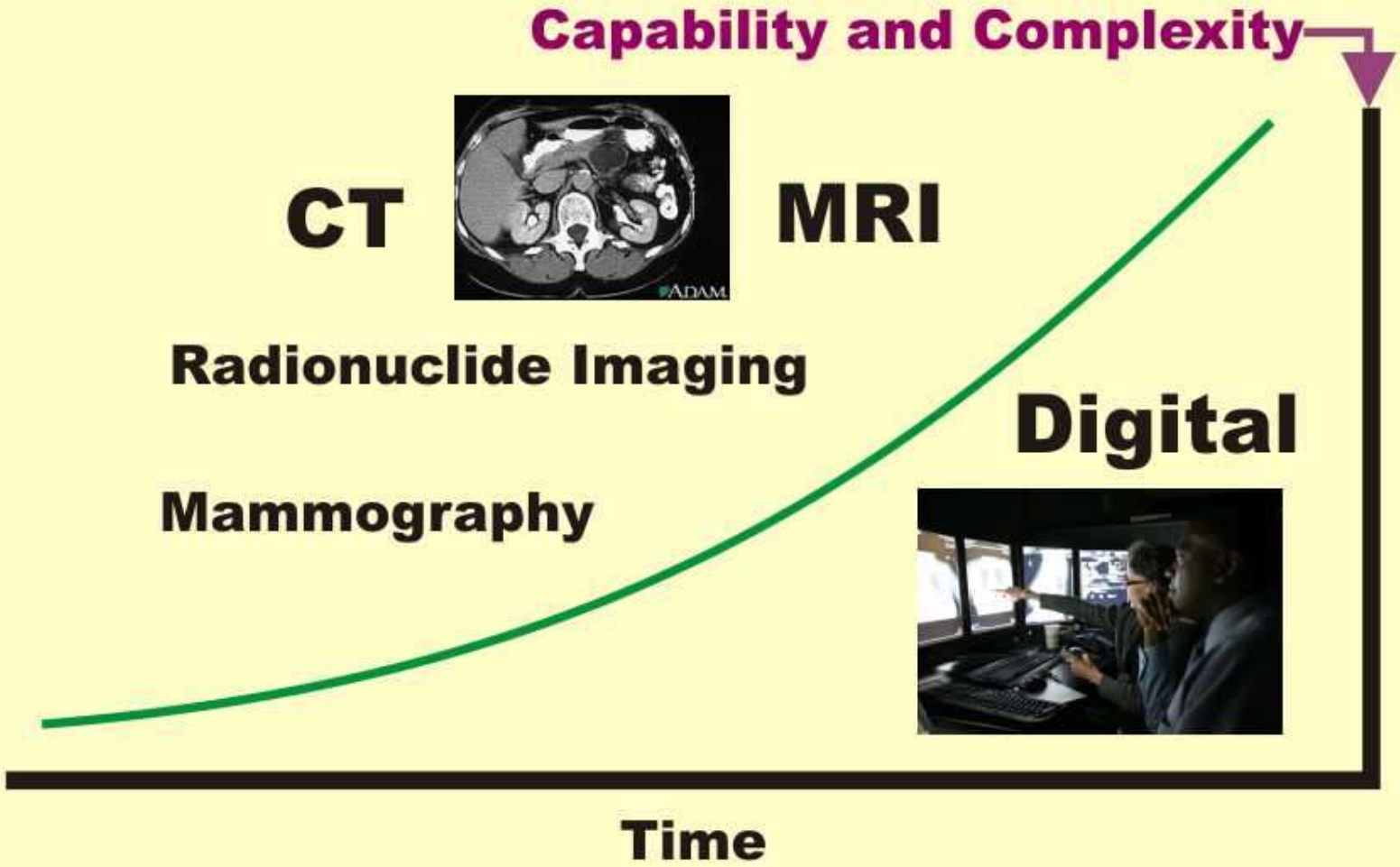
Continuing Growth in the Need for Physics Knowledge



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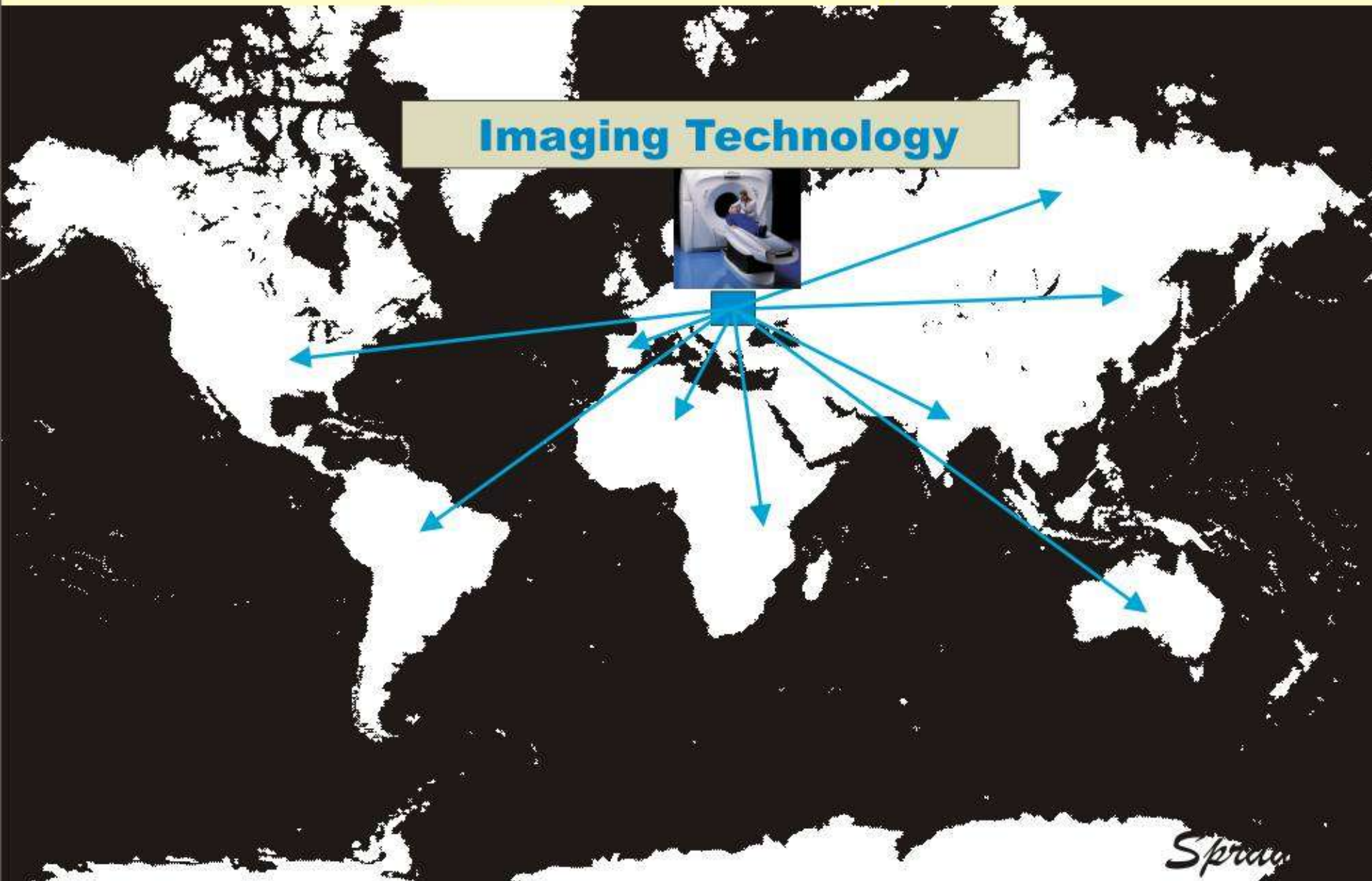
Geographic Dispersion



Medicare National Hospital & Research Centre
Kathmandu, Nepal

Dinesh Mishra

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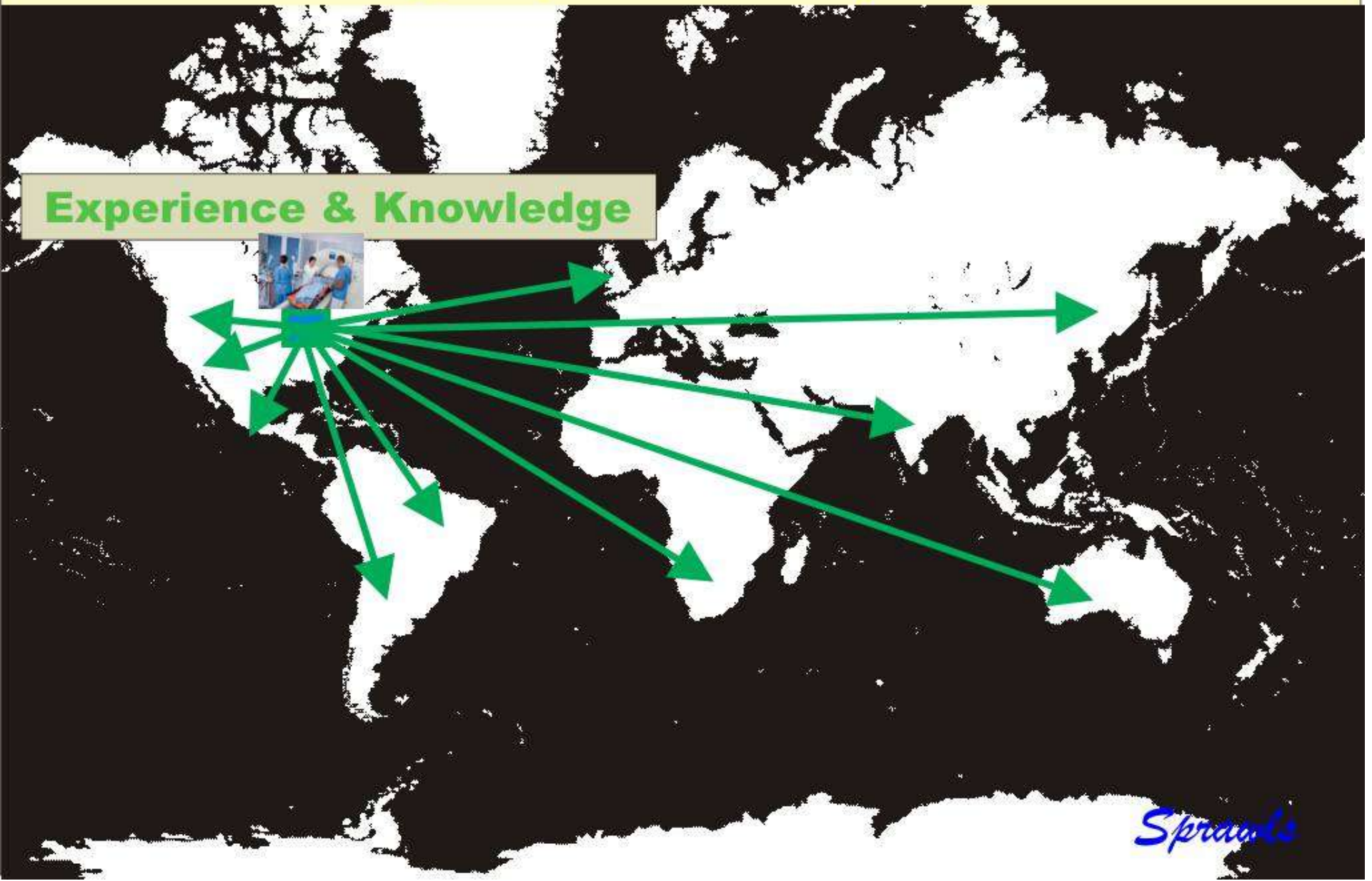
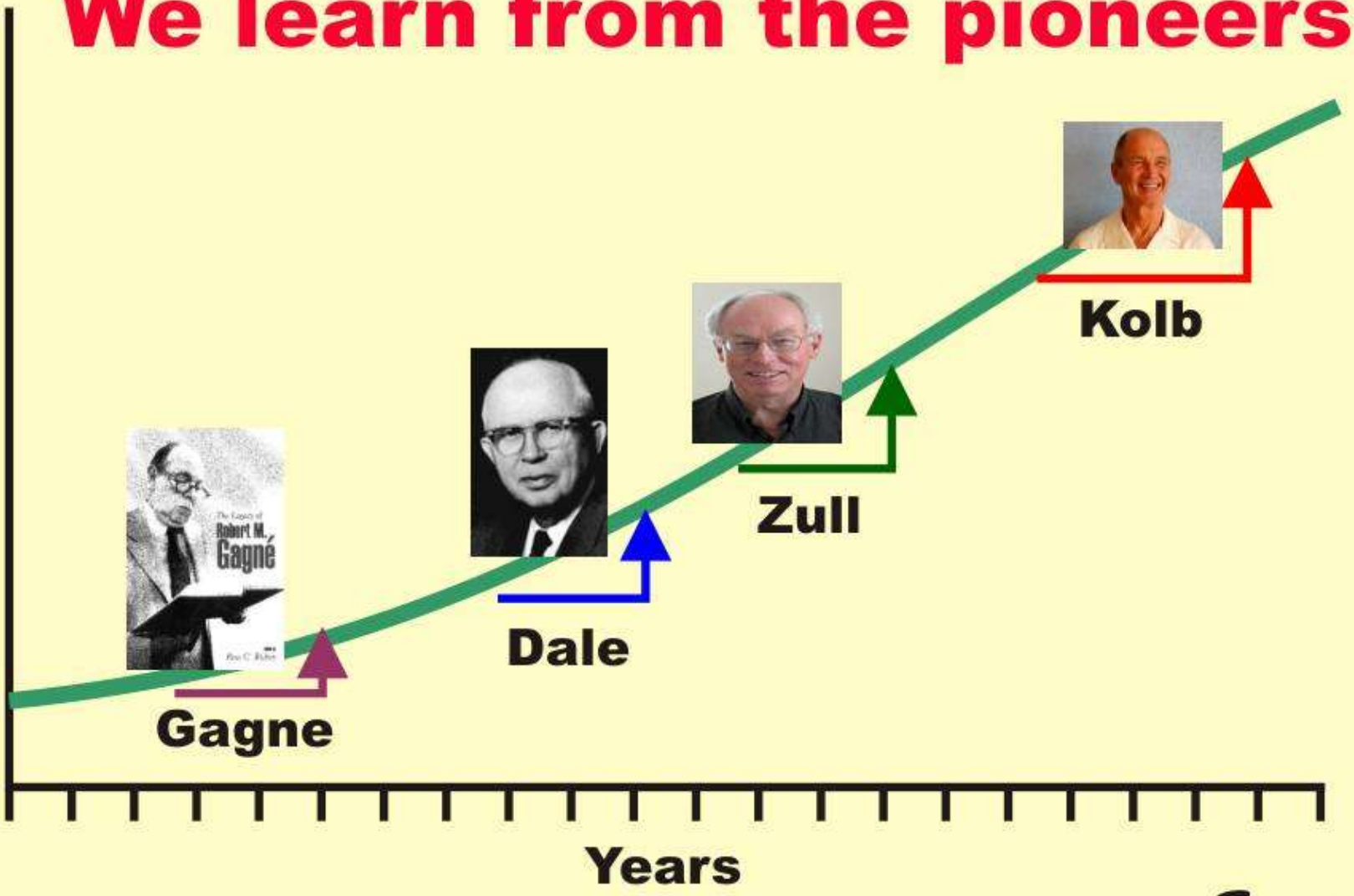
Geographic Dispersion



Knowledge of the Learning & Teaching Process

We learn from the pioneers



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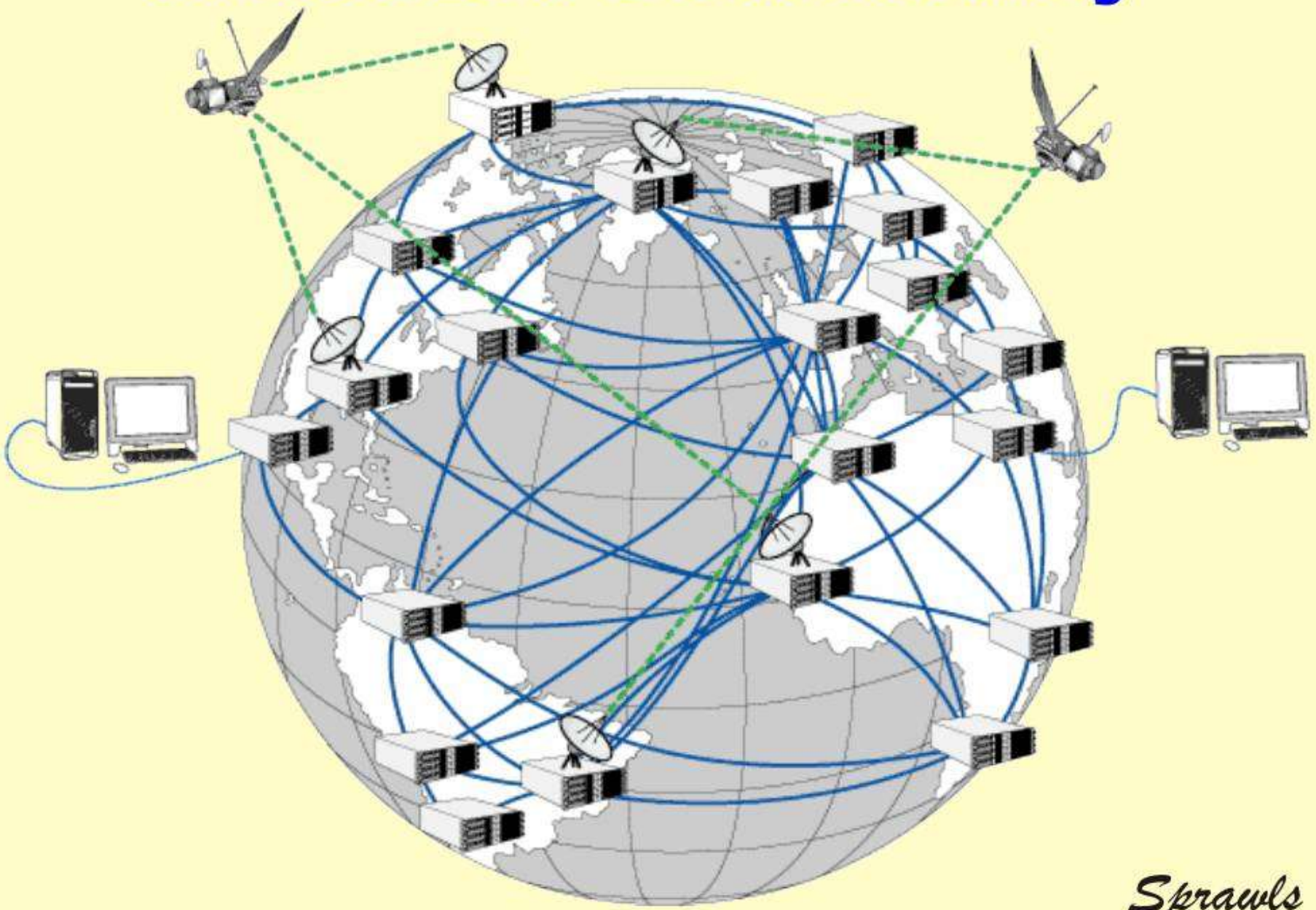
Increased Connectivity



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Digital Resources to Enrich Learning Activities

The Web

Connecting and Sharing

Textbooks
Modules

Visuals

Clinical
Images

Modules

References
Teaching Files

Classroom

Clinical
Conference

Small
Group

"Flying Solo"

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Effective
Medical Imaging Physics Education

Goals & Objectives



Medical imaging professionals with a knowledge of physics that will enable them to perform clinically effective imaging procedures with managed risk to both patients and staff.

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Clinically Focused Physics Education

Classroom

Clinical Conference

Small Group

"Flying Solo"

Learning Facilitator
"Teacher"

Individual
and
Peer Interactive
Learning

Each type of learning activity has a unique value.

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Clinically Focused Physics Education

Classroom | Clinical Conference | Small Group | "Flying Solo"

Learning Facilator "Teacher"

Individual and Peer Interactive Learning

The Goal..

Increase the **EFFECTIVENESS** of each type of learning activity with the **necessary resources** and **understanding of the process** by the Learning Facilators.

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The Barrier

Physics Education

Clinical Imaging

Efficiency

Location, Resources, Human Effort, Cost

Limited Experience

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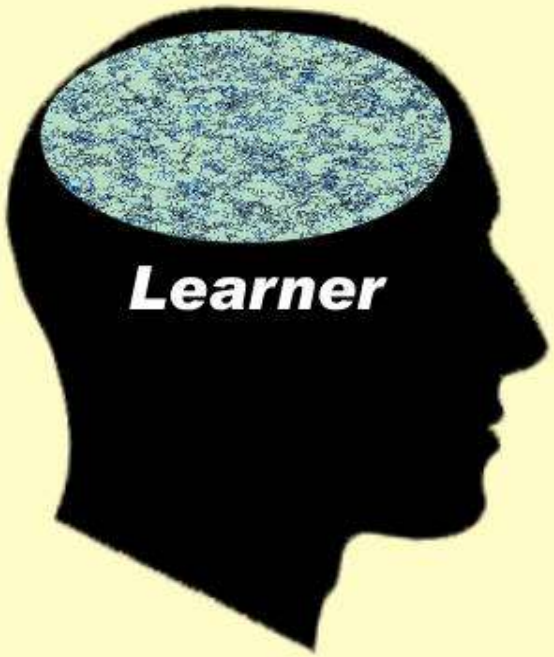
Learning Physics
is
Building a Knowledge Structure
in the Brain



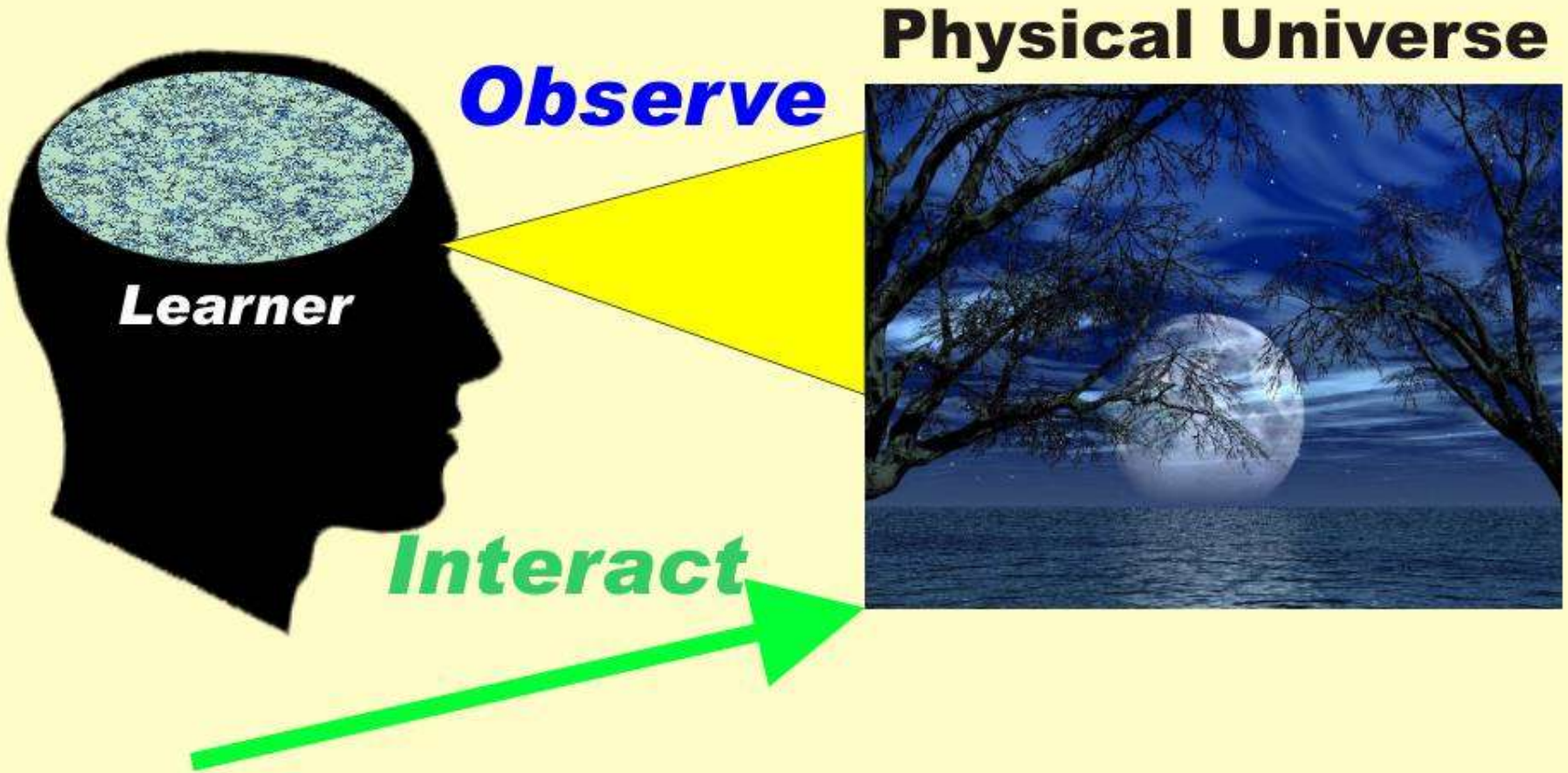
Physical Universe

A mental representation of physical reality

Sprawls

Learning is a Natural Human Process

We Learn by Experience



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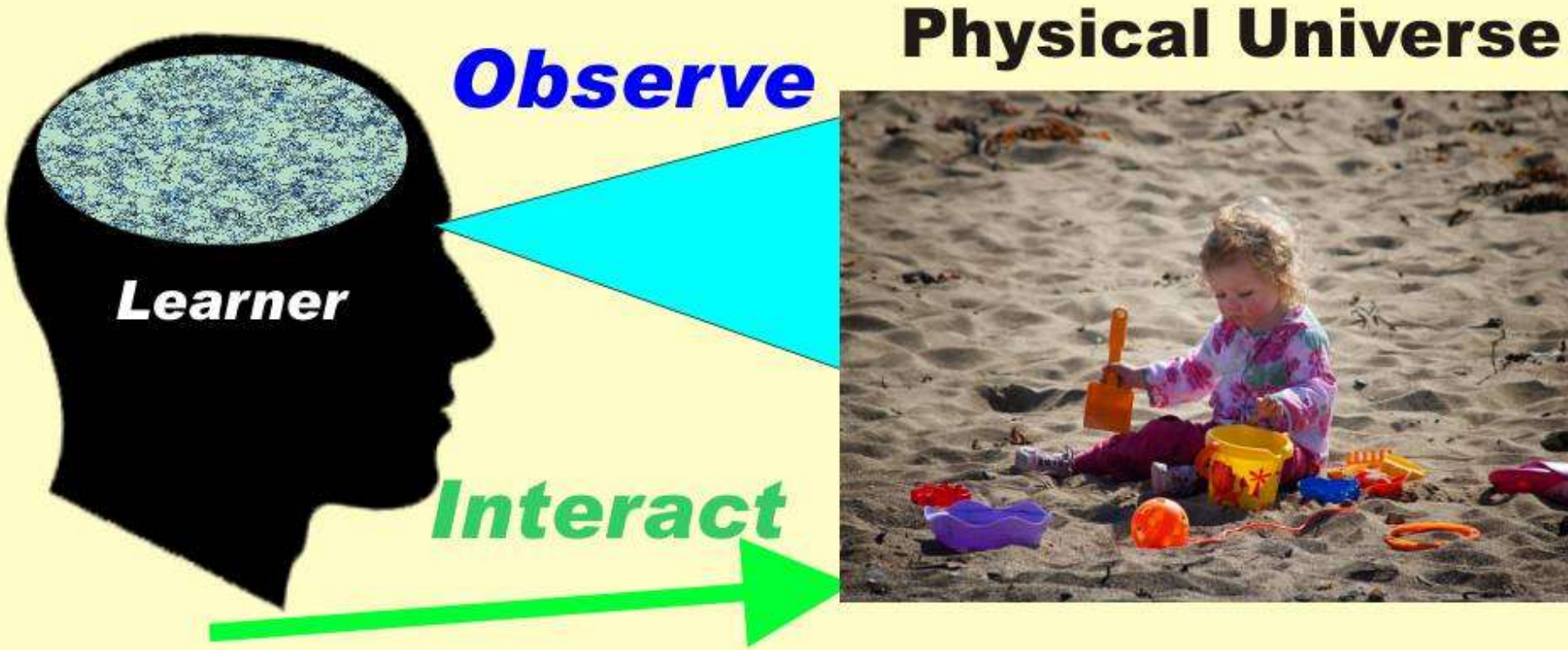


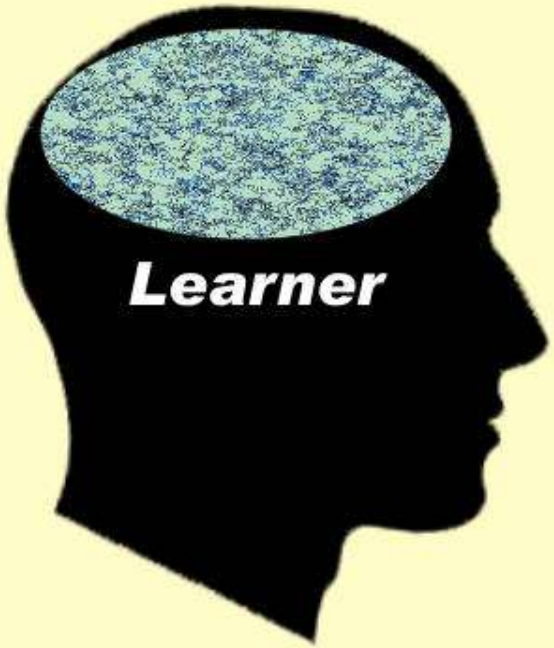
Our Early Physics Learning Activities

Sprouts

Teaching

is helping someone

Building a Knowledge Structure in the Brain



Physical Universe

A mental representation of physical reality

Connect Organize Guide

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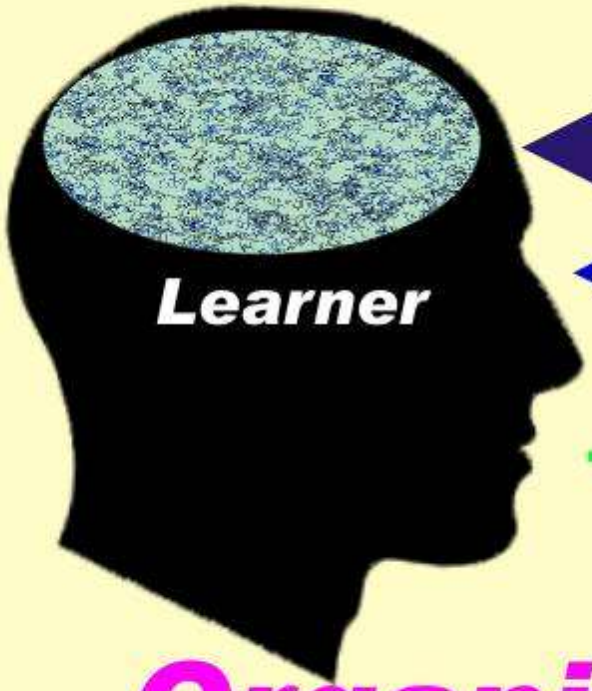
The Role of Formal Education

Connect

Physical Universe



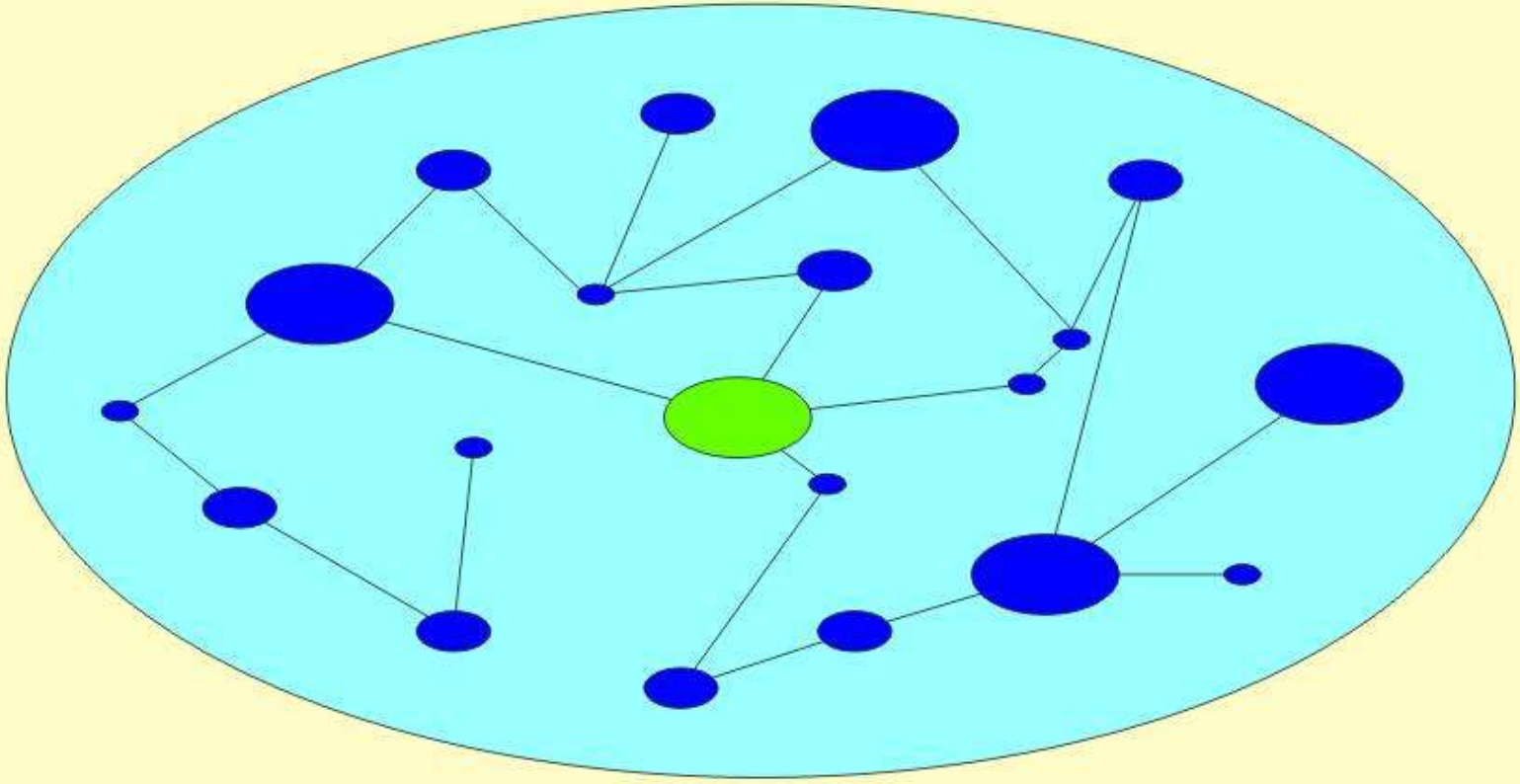
Observe

Interact

Organize and **Guide**

Knowledge Structures in the Brain

A Complex Network



Concepts **Facts**

Images **Language**

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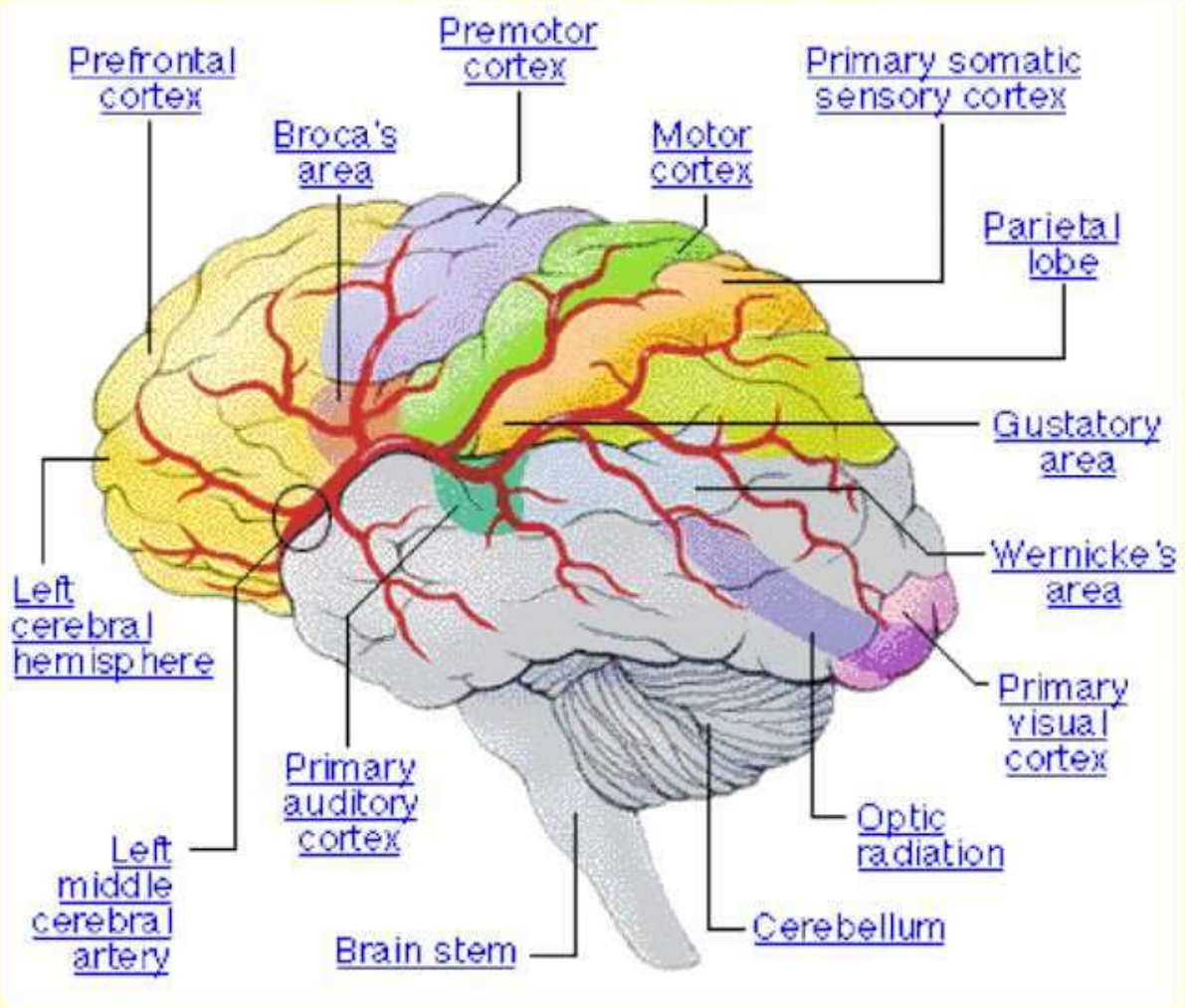
The Brain...

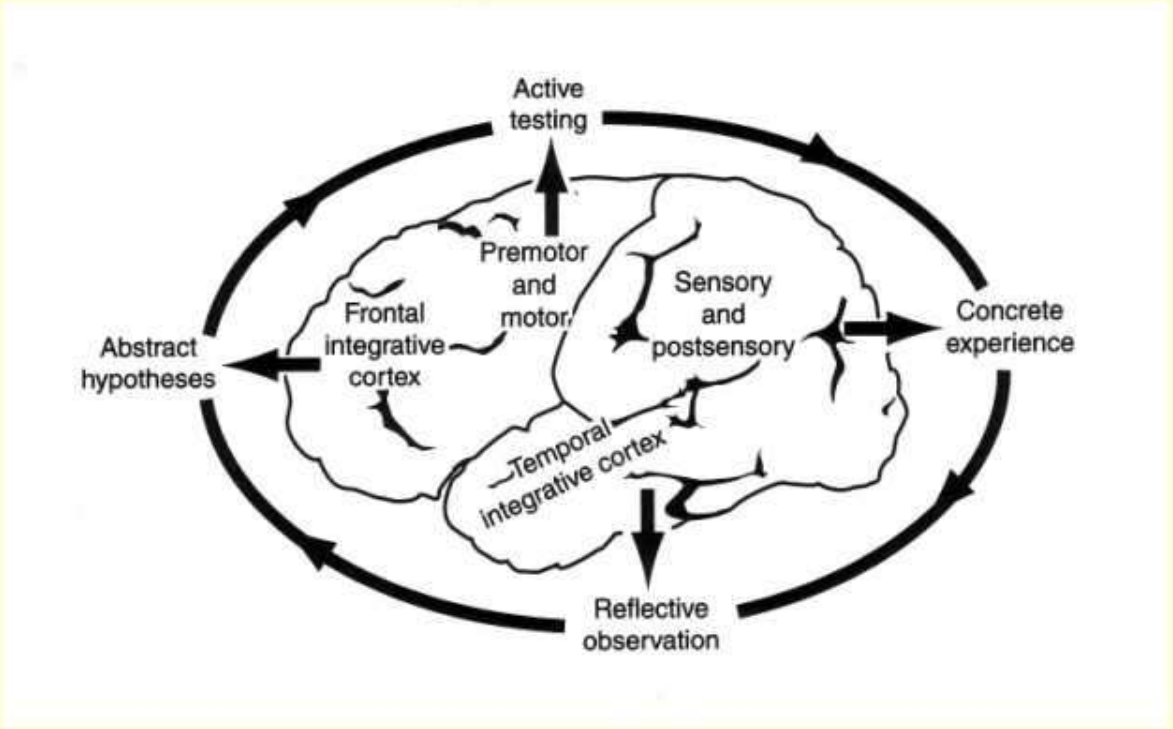


Structure and Function

Image: AMA

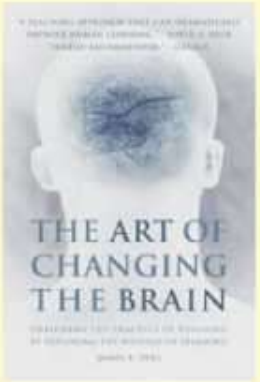
Sprawls

Zull's Model of Brain Function

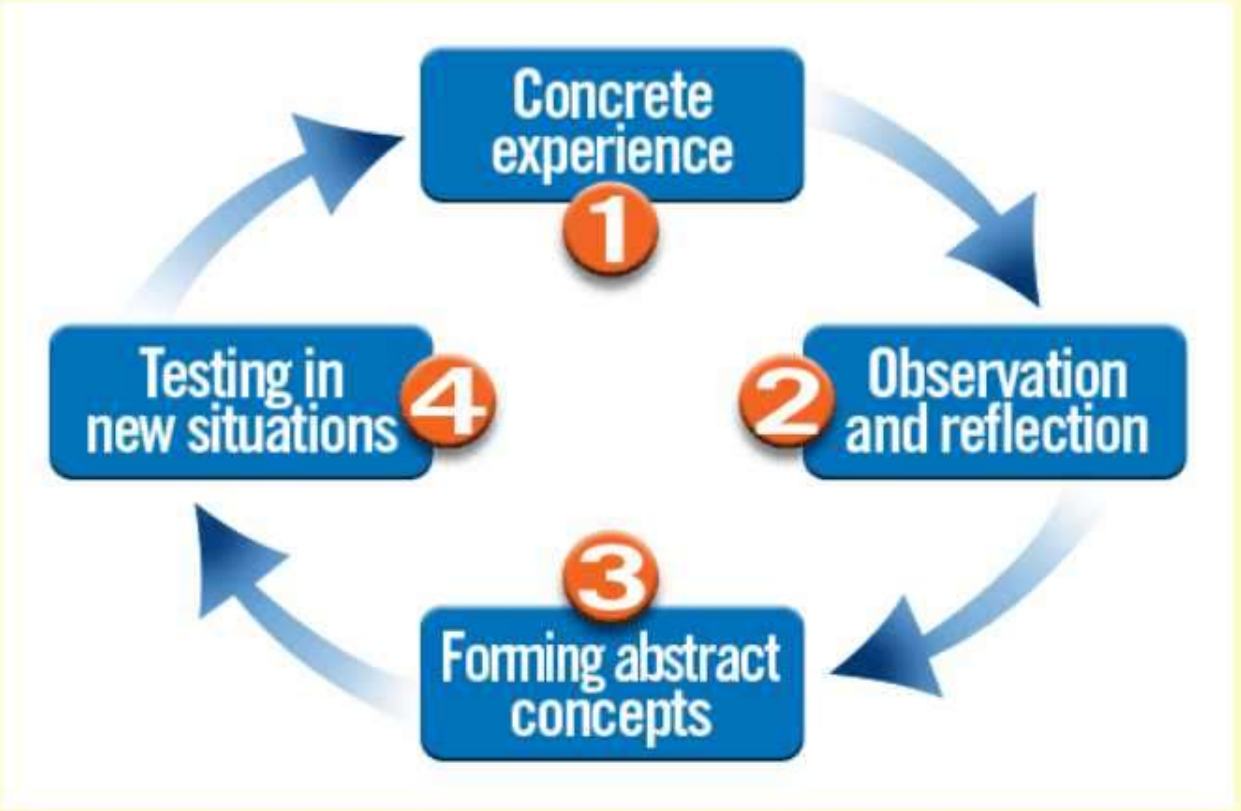


James Zull, Ph.D.
Professor of Biology
Professor of Biochemistry
Director of University Center for Innovation in Teaching and Education
Case Western Reserve

Reference:



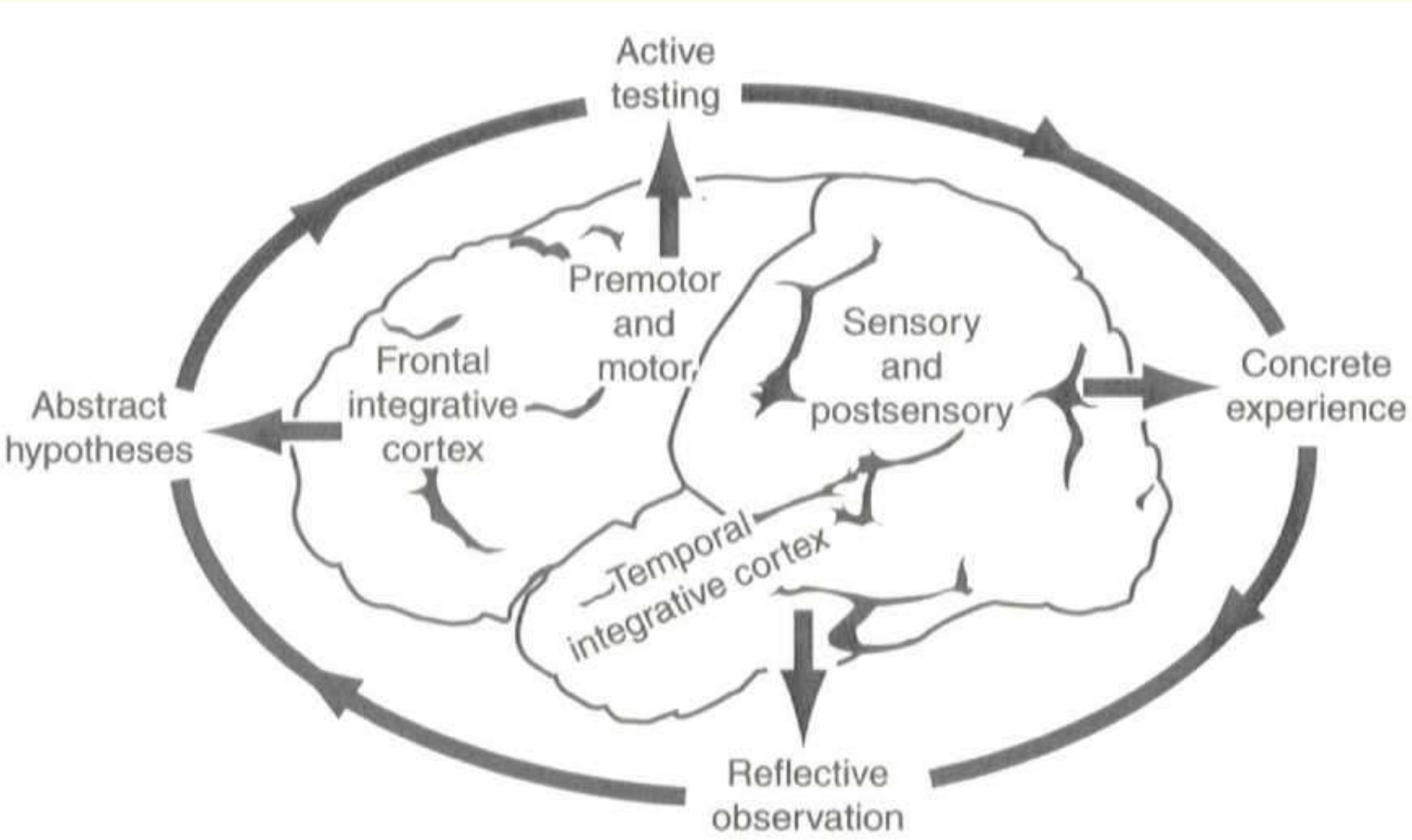
Kolb's Experiential Learning Model



David A. Kolb, Ph.D.
Professor of Organizational Behavior
Case Western Reserve

Website: http://www.learningfromexperience.com

Zull's Model of Brain Function



Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Where

(Relationships)

(Characteristics)

What

(Identification)

Language

Comprehension

Frontal Integrative Cortex

Making Plans
Evaluating
Problem Solving

Language

Assembly

Motor

Emotions

Sprawls

Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Reflection

Frontal Integrative Cortex

Preparation for the Future

Hypotheses

Motor

Emotions

Sprawls

Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Knowing

Frontal Integrative Cortex

Preparation for the Future

Doing

Motor

Emotions

Sprawls

Let's Think about lunch.

Brain Functions for Preparing Lunch

Control

Back Integrative Cortex

Frontal Integrative Cortex

Emotions

Sprawls

Brain Functions for Preparing Lunch

Control

Back Integrative Cortex

Frontal Integrative Cortex

Emotions

Sprawls

Brain Functions for Preparing Lunch

Control

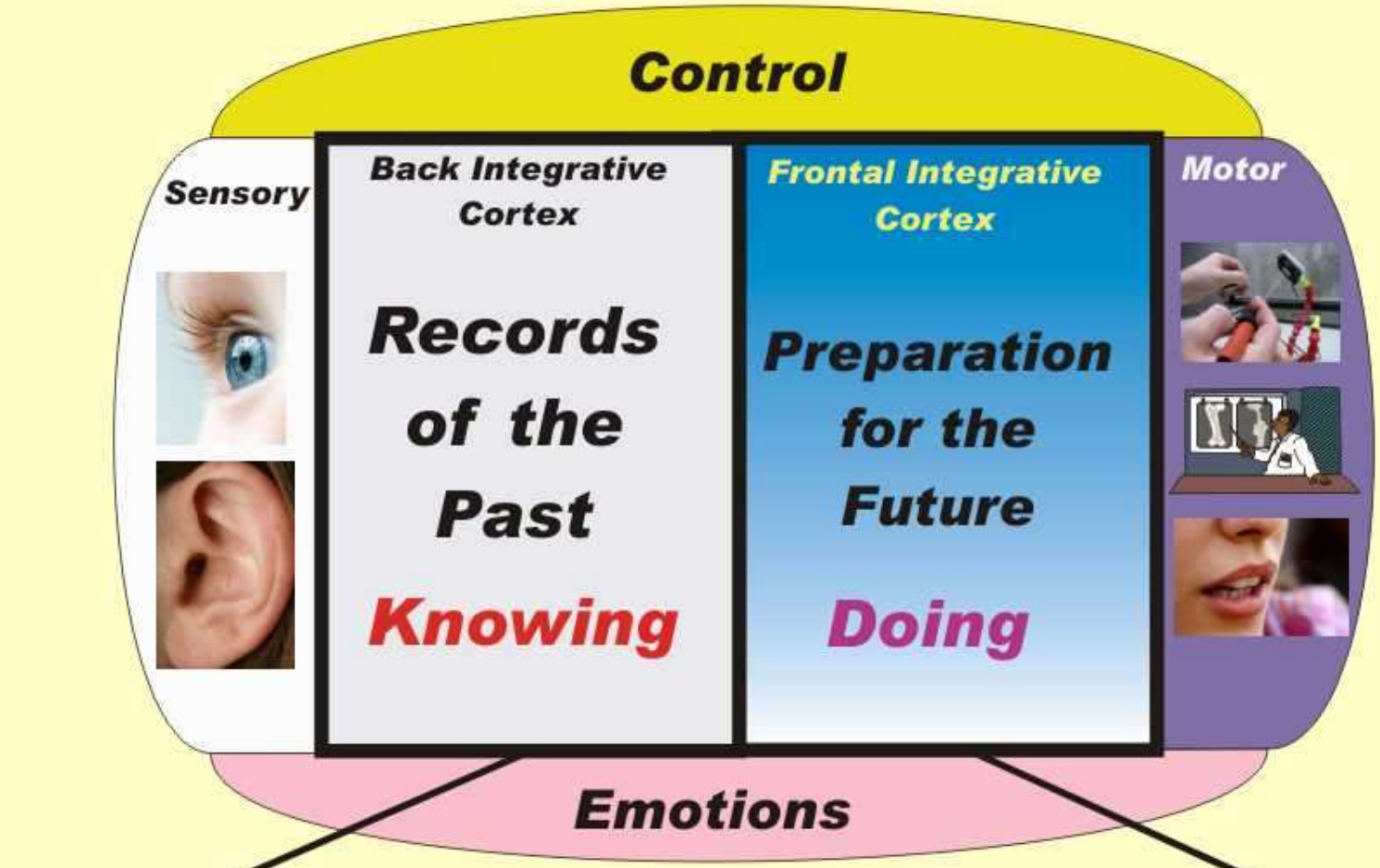
Back Integrative Cortex

Frontal Integrative Cortex

Emotions

Sprawls

Brain Functions for Learning Physics



Balanced Education

Sprawls

Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Sensory

Visible Physical Objects

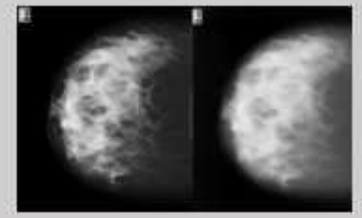
Sprawls

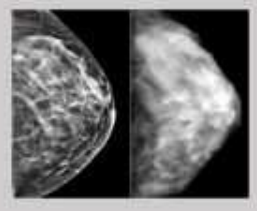
Forming Knowledge Structures

Physical Universe

Sensory

Back Integrative Cortex





Visible Physical Objects

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Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Sensory

Radiation
Electrons
Magnetic
Atomic
Nuclear

? ? ?

Invisible Physical Objects

Sprawls

Forming Knowledge Structures

Physical Universe

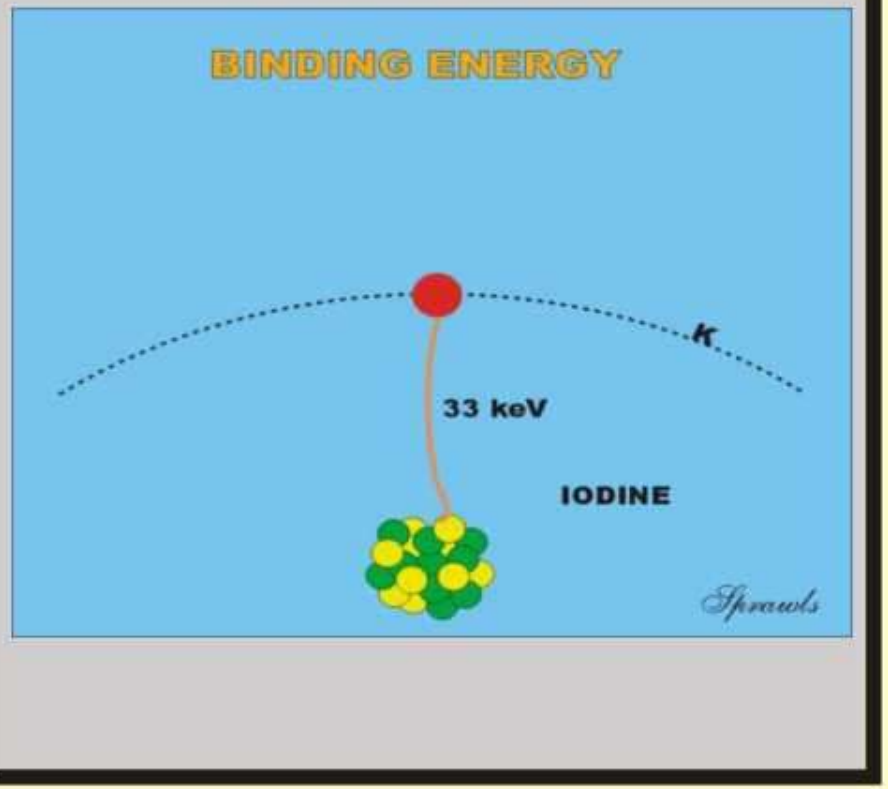
Radiation
Electrons
Magnetic
Atomic
Nuclear

Invisible

Physical Objects

Back Integrative Cortex

Sensory



Visuals

Sprawls

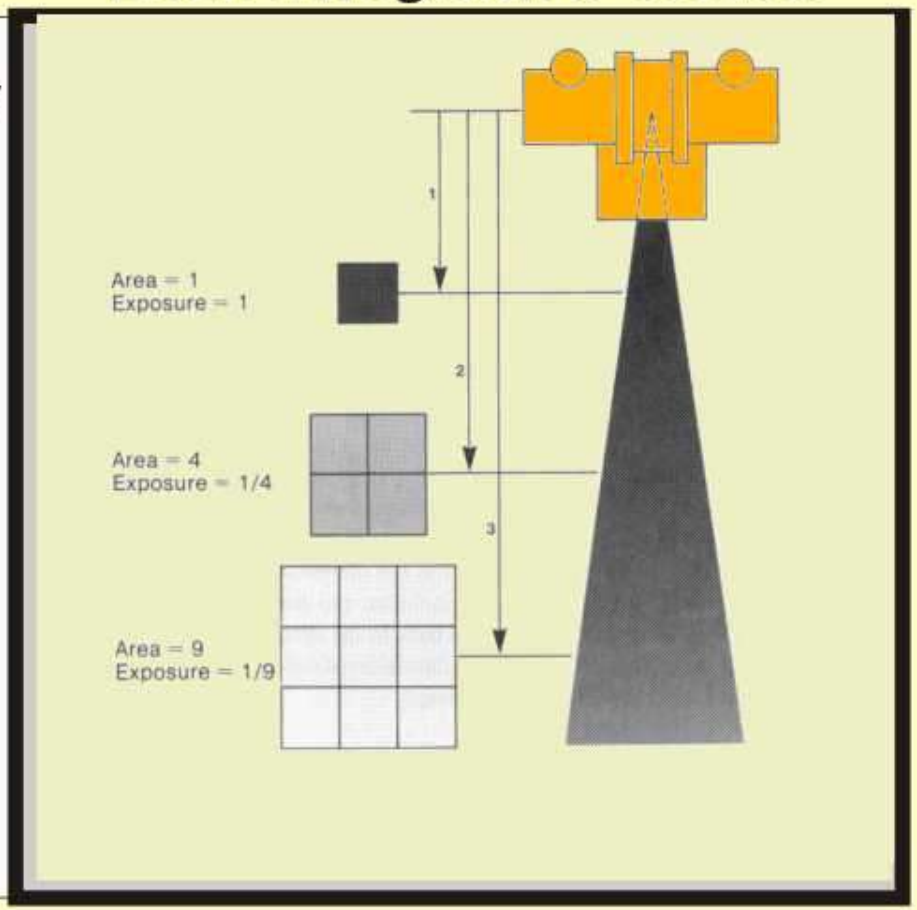
Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Inverse Square Effect

Sensory



Invisible

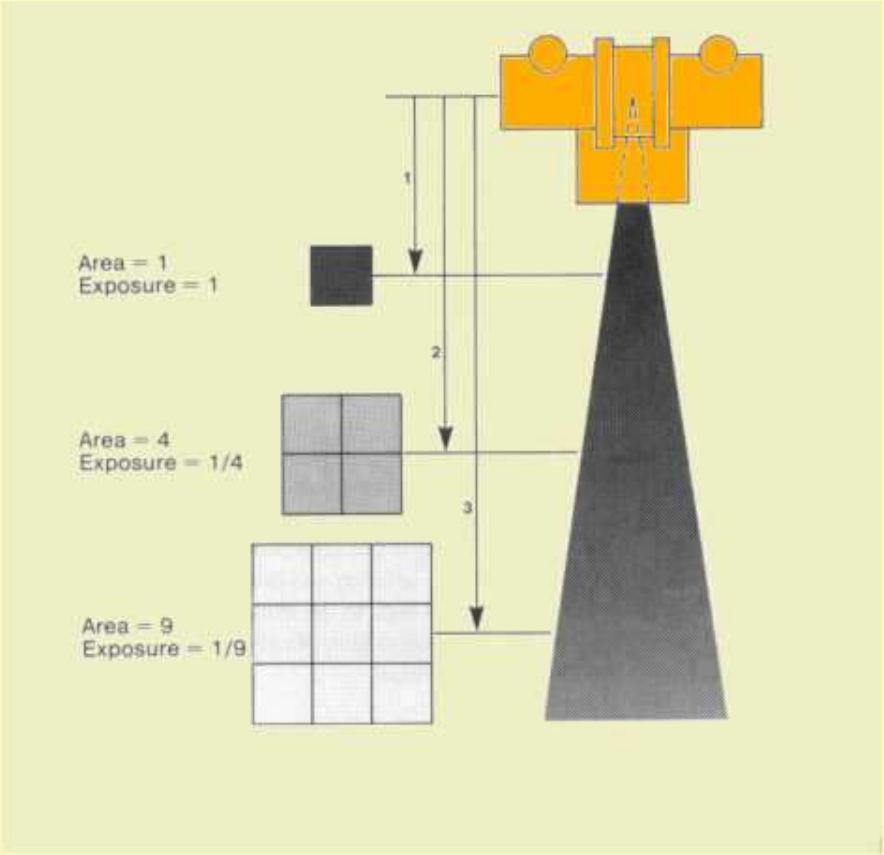
Concepts

Ideas

Visuals

Sprawls

Forming Knowledge Structures



Intensity = Power / Area

Surface area of a sphere = $\frac{4\pi r^2}{3}$

So, the luminous intensity on a spherical surface a distance r from a source radiating a total power P is:

$$I = 3P / 4\pi r^2$$

As P and pi remain constant, the luminous intensity is proportional to the inverse square of distance:

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Visual

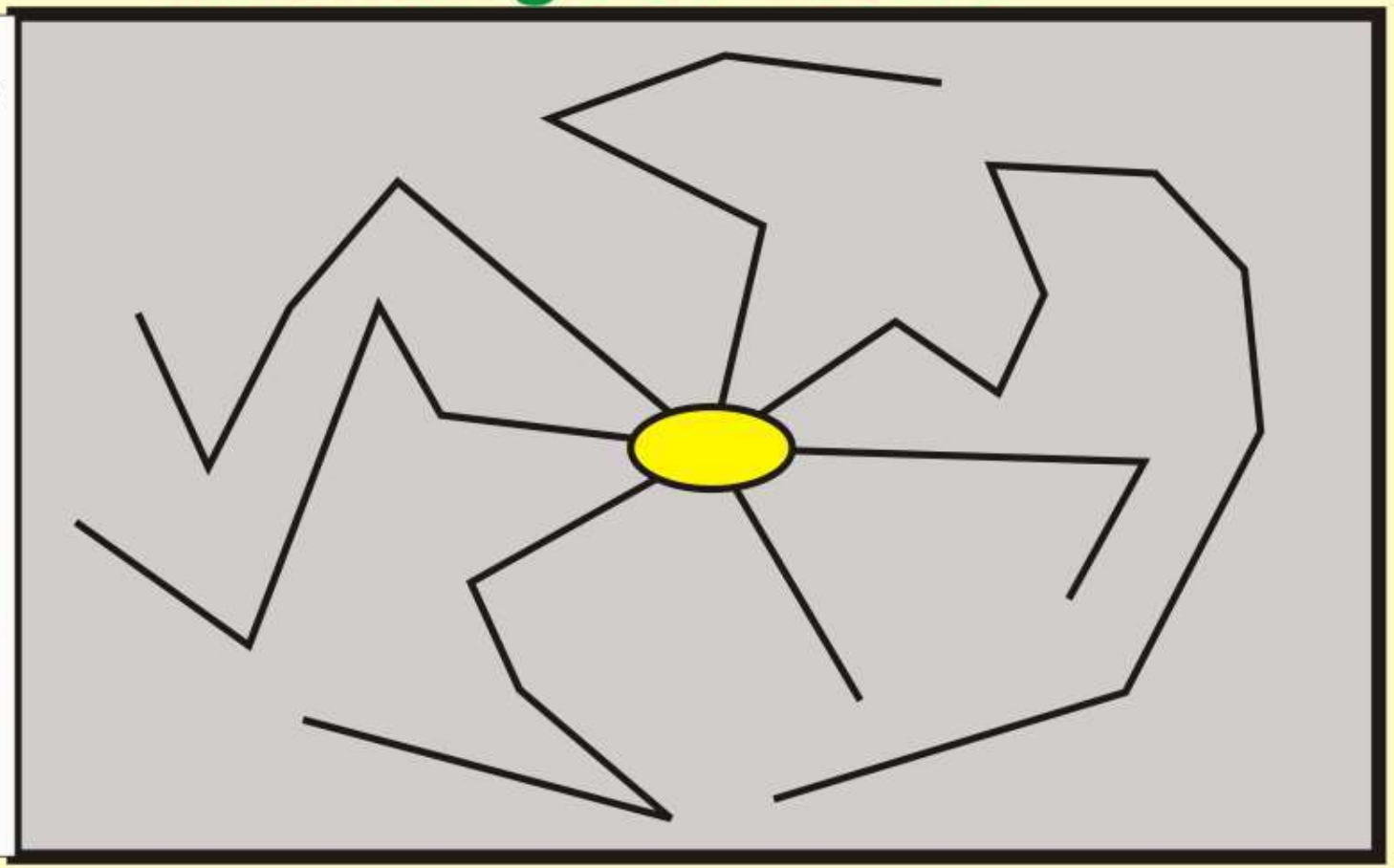
Verbal and Symbolic

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



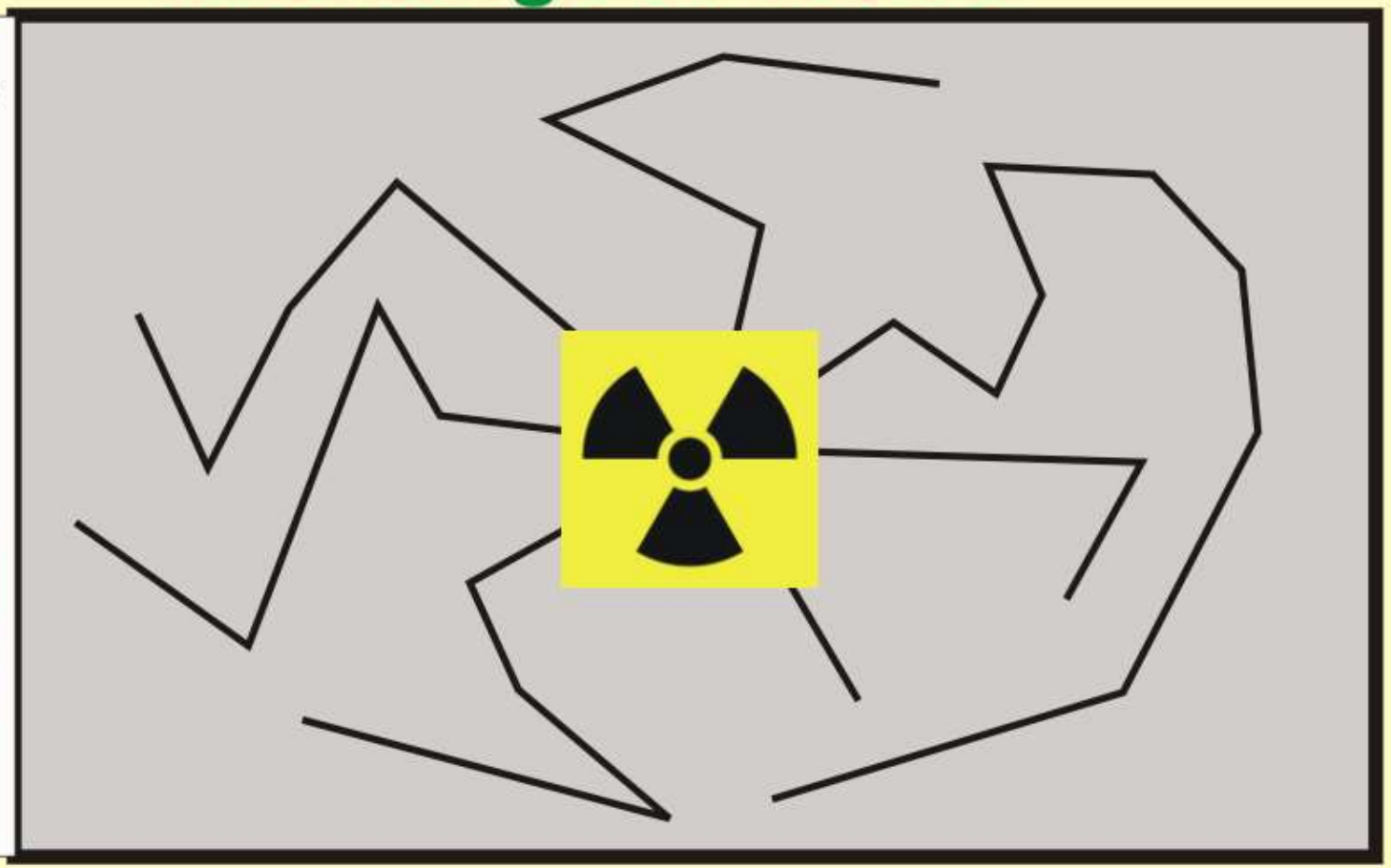
Meaning

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



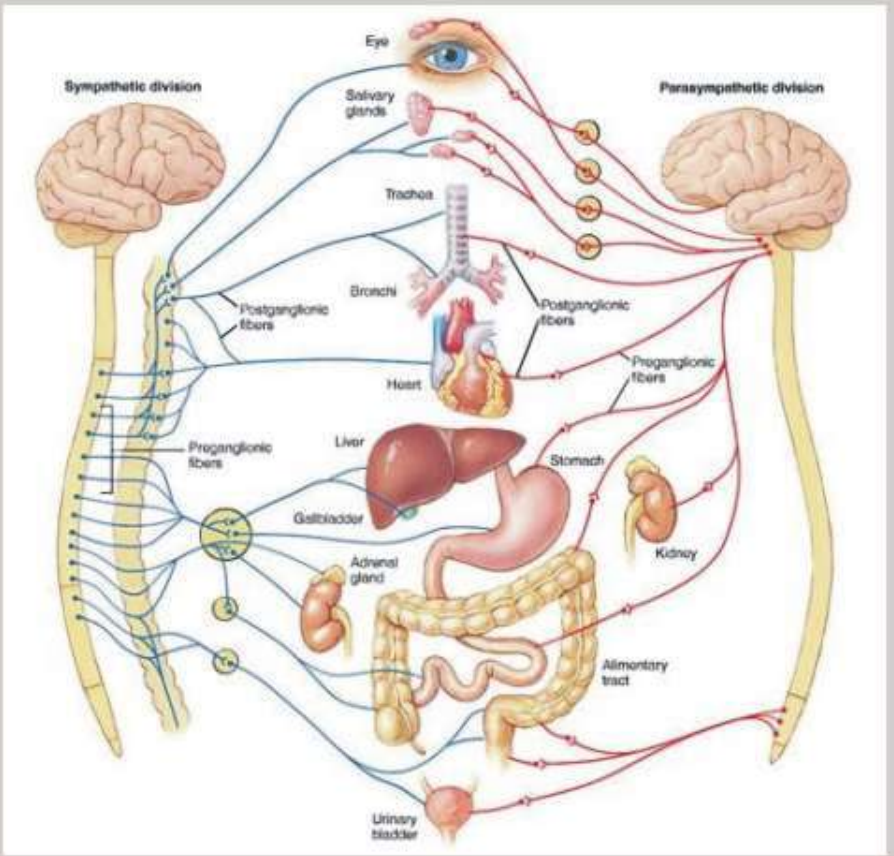
Meaning

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



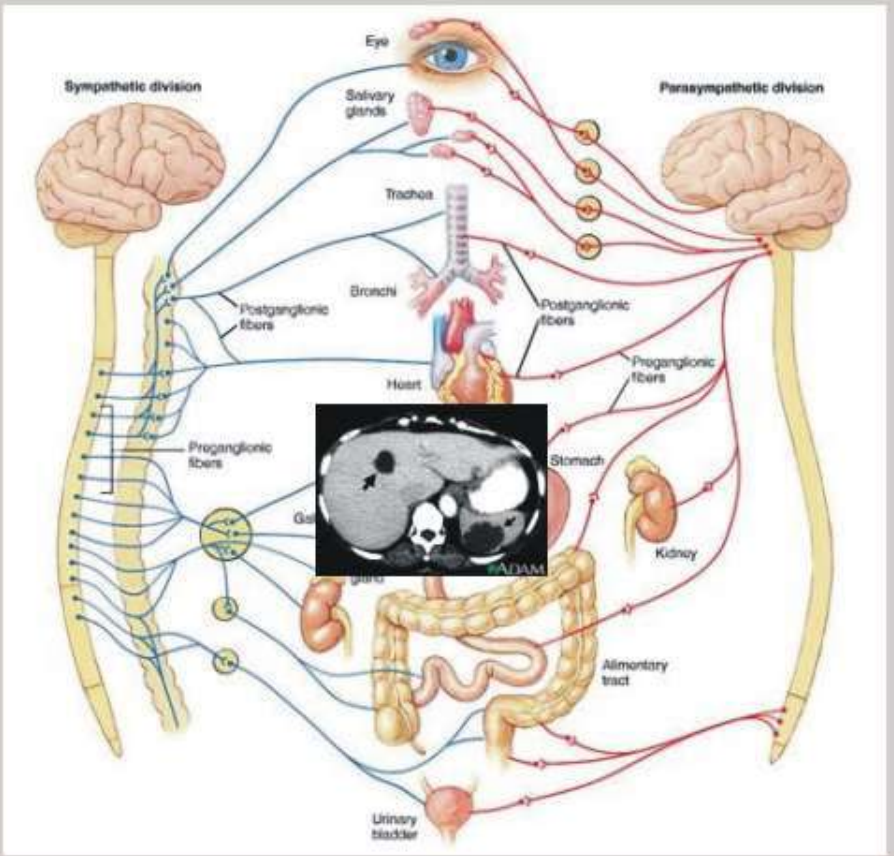
Medical Knowledge

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



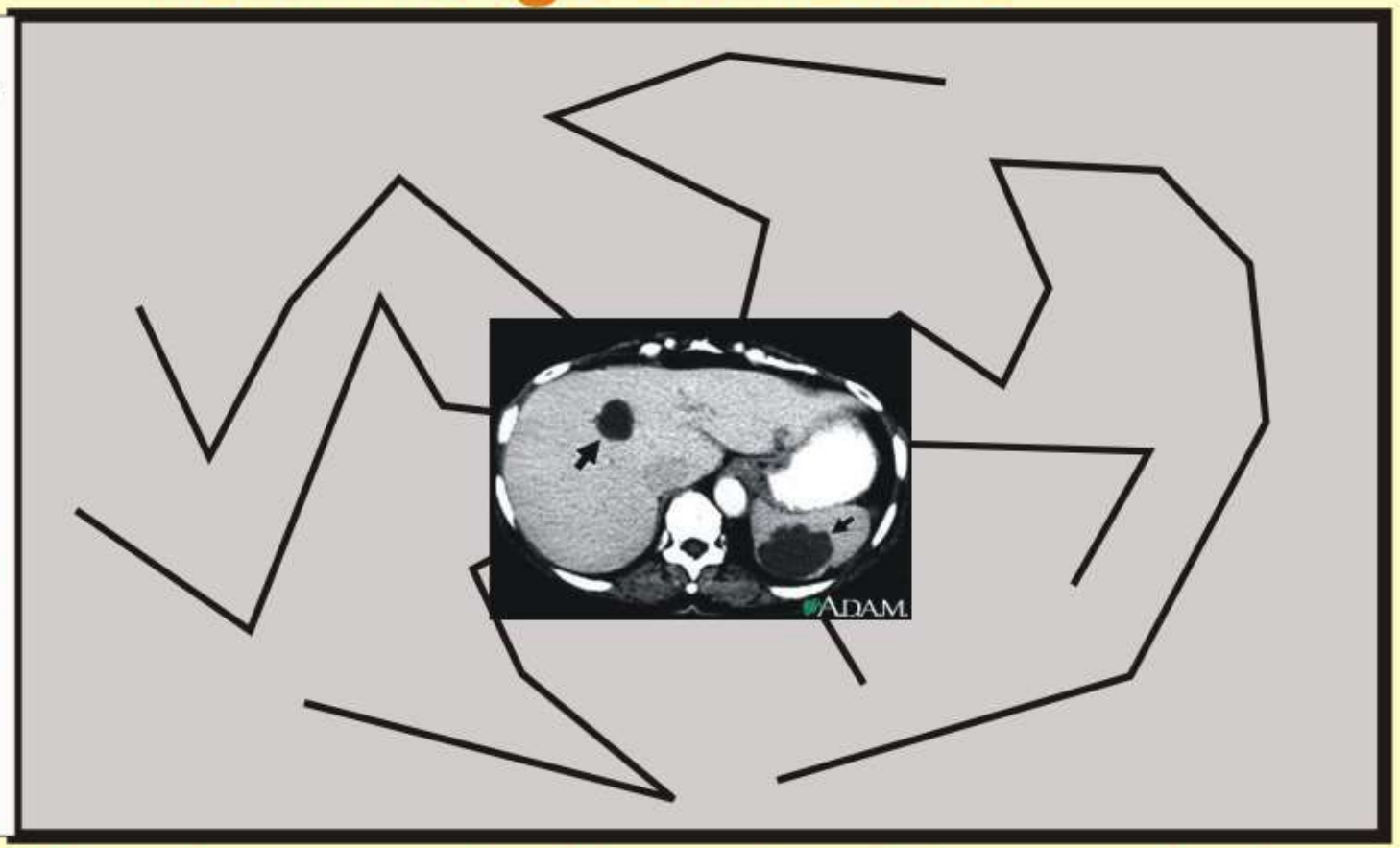
The image is the connection

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



The image is the starting point for learning physics

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COMPUTED TOMOGRAPHY QUALITY CHARACTERISTICS

SPATIAL

ARTIFACTS

DETAIL (BLURRING)

CONTRAST SENSITIVITY

NOISE

PROTOCOL FACTORS

SLICE TH.

MAS

Matrix

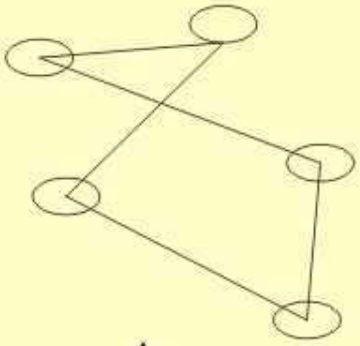
OPERATION

Sprawls

Forming Knowledge Structures

Physical Universe

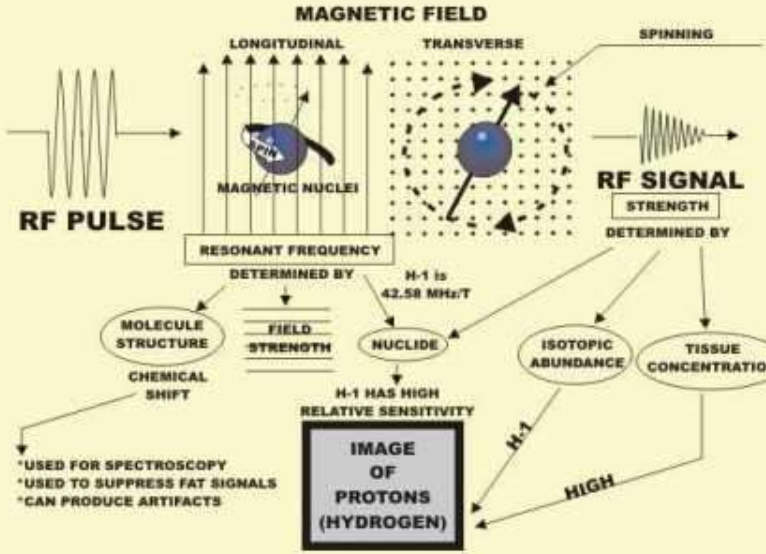
NMR Process



Elements and Relationships

Sensory

Back Integrative Cortex



Visuals

Mindmaps

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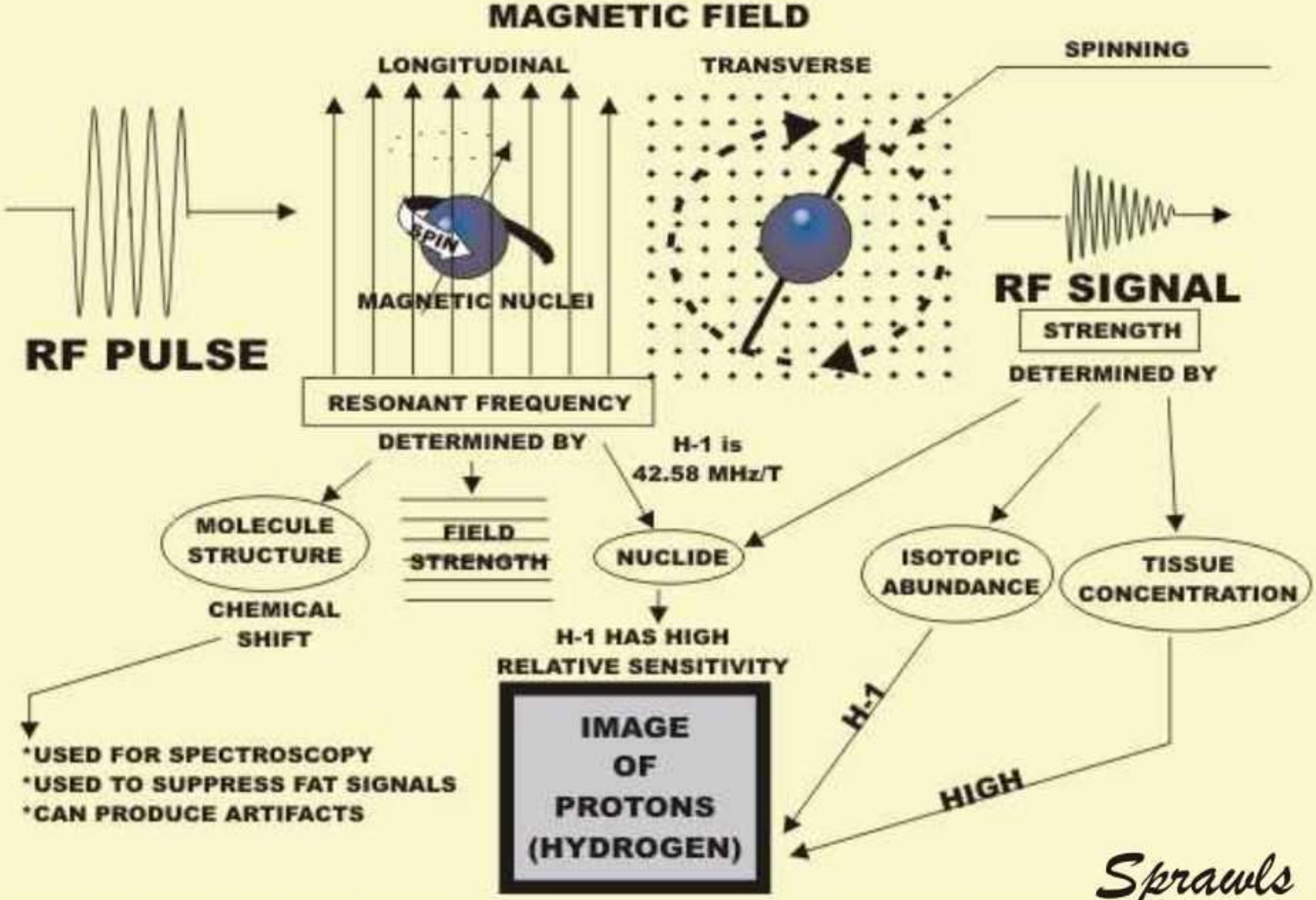
Mind Map of the NMR Process



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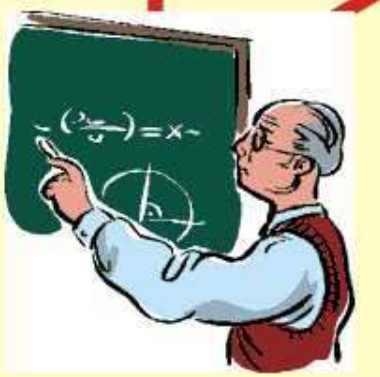
Forming Knowledge Structures

Physical Universe

Inverse Square Effect



Back Integrative Cortex

Sensory

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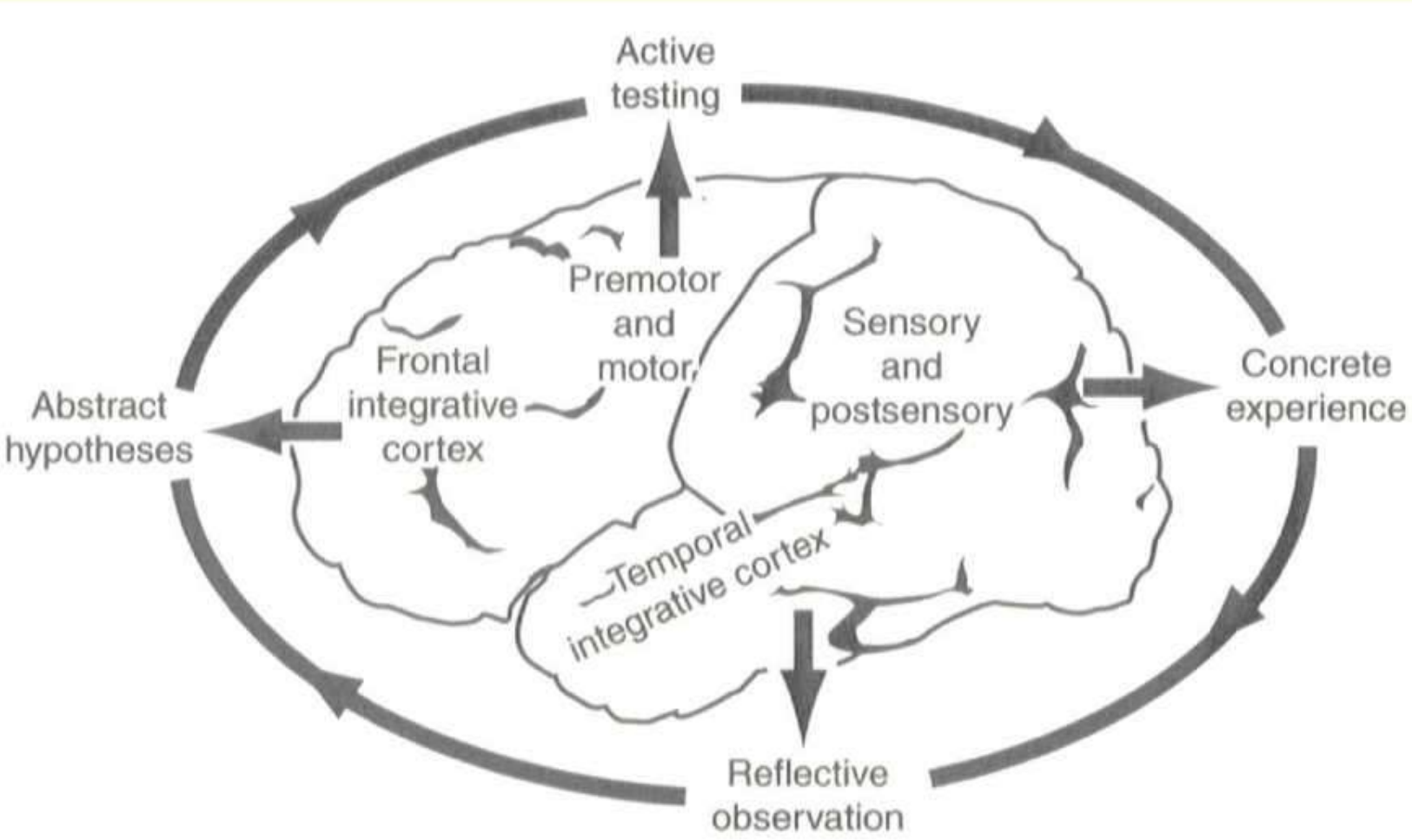
Verbal and Symbolic

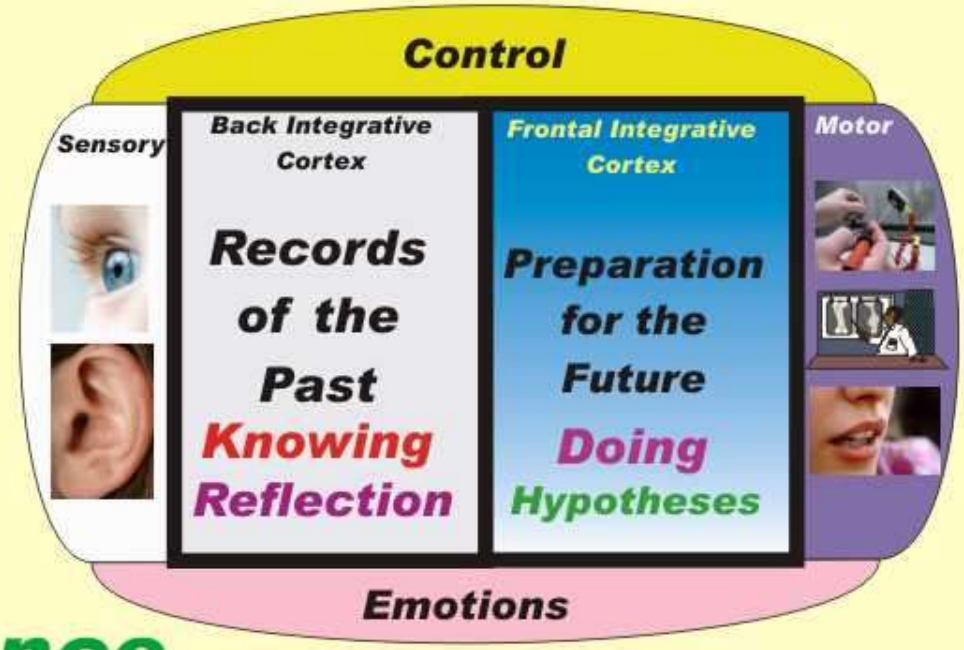
Sprawls

Zull's Model of Brain Function



Brain Functions for Learning Physics

Active Experimentation and Testing



Sense and Experience Observe

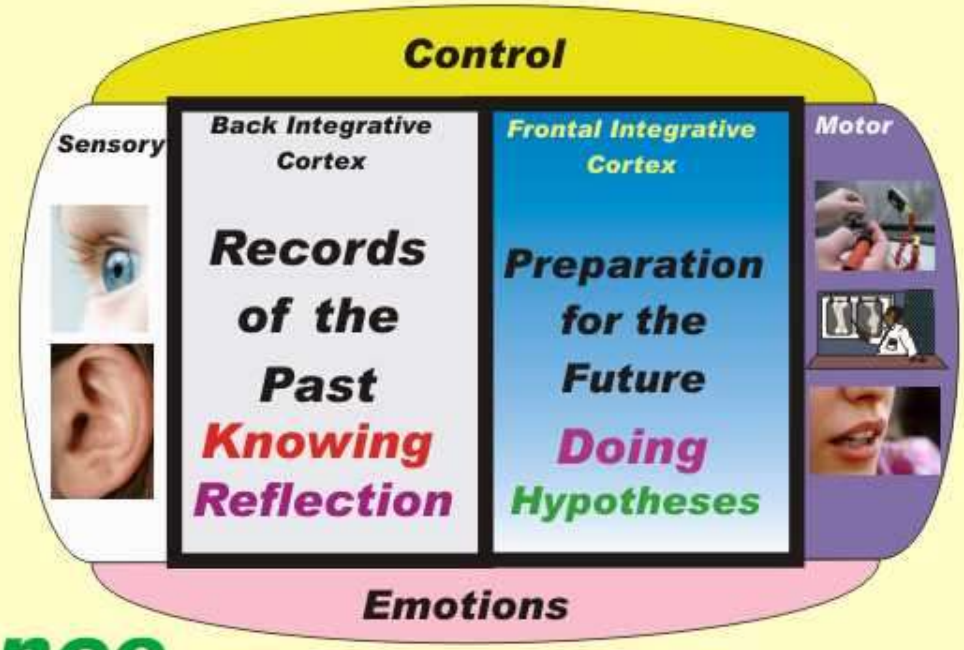
Interact and Affect

Physical Universe

Sprawls

Brain Functions for Learning Physics

Active Experimentation and Testing



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Physical Universe

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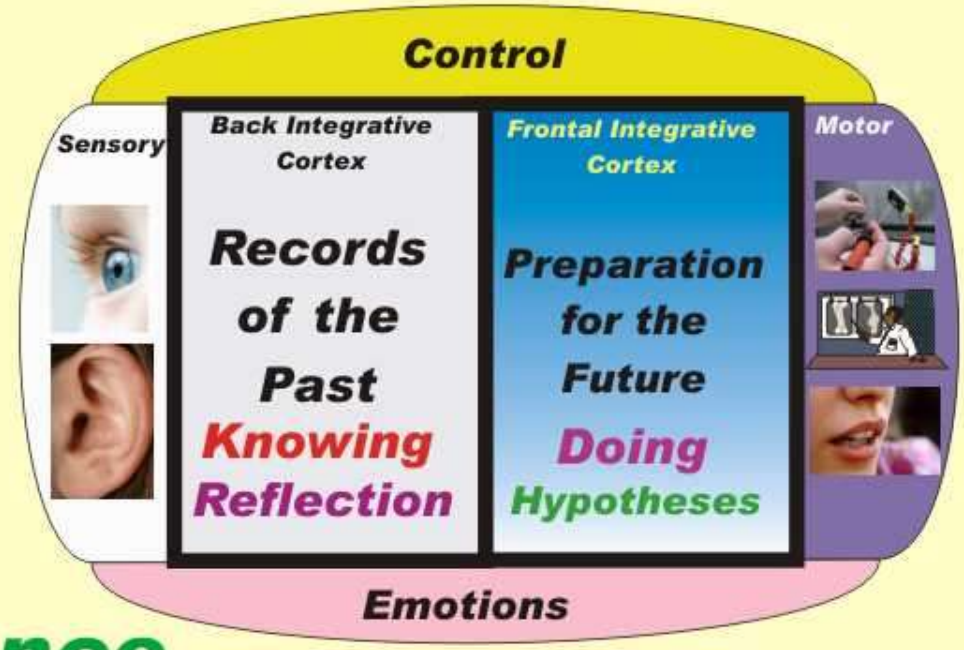
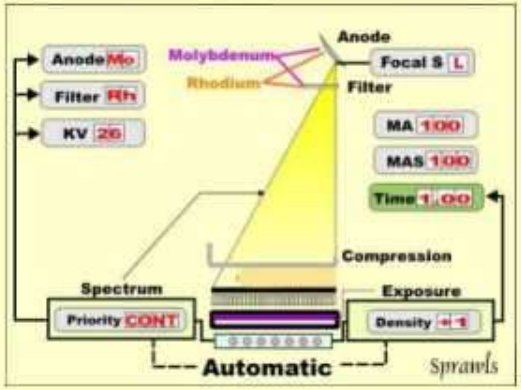
Active Experimentation and Testing



Sense and Experience Observe

Interact and Affect



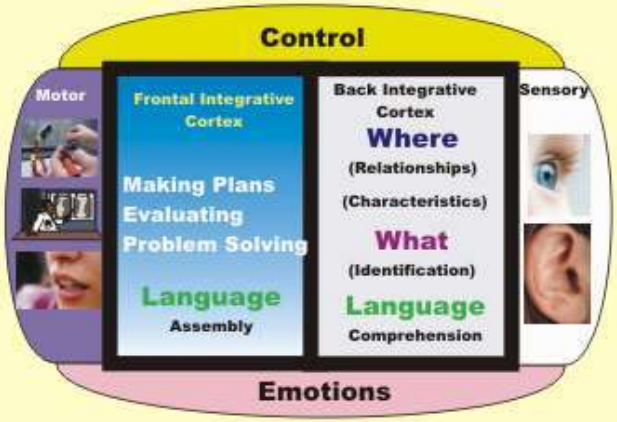
Physical Universe

Sprawls

Brain Functions for Learning Physics

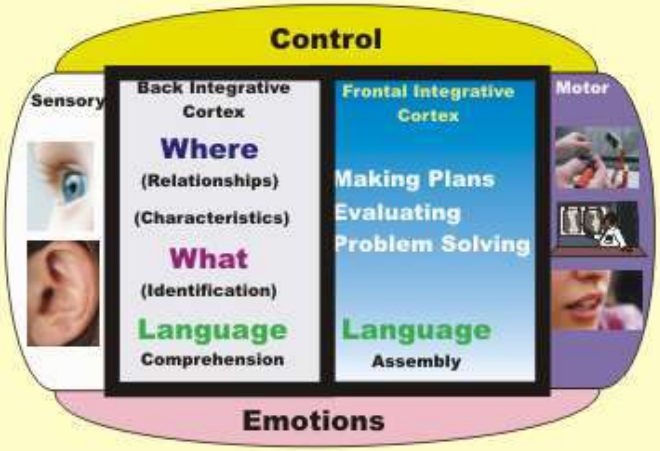
Two brains are better than one!

Collaborative Learning



Ben

?



Jerry

Problem Solving

Sprawls

Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning

Problem Solving

Sprawls

Brain Functions for Learning Physics

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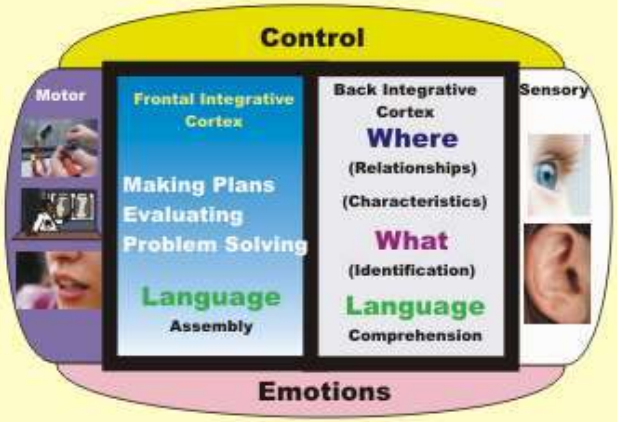
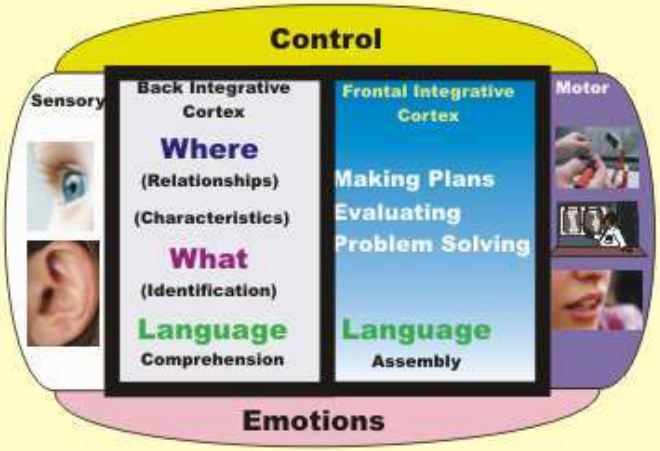
Collaborative Learning





Views
Perspectives
Experiences

Views
Perspectives
Experiences

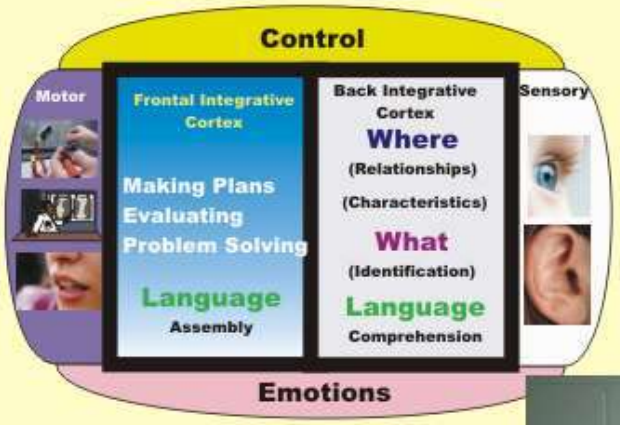
Problem Solved!

Sprawls

Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning



Views
Perspectives
Experiences

Views
Perspectives
Experiences

Analysis and Evaluation

Image: UGA

Sprawls

Brain Functions for Learning Physics

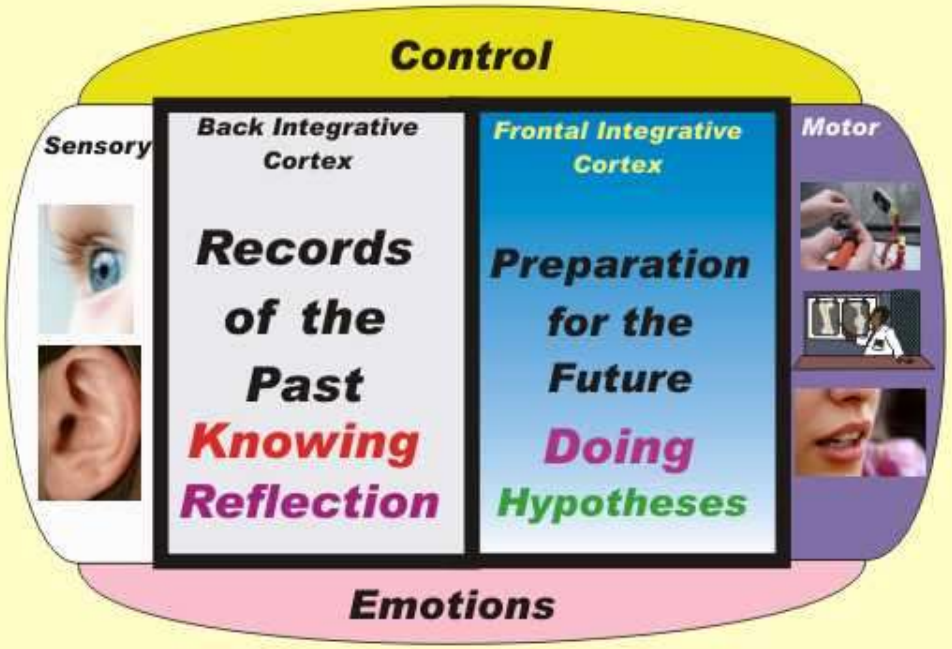
Two brains are better than one!

Collaborative Learning

Problem Solving
Analysis and Evaluation
Developing Plans

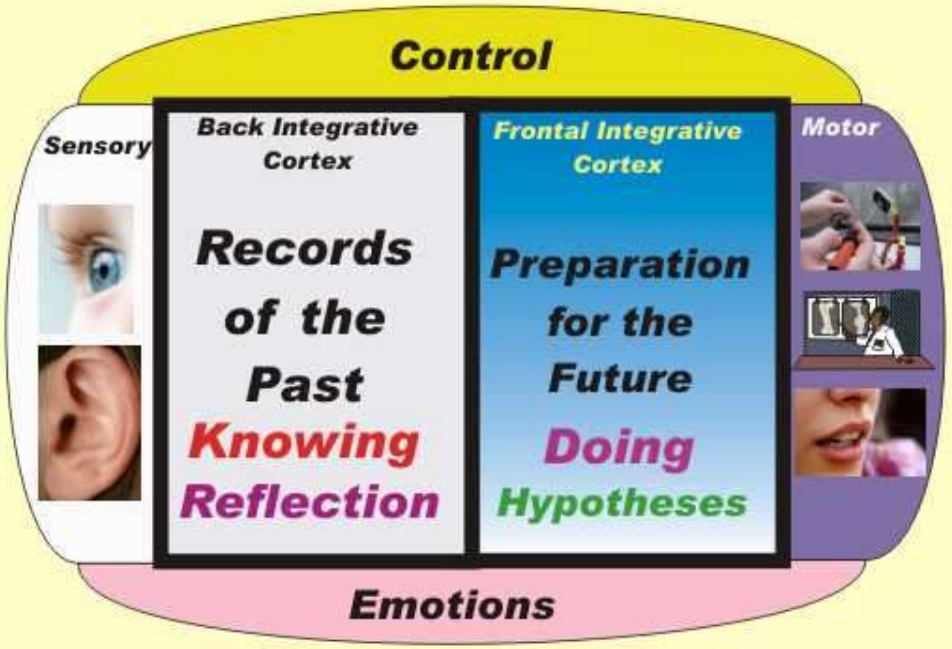
Sprawls

The Learning Environment



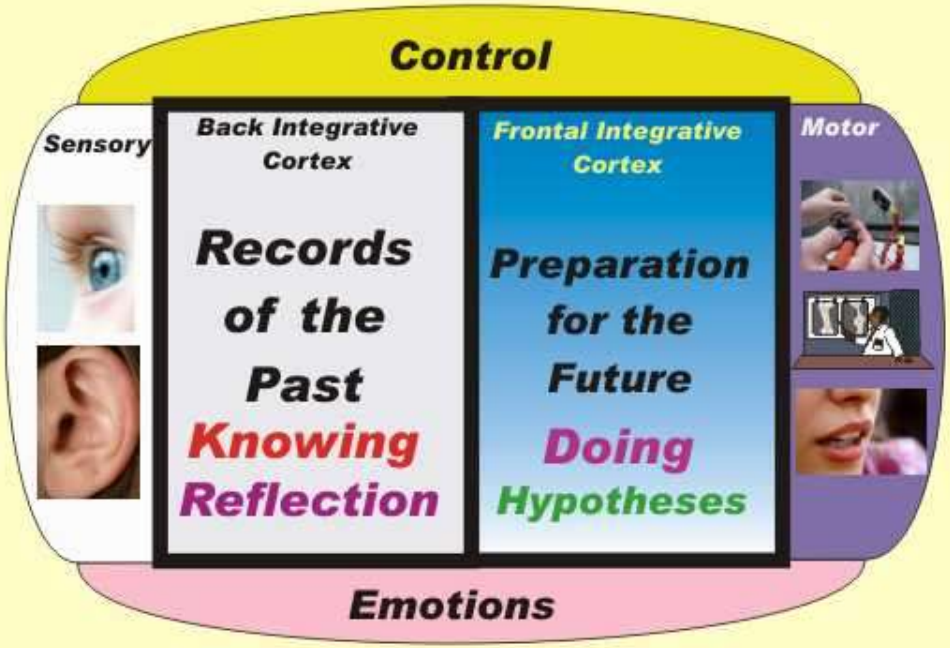
Sprawls

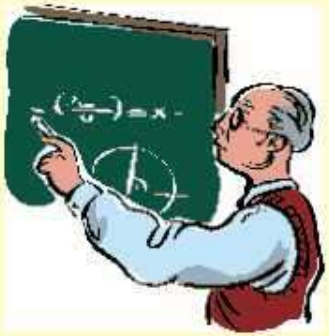
Rich Learning Environments



Sprawls

Challenging Learning Environments





Sprawls

Effective Learning

Rich Learning Environment

New and Different

Integrate into Existing Knowledge

Reflection →

Sprawls

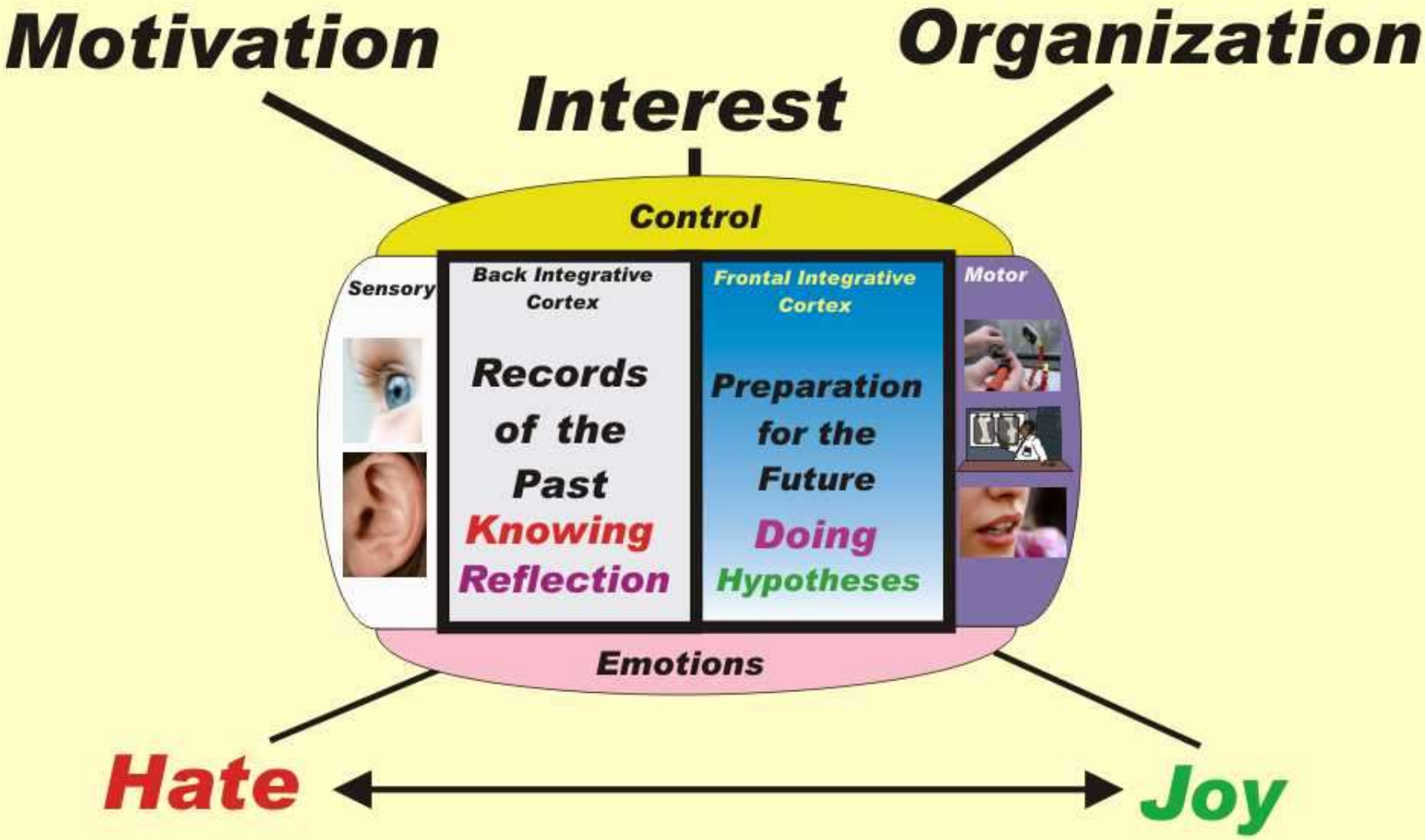
Effective Learning

Interact **Review** **Reflect**

Developing useful knowledge for the future

Sprawls

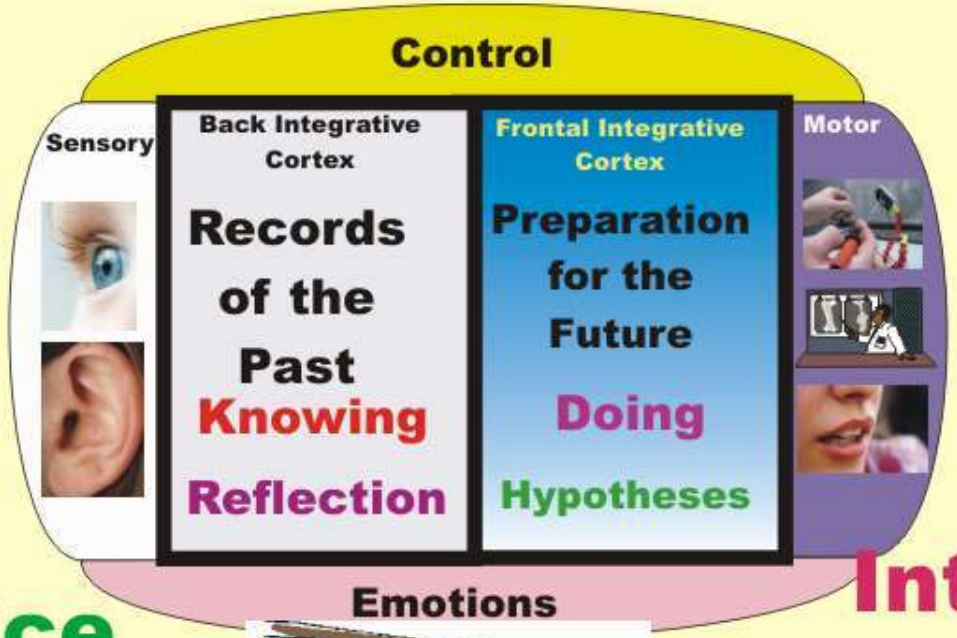
Brain Functions for Learning Physics



Sprawls

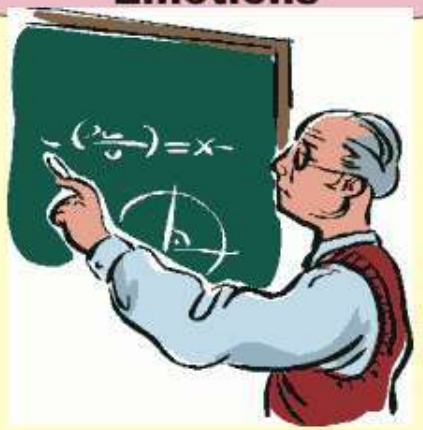
Brain Functions for Learning About

Learning Physics



Sense and Experience Observe

Interact and Affect



Our Teaching

Sprawls

Robert Gagne (1916-2002)

Best known for his Nine Events of Instruction

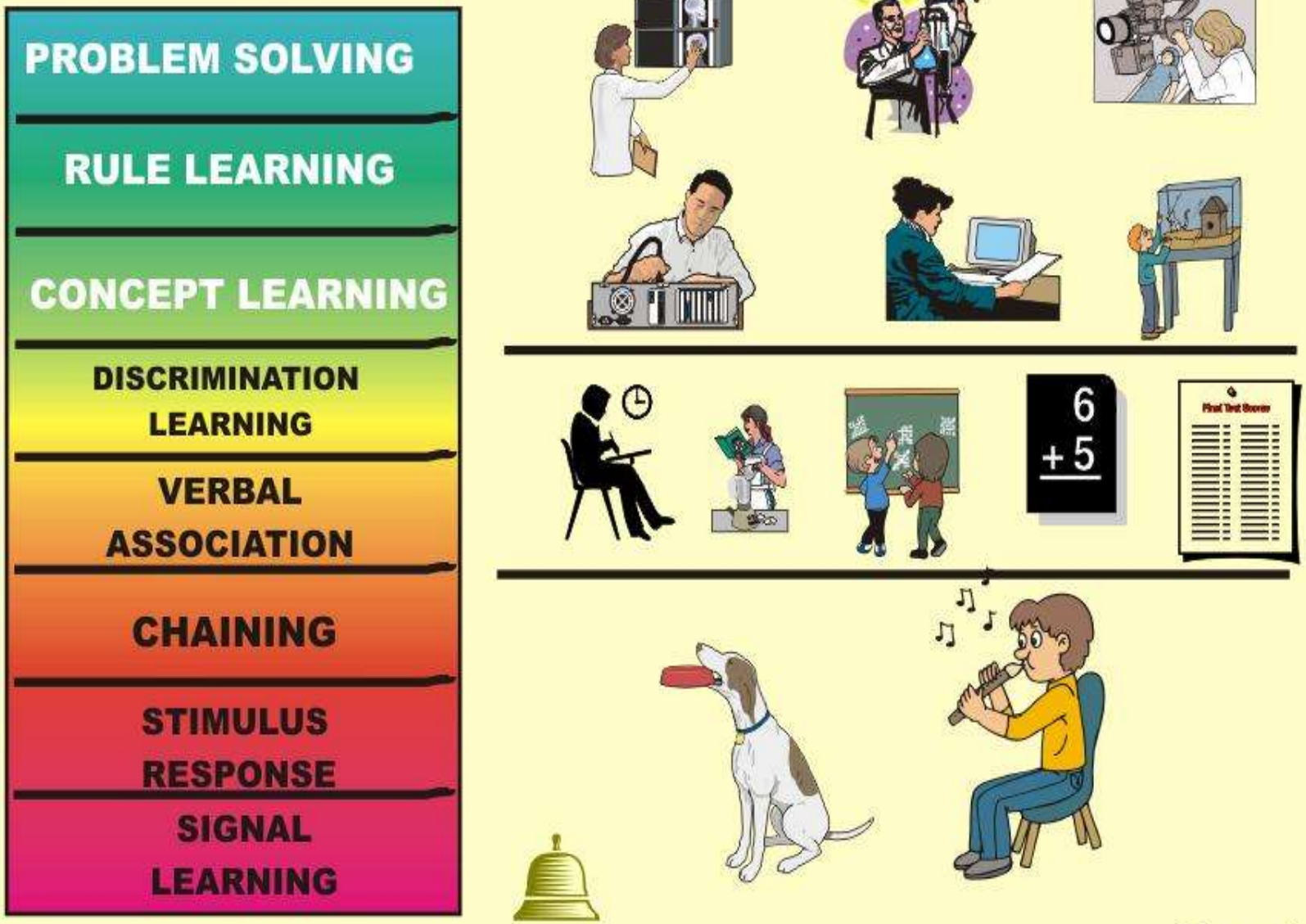
The Gagne assumption is that different types of learning exist, and that different instructional conditions are most likely to bring about these different types of learning

Gagné was also well-known for his sophisticated stimulus-response theory of eight kinds of learning which differ in the quality and quantity of stimulus-response bonds involved. From the simplest to the most complex, these are:

signal learning (Pavlovian conditioning)
stimulus-response learning (operant conditioning)
chaining (complex operant conditioning)
verbal association
discrimination learning
concept learning
rule learning
and problem solving.

Sprawls

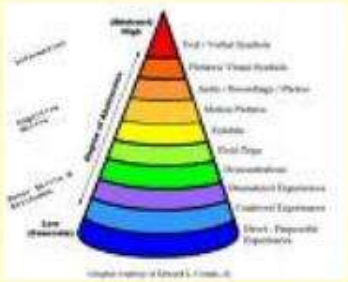
Gagne's Hierarchy of Learning



Edgar Dale (1900-1985)

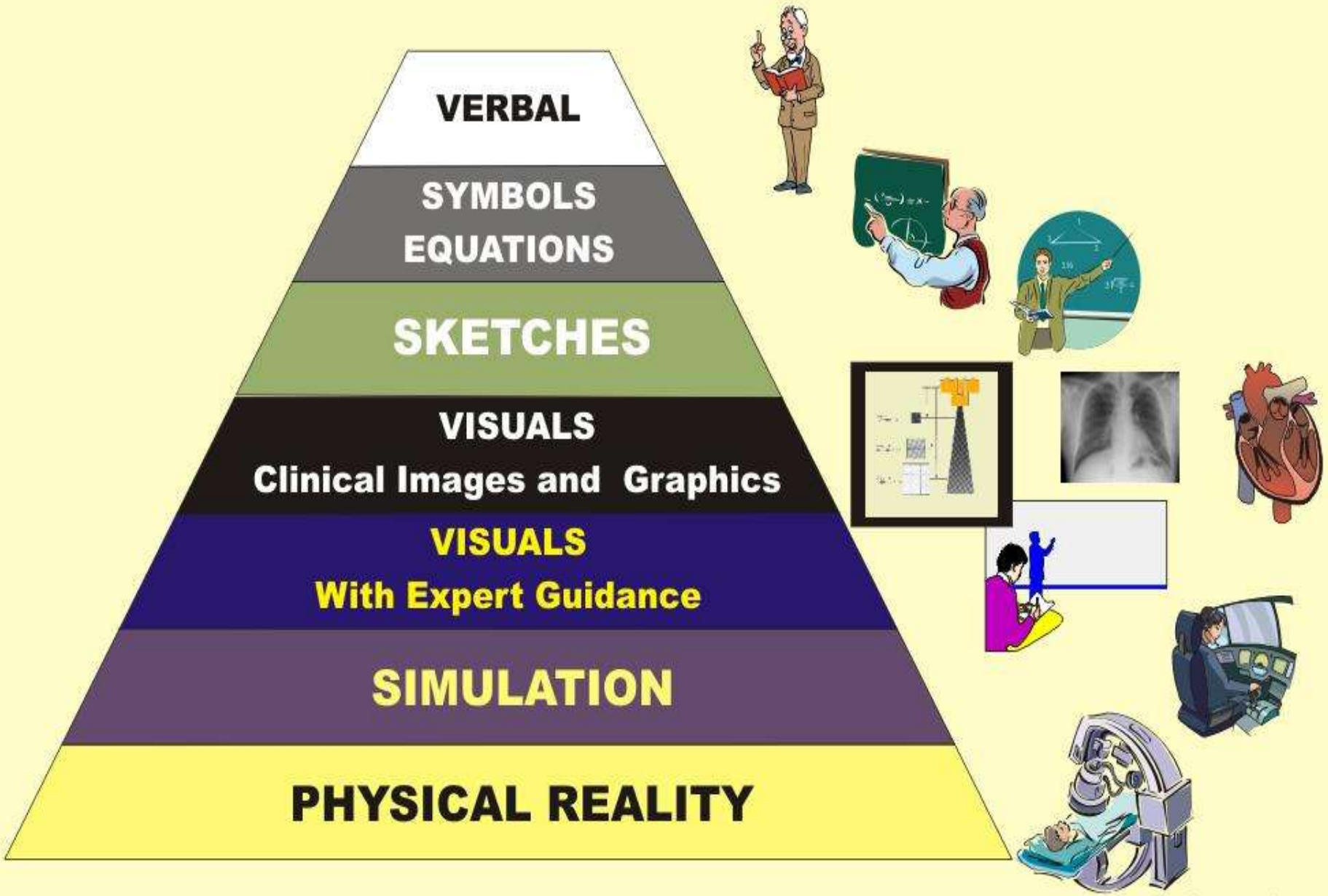
Educationalist who developed the famous

Cone of Experience theory

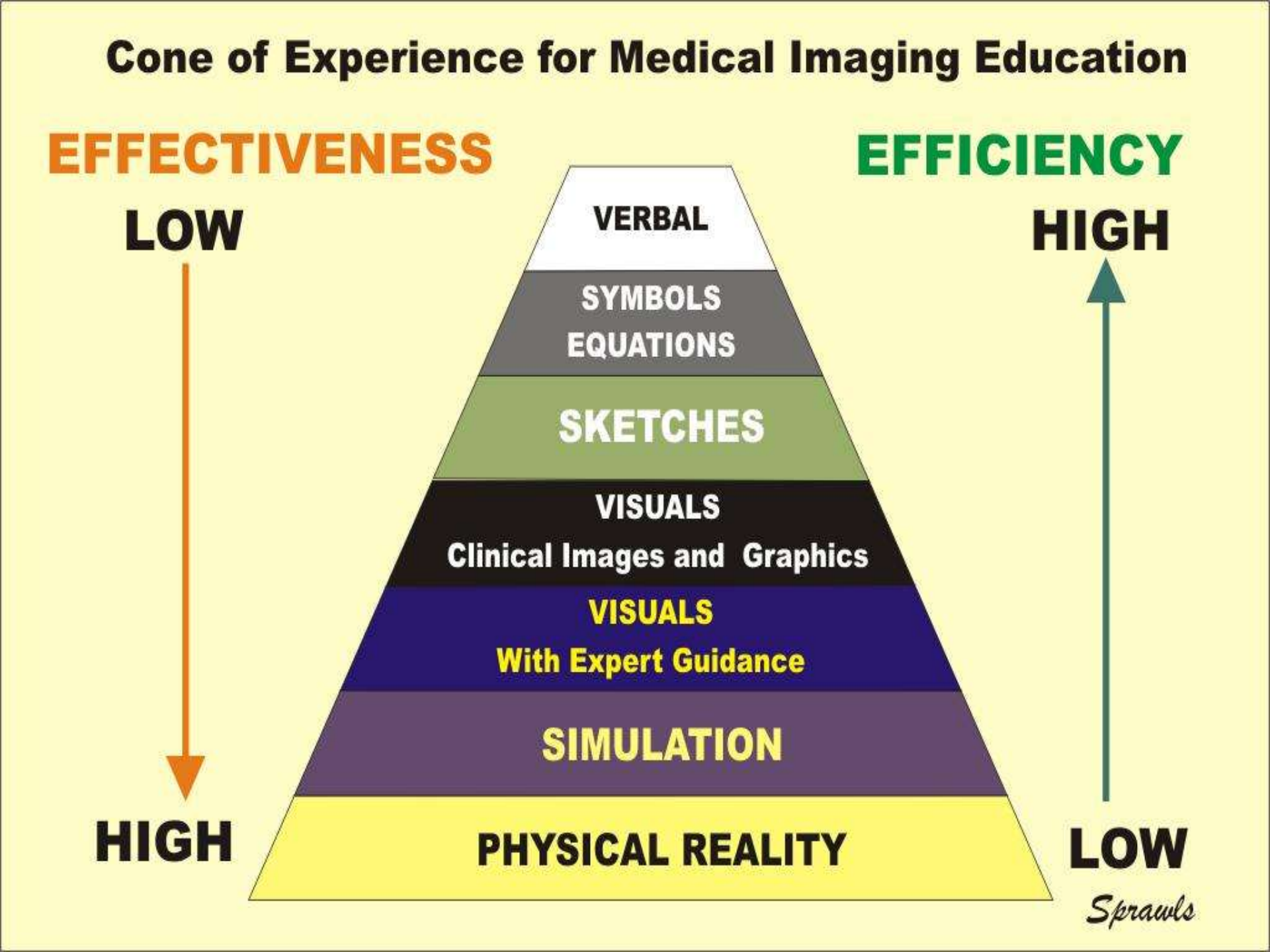


Sprawls

Cone of Experience for Medical Imaging Education

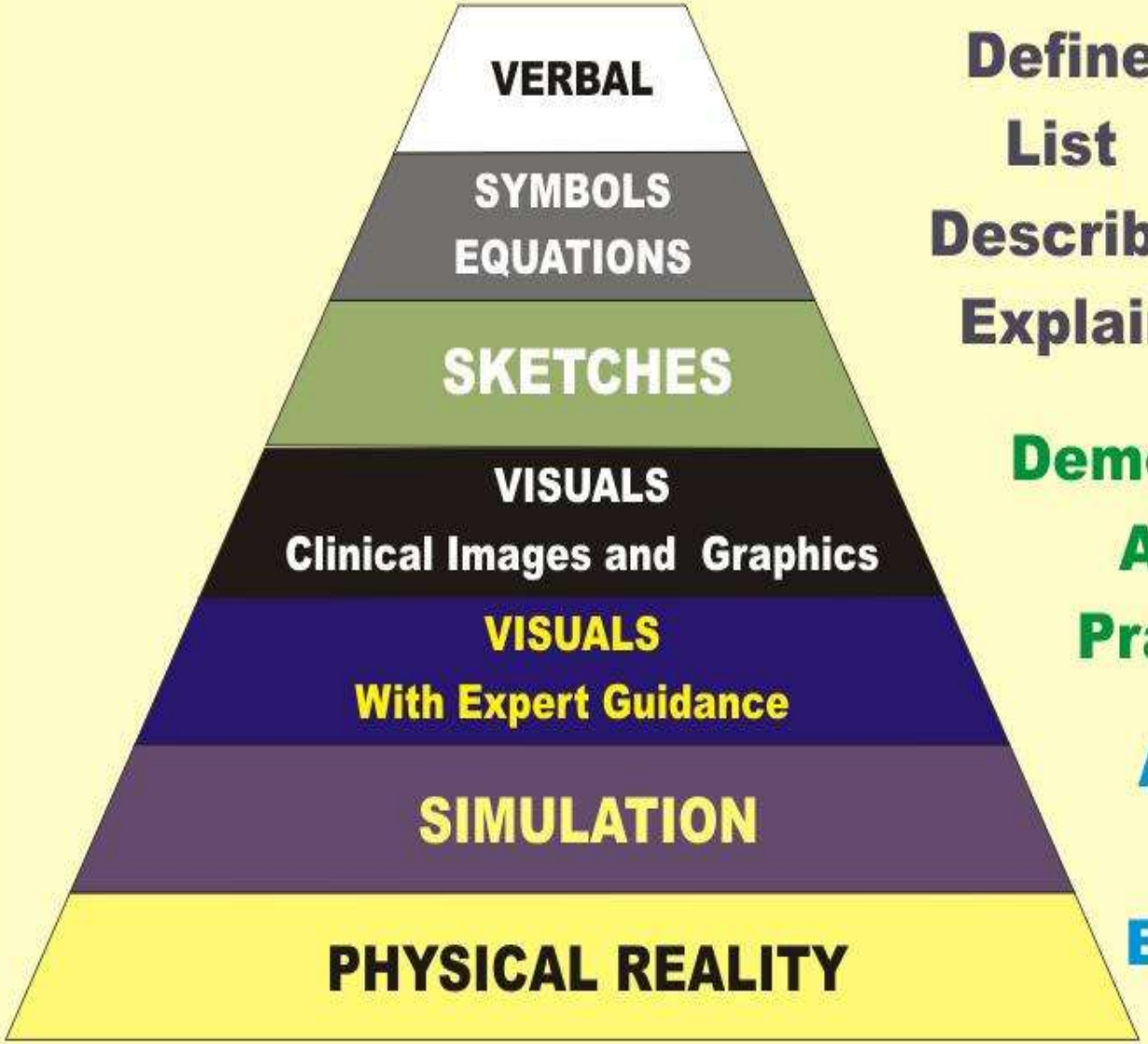


Cone of Experience for Medical Imaging Education



Cone of Experience for Medical Imaging Education

LEARNING OUTCOMES



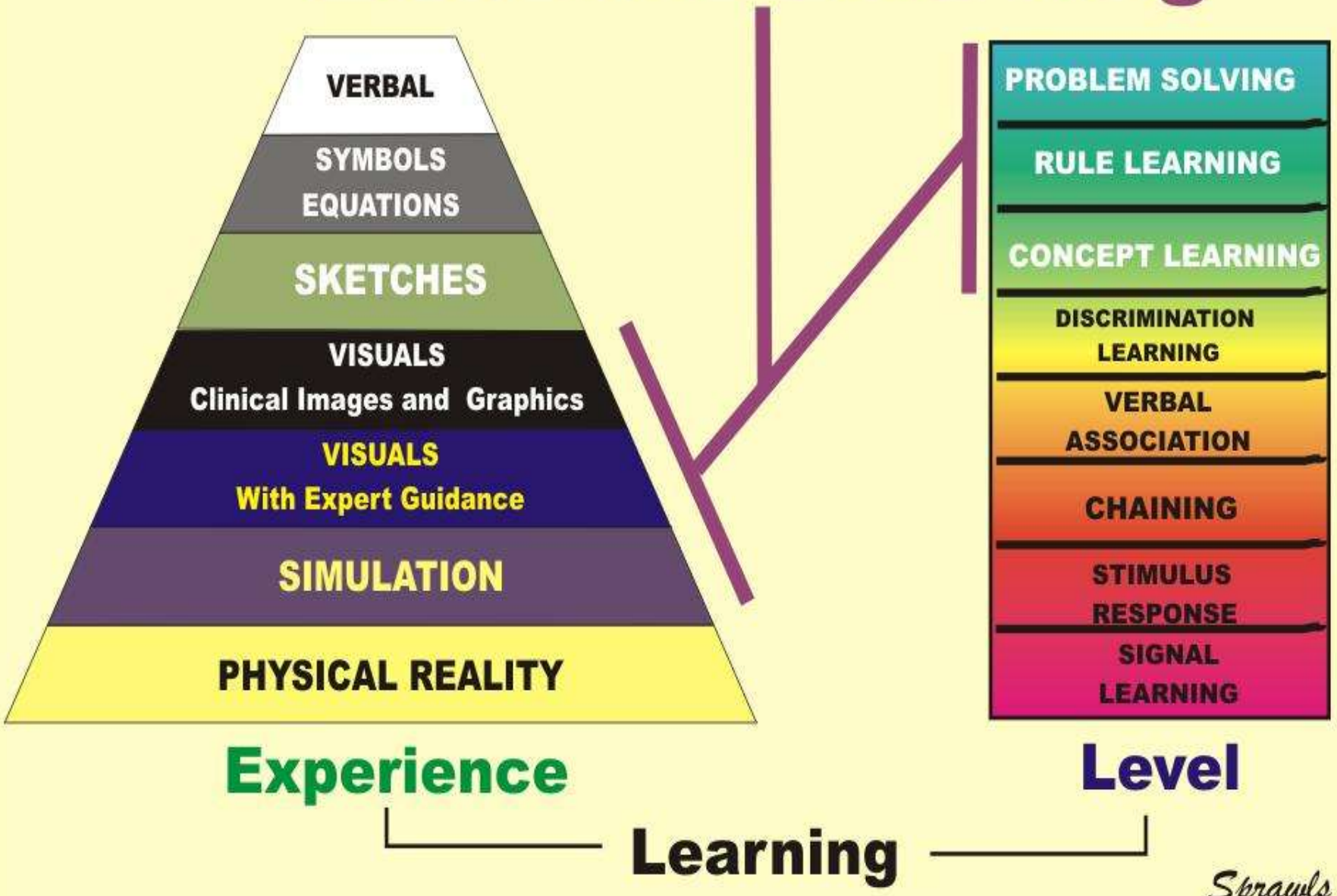
Define
List
Describe
Explain

Demonstrate
Apply
Practice

Analyze
Create
Evaluate

Sprawls

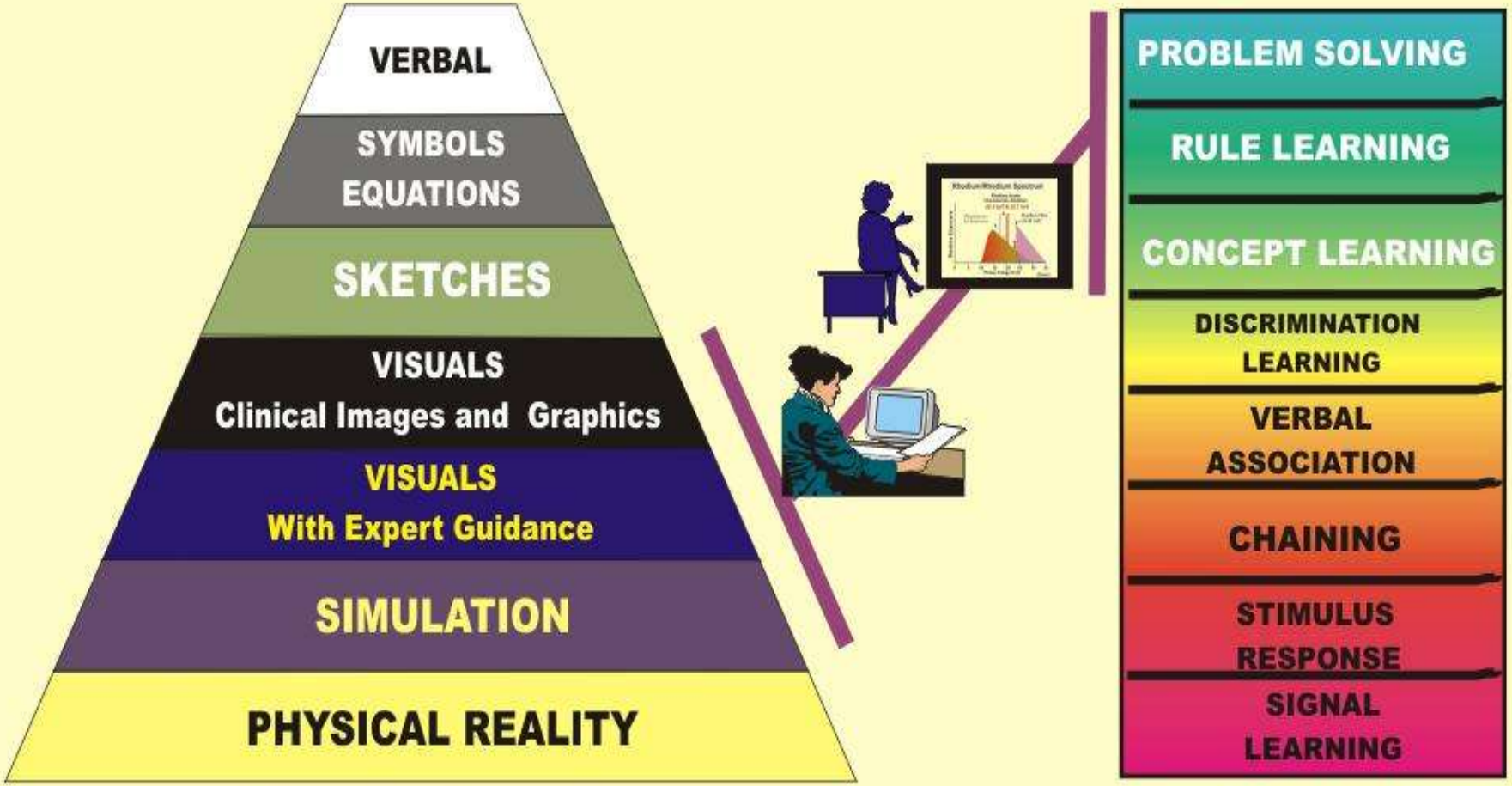
Effective Learning



Sprawls

Technology Enhanced

Learning and Teaching



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**

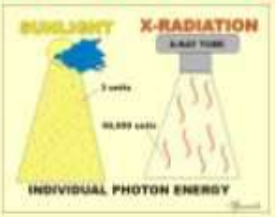
Resources and References

Sprawls

Physics Education

Images

Radiation



General Basics

Contrast
Detail
Noise
Artifacts
Spatial

Characteristics and Comparison of Modalities

Radiation for Imaging
Quantities and Units
X-Ray Production
Radioactivity
Interactions

Digital Image Structure and Characteristics

Clinical

X-Ray Image Formation
Radiographic Receptors
Radiographic Detail
Fluoroscopic Systems
CT Image Formation
CT Image Quality and Dose Optimization
Radionuclide Imaging, SPECT, PET
MRI
Ultrasound

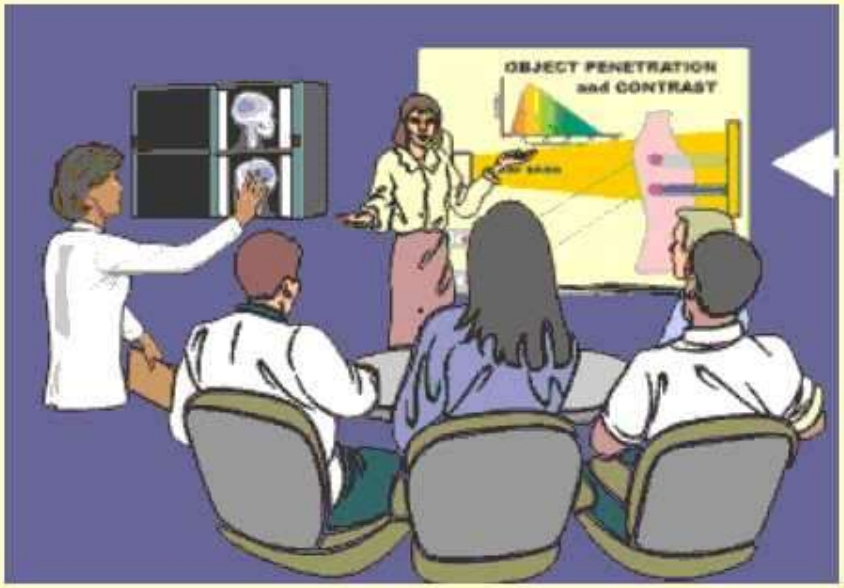
Radiation Safety

Biological Effects
Personnel Protection
Patient Dose Management

Sprawls

Rich Classroom and Conference Learning Activities

Learning Facilitator "Teacher"



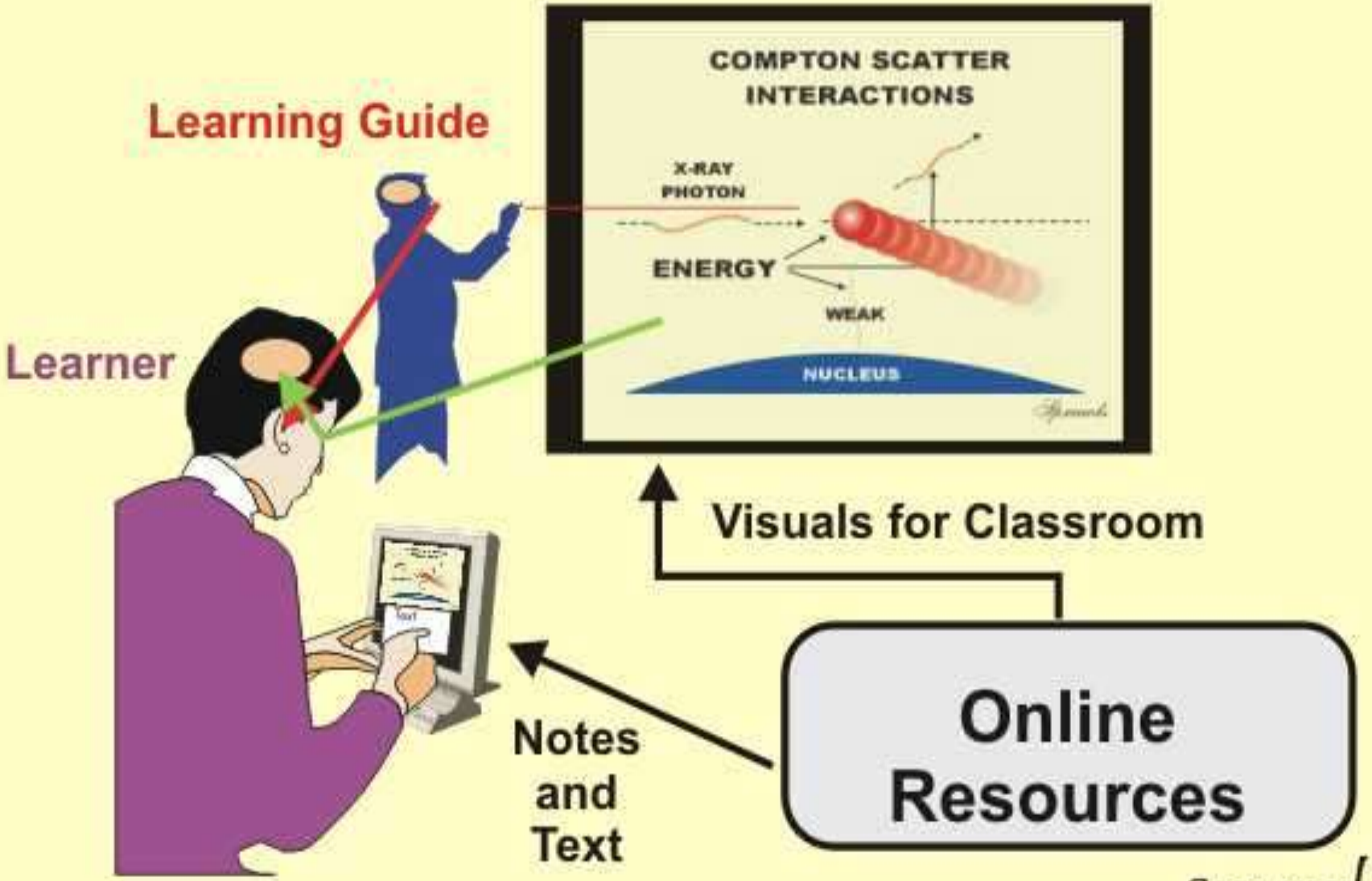
Visuals

Representations of Reality

- **Organize and Guide the Learning Activity**
- **Share Experience and Knowledge**
- **Explain and Interpret What is Viewed**
- **Motivate and Engage Learners**

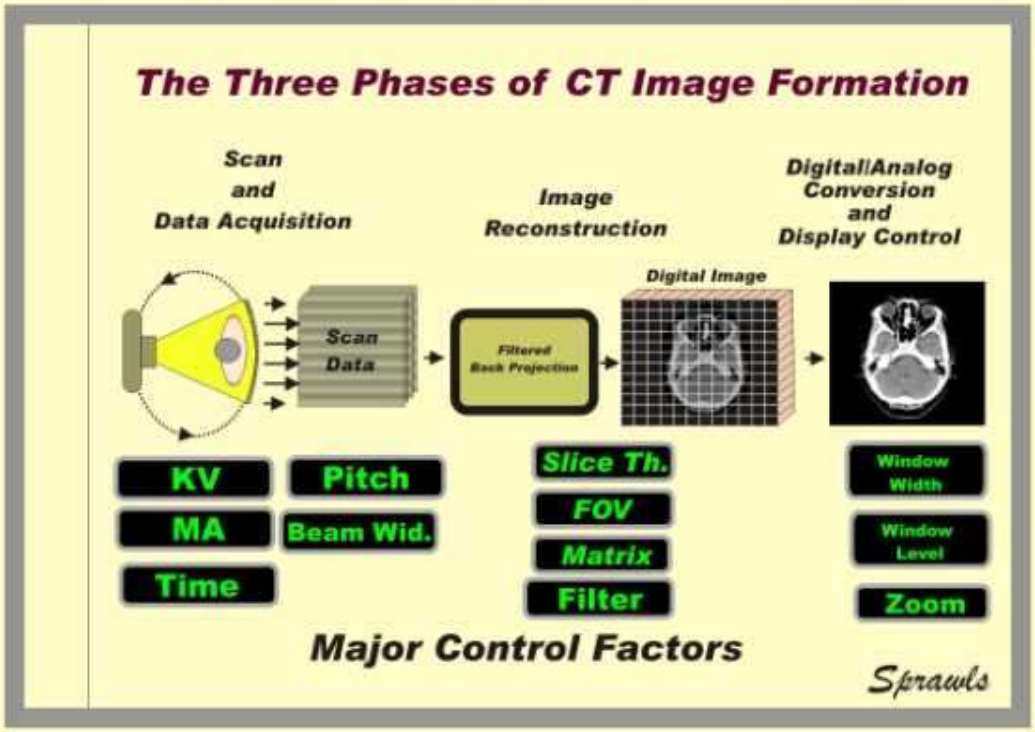
Sprawls

Technology Enhanced Learning



Visuals for Learning and Teaching

The Imaging Process



Clinical Images

Sprawls

Visuals

to be used by

Physicists in Classroom and Conference Discussions

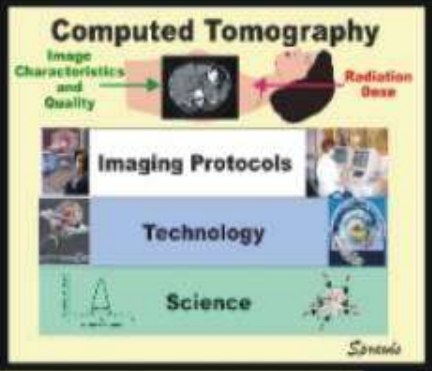
SPRAWLS EDUCATIONAL FOUNDATION
Open Resources for Learning and Teaching
The Physical Principles of Medical Imaging

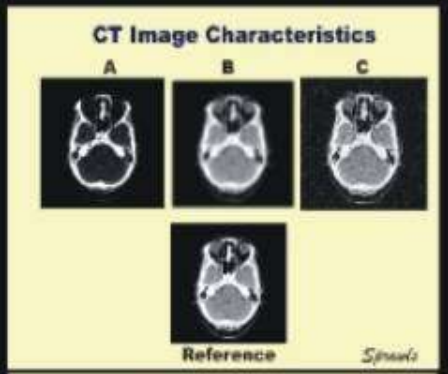
Visuals
for
Classroom, Conference, and Collaborative Learning

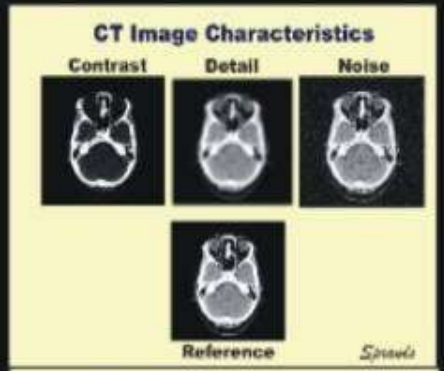
RIGHT CLICK on each visual to download and use in PowerPoint or other display programs.

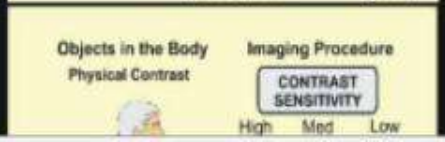
Computed Tomography Image Quality Optimization and Dose Management

Companion Module
http://www.sprawls.org/resources/CTIQDM/









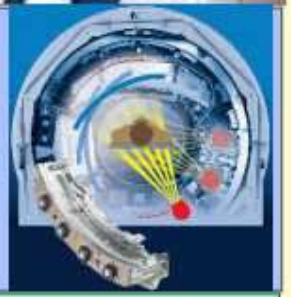
Computed Tomography

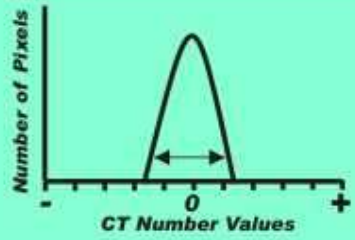
Image Characteristics and Quality

Radiation Dose

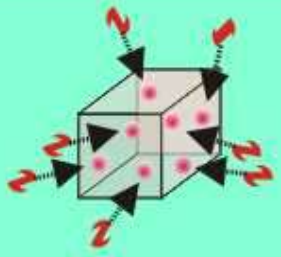
Imaging Protocols

Technology



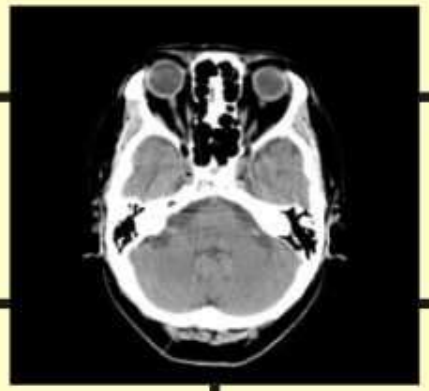


Science



Sprawls

CT Image Characteristics



Spatial

Artifacts

Detail

Noise

Contrast Sensitivity

KV

Pitch

Slice Th.

Window Width

MA

Beam Wid.

FOV

Window Level

Time

Filter

Matrix

Zoom

Major Protocol Factors

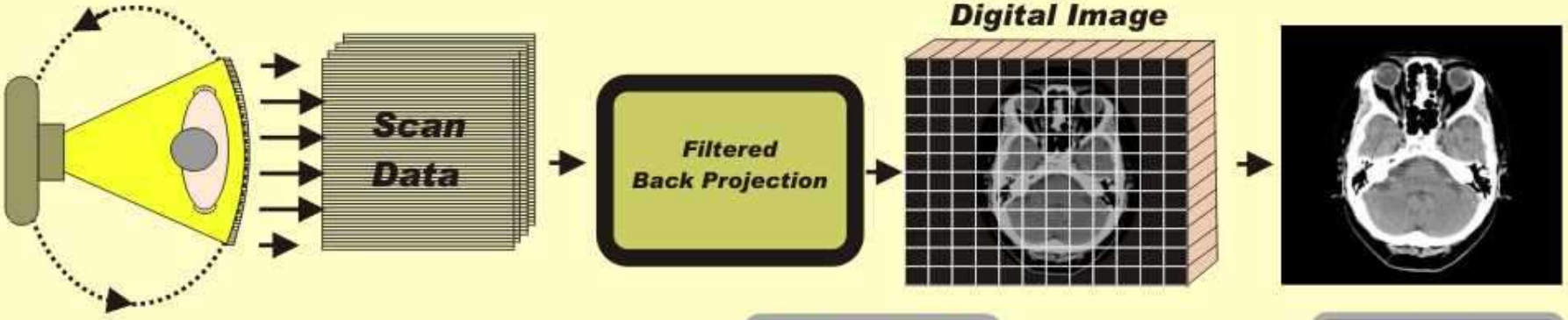
Sprawls

The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

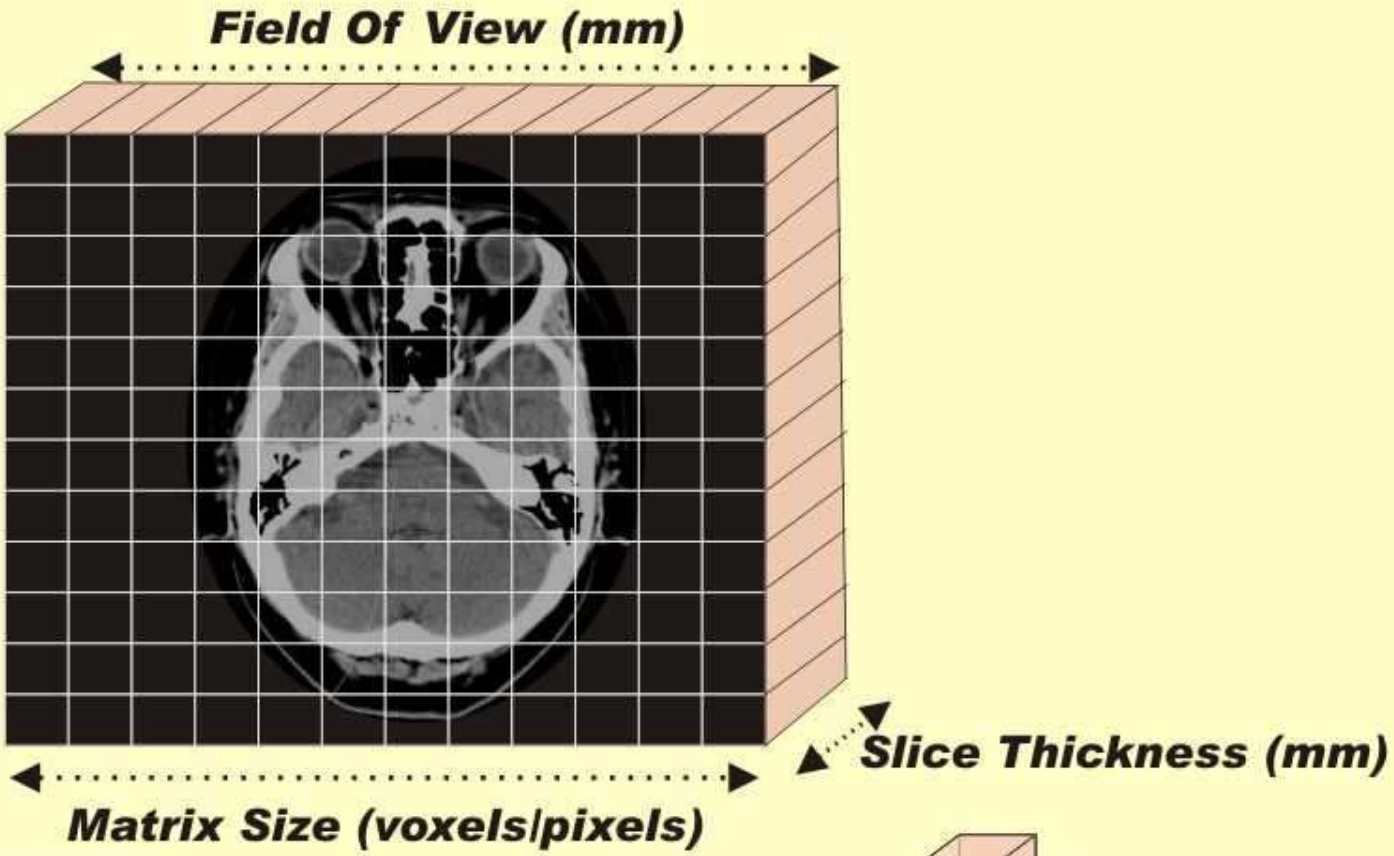


- KV
- MA
- Time
- Pitch
- Beam Wid.
- Slice Th.
- FOV
- Matrix
- Filter
- Window Width
- Window Level
- Zoom

Major Protocol Factors

Sprawls

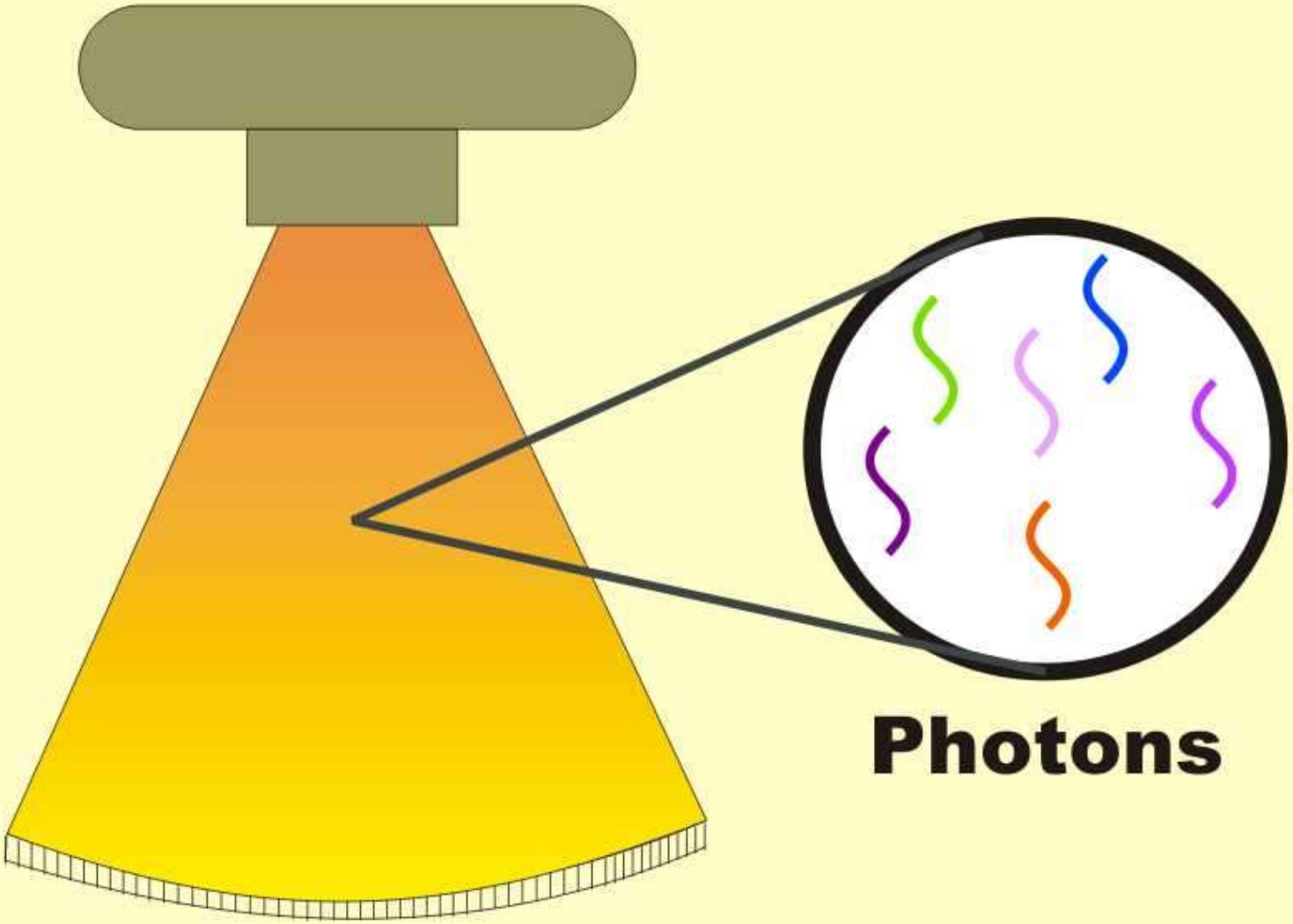
CT Slice Divided into Matrix of Voxels



Voxel Size Controlled By

Sprawls

The Quantum Structure of the X-ray Beam



Sprawls

X-ray Photons Interact With Tissue in A Voxel

Radiation Dose

determined by

Concentration of Absorbed Energy

per voxel

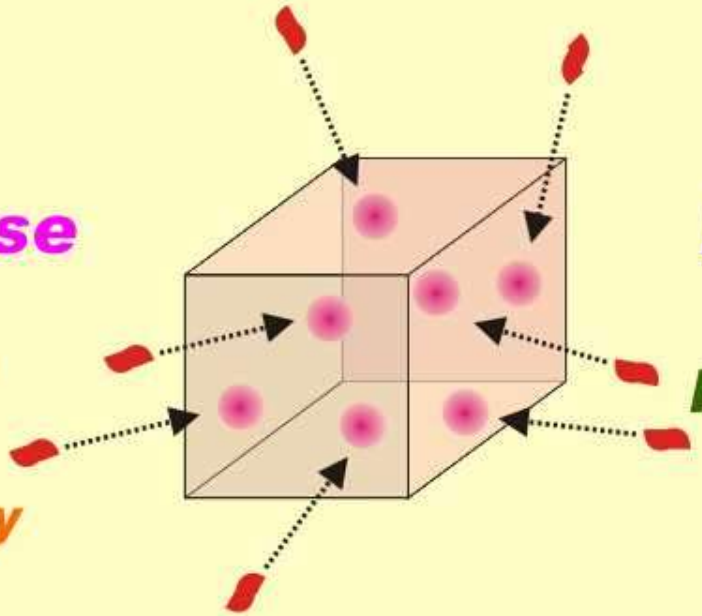


Image Noise

determined by

Number of Photons

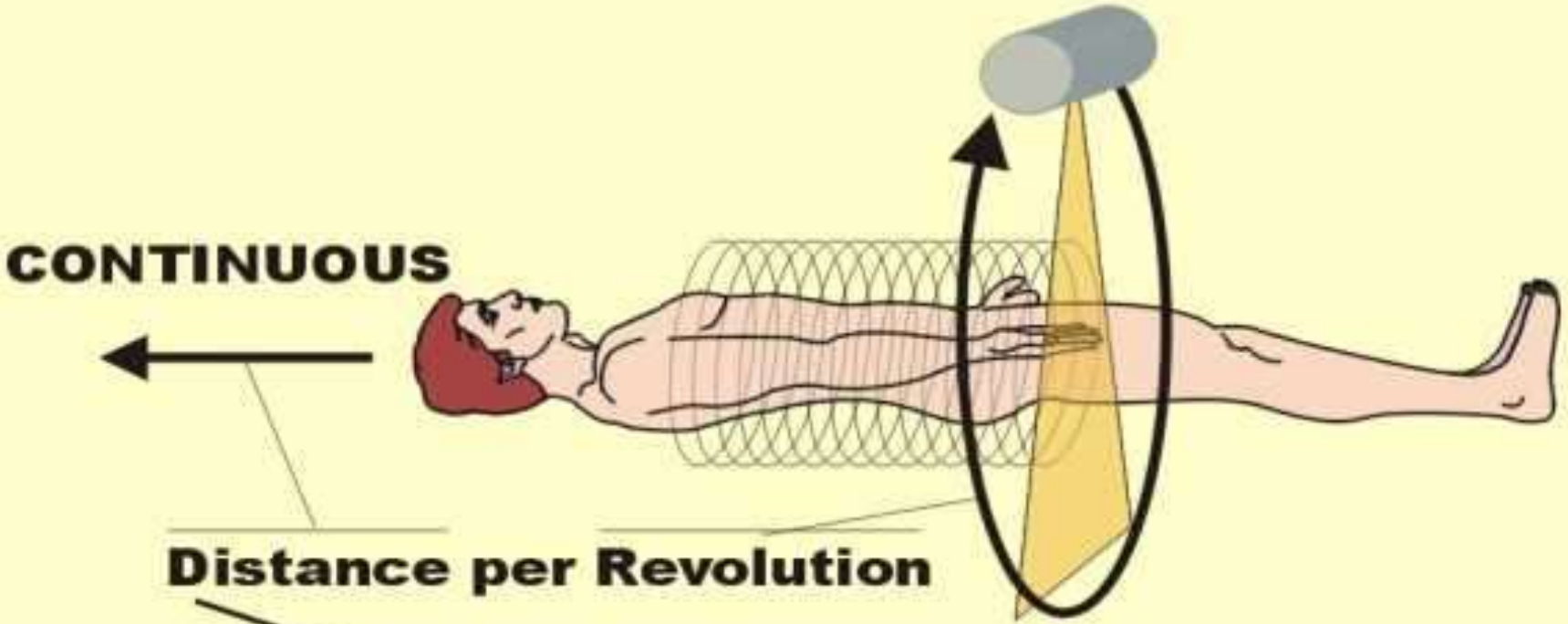
per voxel

Dose is increased by increasing number of photons.

Noise is reduced by increasing number of photons.

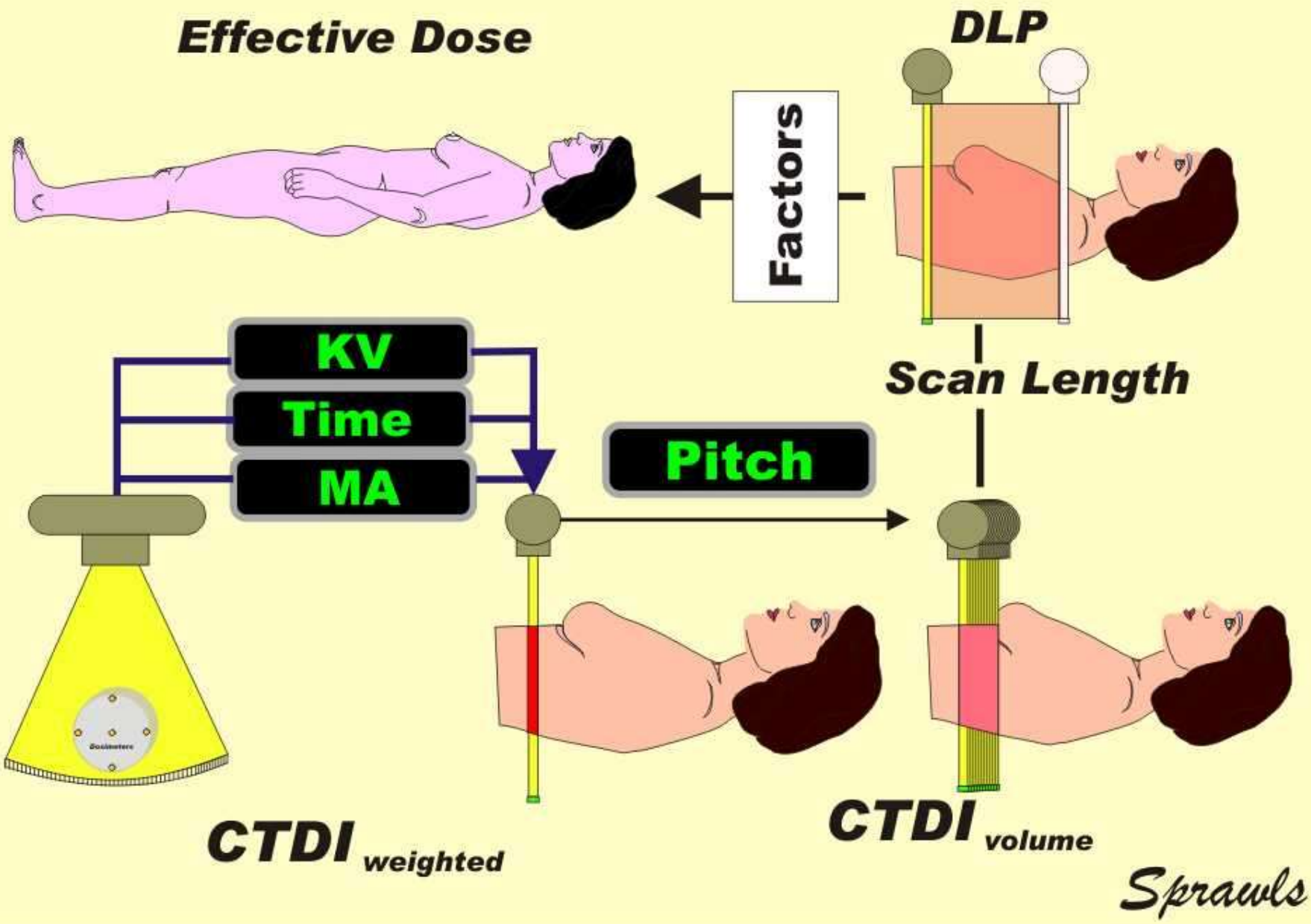
Sprawls

SPIRAL SCAN



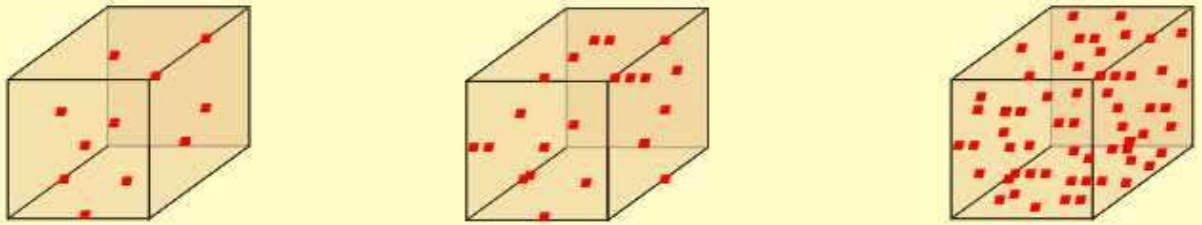
Sprawls

CT Dose Quantities



Decreasing Noise

Requires Increased Photons Absorbed Per Voxel



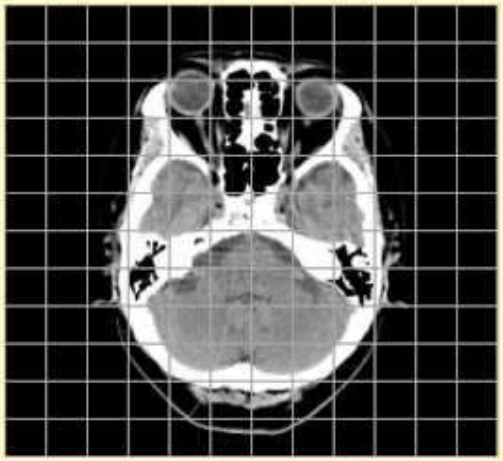
Produces Increasing Dose

Sprawls

Effect of Matrix Size on Image Noise

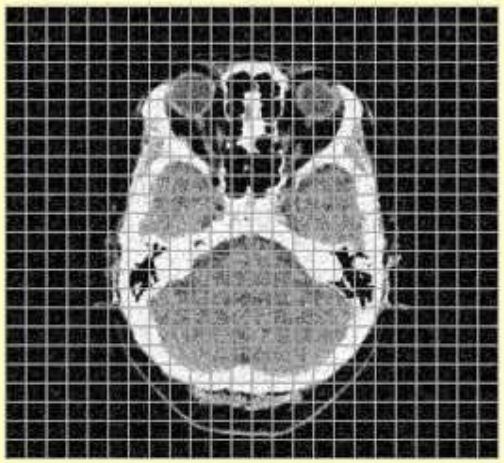
Small **Matrix** ***Large***

Large Voxels



Low Noise

Small Voxels

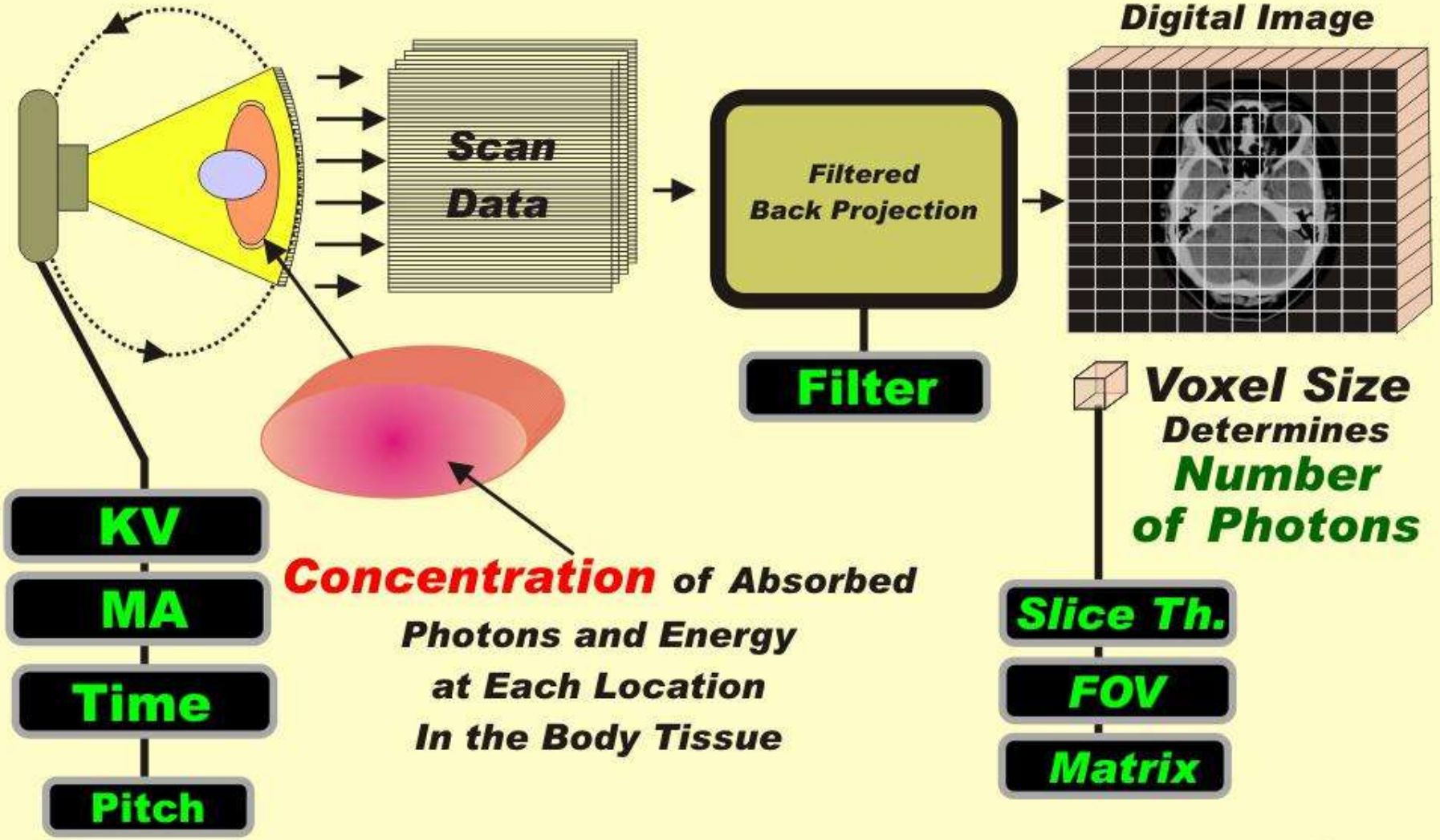


High Noise

The same radiation dose for both images.

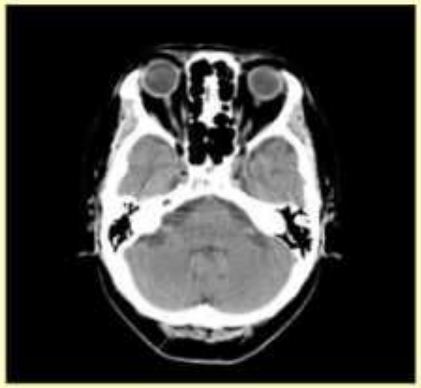
Sprawls

Factors That Determine Image Noise



Sprawls

Two Major Image Quality Goals



High Detail

Low Noise

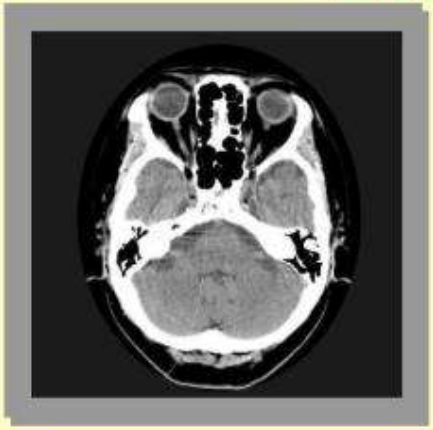
FOV | **Matrix** | **Slice Th.**

Protocol Factors

Sprawls

Relationship of Radiation Dose to Image Detail

Lower Dose



When detail is increased by

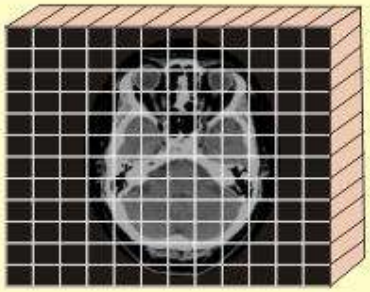
Decreasing **Slice Th.**

Increasing **Matrix**

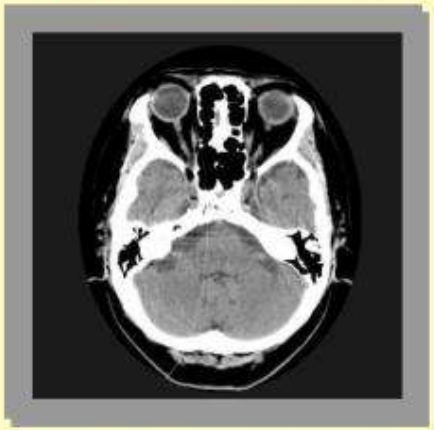
Decreasing **FOV**

Noise Increases

Because of decreased voxel size



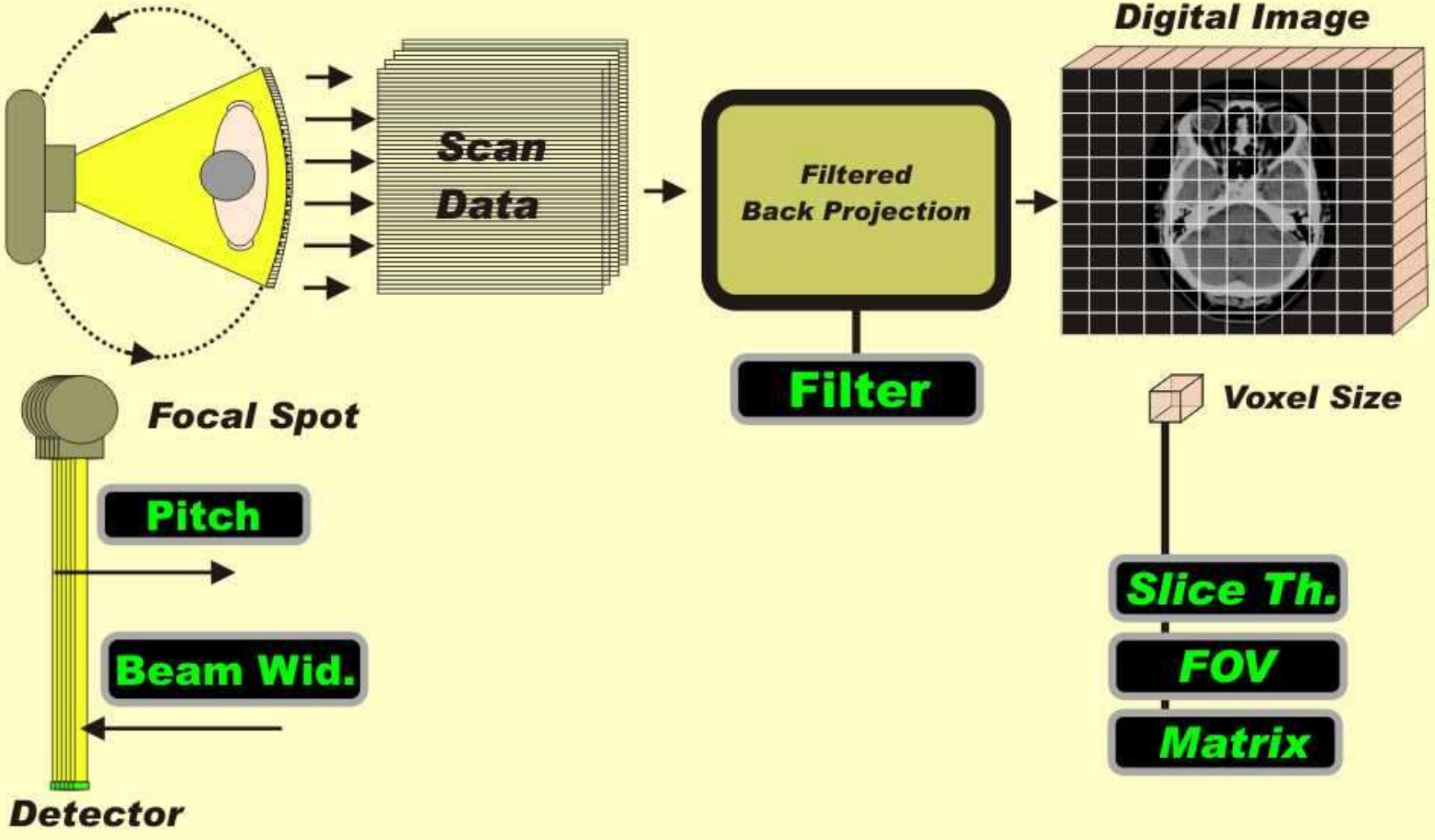
Higher Dose



Dose must be **increased** to **reduce noise.**

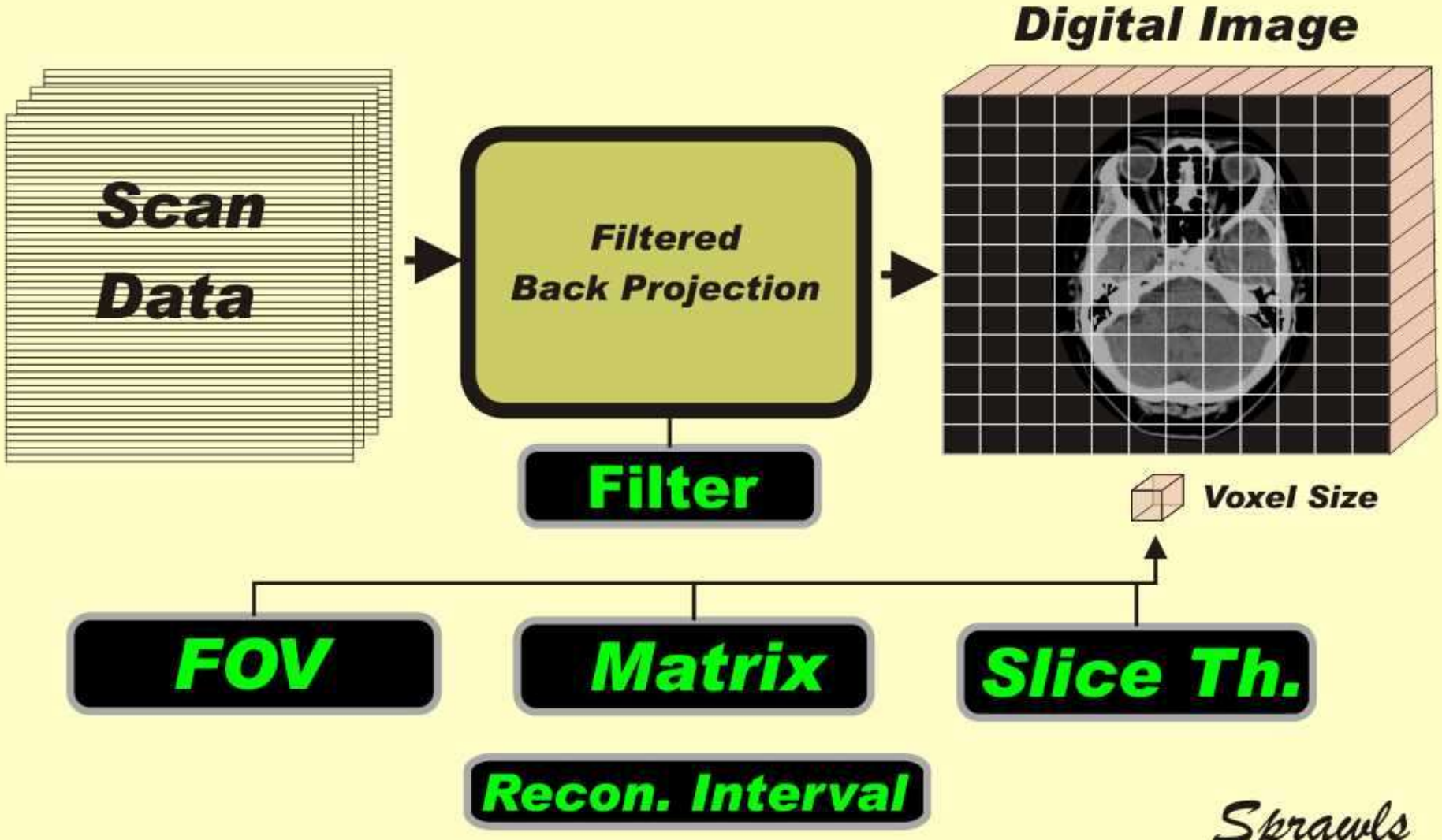
Sprawls

Factors That Determine Image Detail (Sources of Blurring)



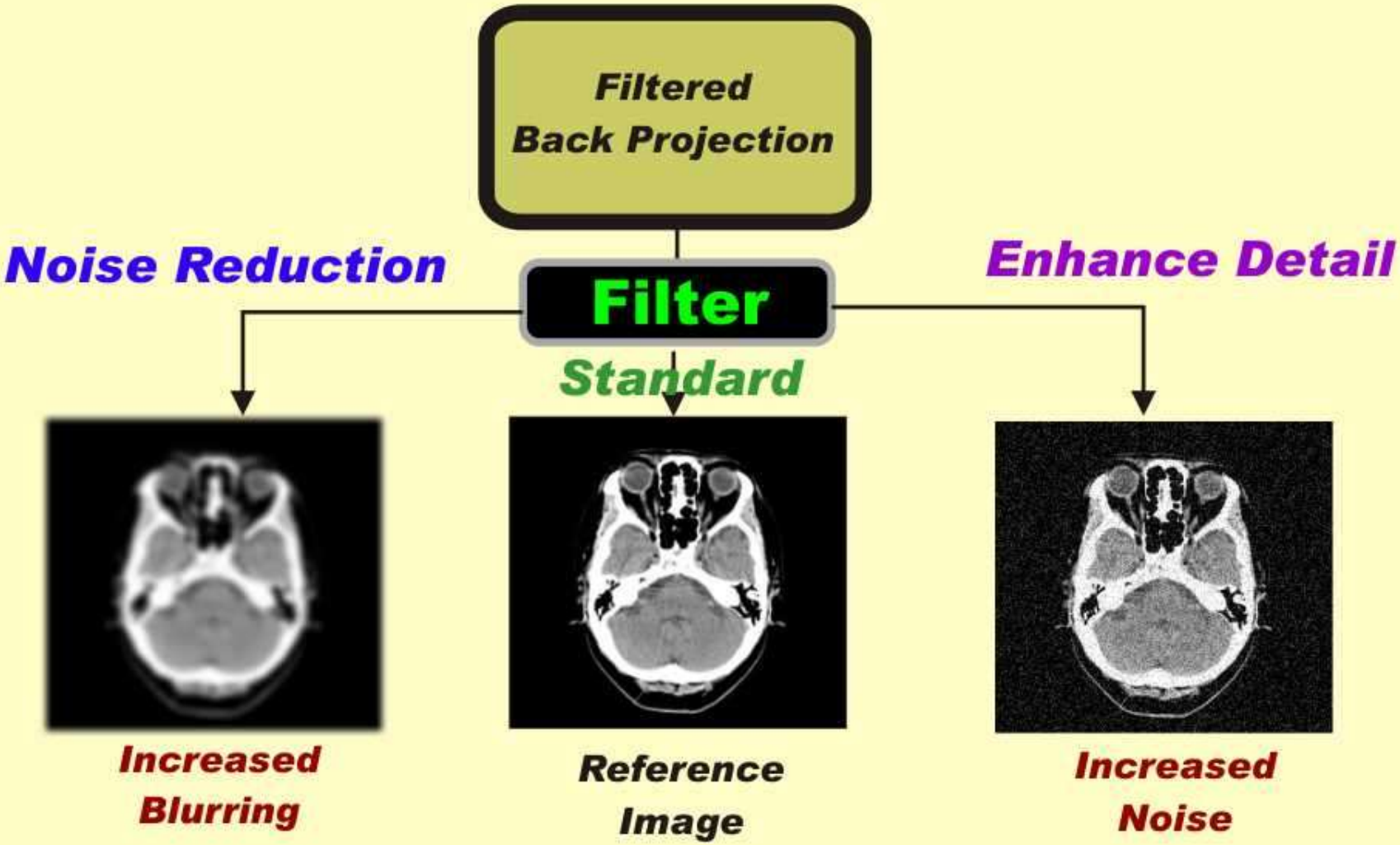
Sprawls

CT Image Reconstruction



Sprawls

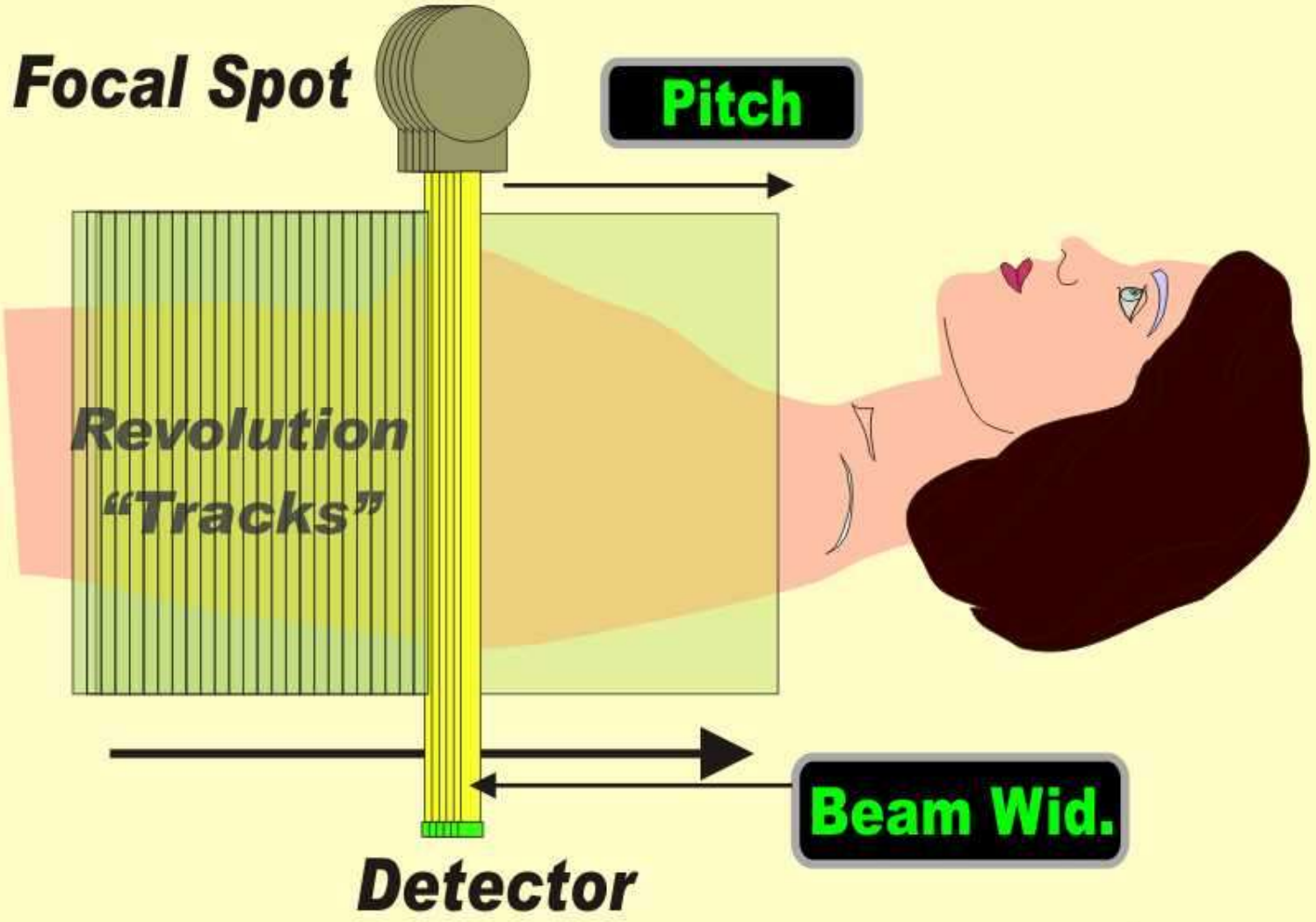
Reconstruction Filter Kernels



(Effects exaggerated for illustration here)

Sprawls

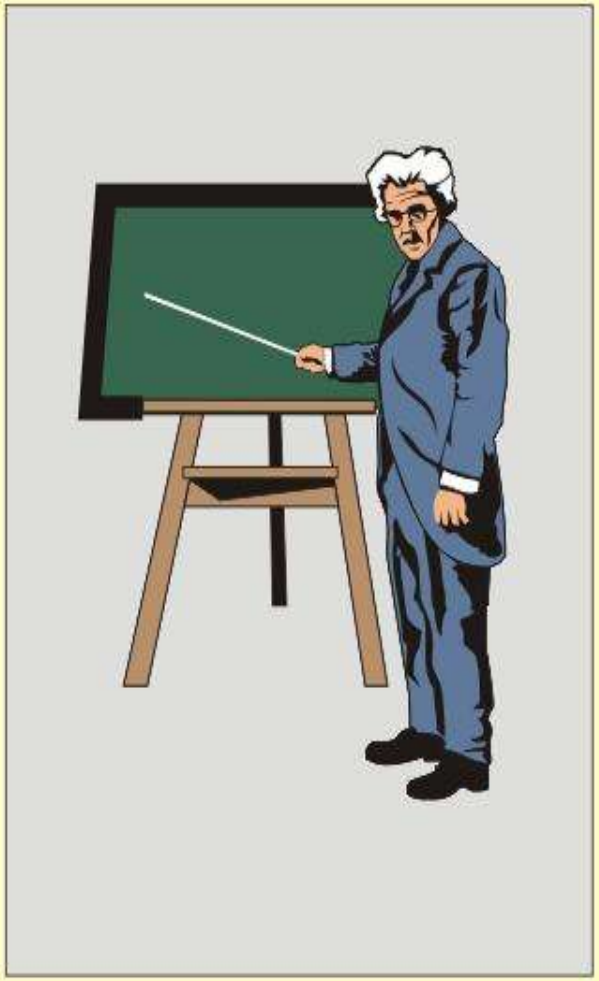
Scan Data Set



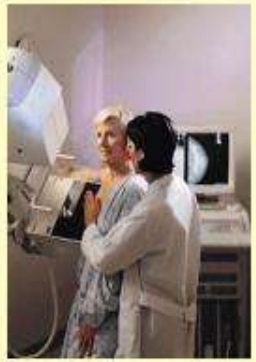
Sprawls

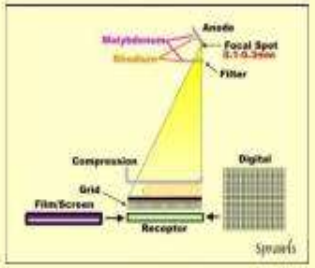
WINDOW
or
BARRIER

THE LEARNERS



PHYSICAL UNIVERSE



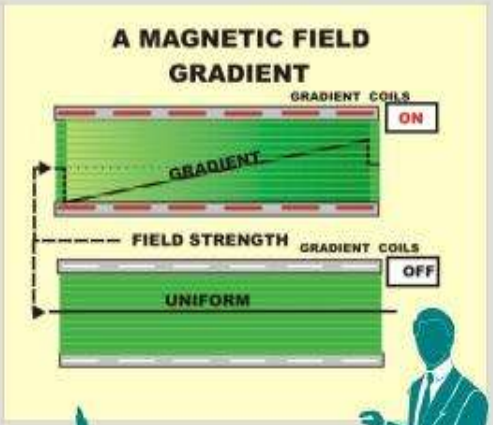


Sprawls

WINDOW or BARRIER

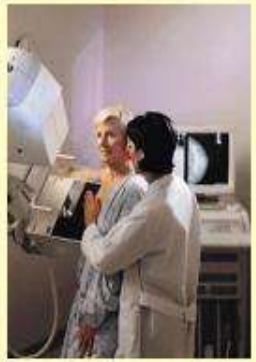
THE LEARNERS

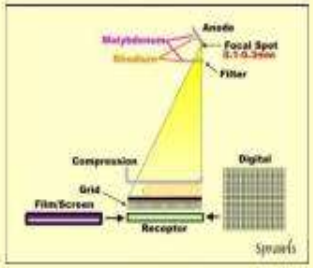
Visuals



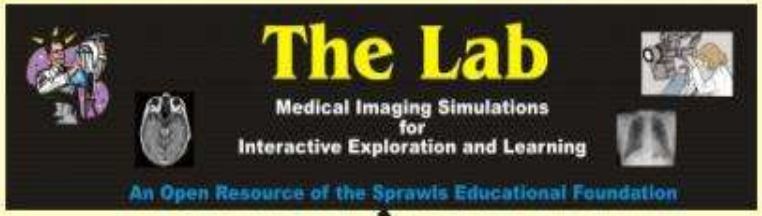
Physicists

PHYSICAL UNIVERSE





Sprawls



In Partnership with Other Medical Physics Teachers

to be More Effective and Efficient in Providing

Medical Imaging Education

Clinically Focused Physics Education

Classroom

Clinical Conference

Small Group

"Flying Solo"

Learning Facilitator
"Teacher"

Individual
and
Peer Interactive
Learning

Each type of learning activity has a unique value.

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Effective Medical Imaging Physics Learning ...In The Clinic

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

The Physicist Provides:
Learning Modules & Collaboration

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Modules for Self Study
and
Collaborative Learning in the Clinic

Computed Tomography Image Quality Optimization and Dose Management

Perry Sprawls, Ph.D.

To step through module, CLICK HERE.
To go to a specific topic click on it below.

Introduction and Overview	Image Quality Characteristics	Contrast Sensitivity
Visibility of Detail	Visual Noise	Spatial (Geometric) Characteristics
Artifacts	Identifying Characteristics	Characteristics Identified
Image Quality and Dose	CT Image Formation Process	The Scanning Motions
Views and Rays	Multiple Row Detectors	Helical and Spiral Scanning
Image Reconstruction and Voxels	CT Numbers	Hounsfield Unit Scale
Optimizing CT Procedures	Absorbed Dose	Dose Distribution Within Patient
CT Dose Index (CTDI)	Weighted CTDI	Volume CTDI
Dose for Multiple Slices	Dose Length Product (DLP)	Effective Dose
Summary of CT Dose Quantities	Factors That Determine Dose	Factors Affecting Image Detail

How to Use This Resource

Table of Contents and List of Topics

Mammography Physics and Technology
for effective clinical imaging

Perry Sprawls, Ph.D.

Outline	Mind Map	Learning Objectives	Visuals for Discussion		Text Reference

To step through module, CLICK HERE.

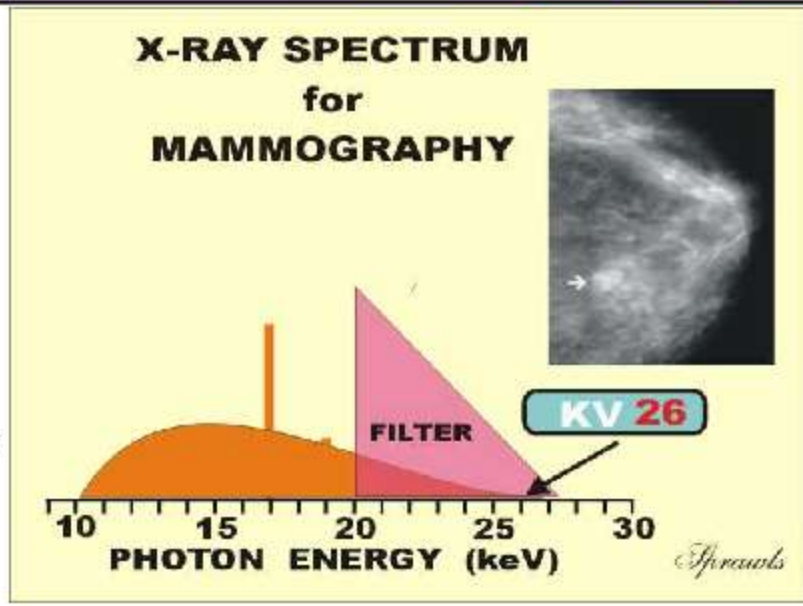
To go to a specific topic click on it below

e x-ray beam spectrum is one of the most critical factors that must be
justed to optimize a procedure with respect to contrast sensitivity and dose.

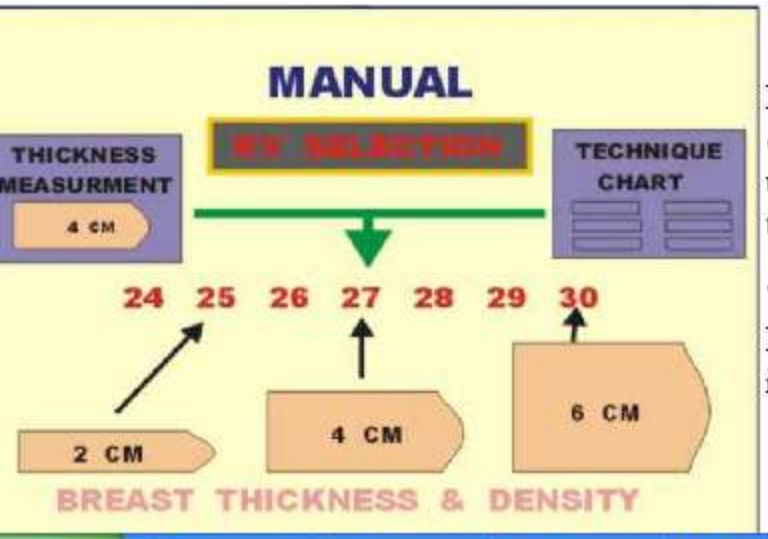
e can think of it as a three-step procedure:

1. Select the appropriate anode (moly or rhodium)
2. Select the appropriate filter (moly or rhodium)
3. Select the appropriate KV (In the range 24 kV to 32 kV)

reasing the KV has two effects on the x-ray beam. It increases the efficiency
d output for a specific MAS value and it shifts the photon energy spectrum
ward so that the beam becomes more penetrating.



hile a more penetrating beam does reduce contrast sensitivity it is necessary
hen imaging thicker and more dense breast. Therefore compressed breast thickness is the principal factor that determines the optimum
V.



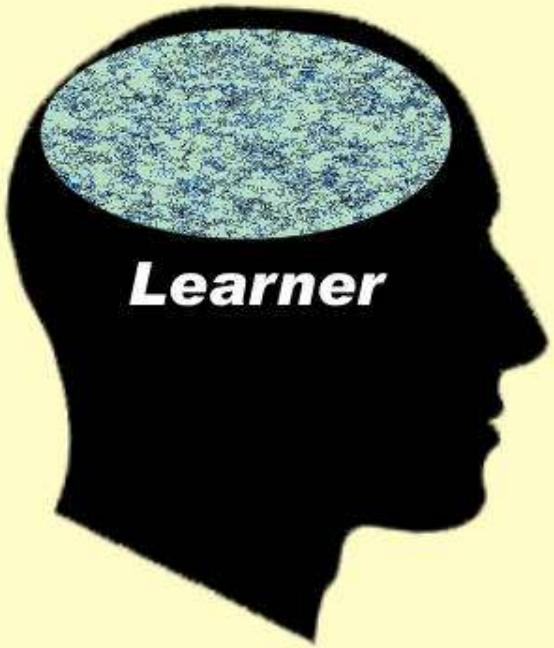
Mammography systems have indicators that display the thickness of the compressed breast. This along with a general assessment of breast density is used to manually select an optimum KV either from experience or an established technique chart.

The general goal is to increase the KV as necessary to keep the exposure time, MAS, and dose to the breast within reasonable limits as breast thickness increases.

Teaching

is helping someone

Building a Knowledge Structure in the Brain



Physical Universe

A mental representation of physical reality

Connect Organize Guide

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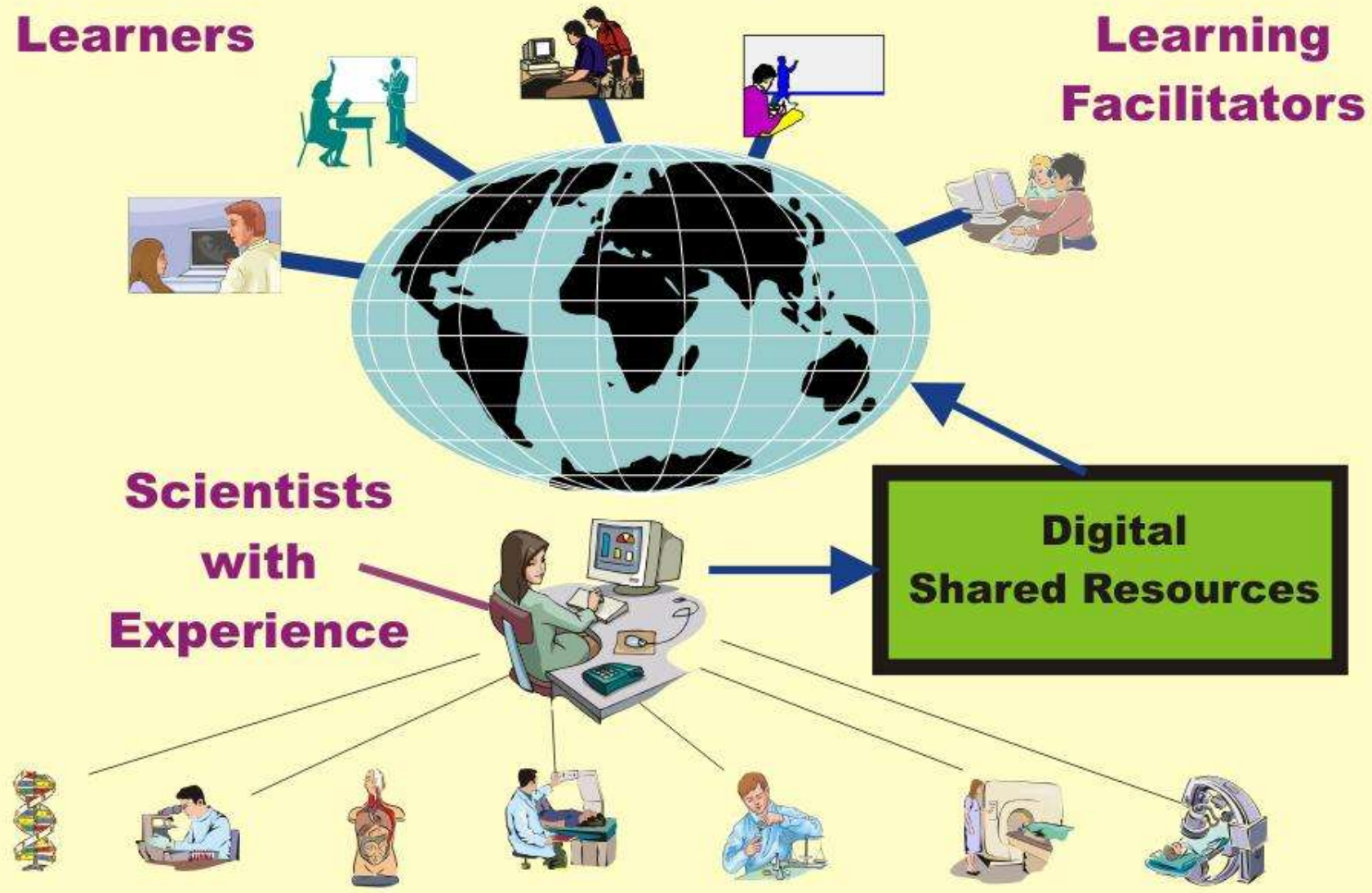
Enriched Learning Environments



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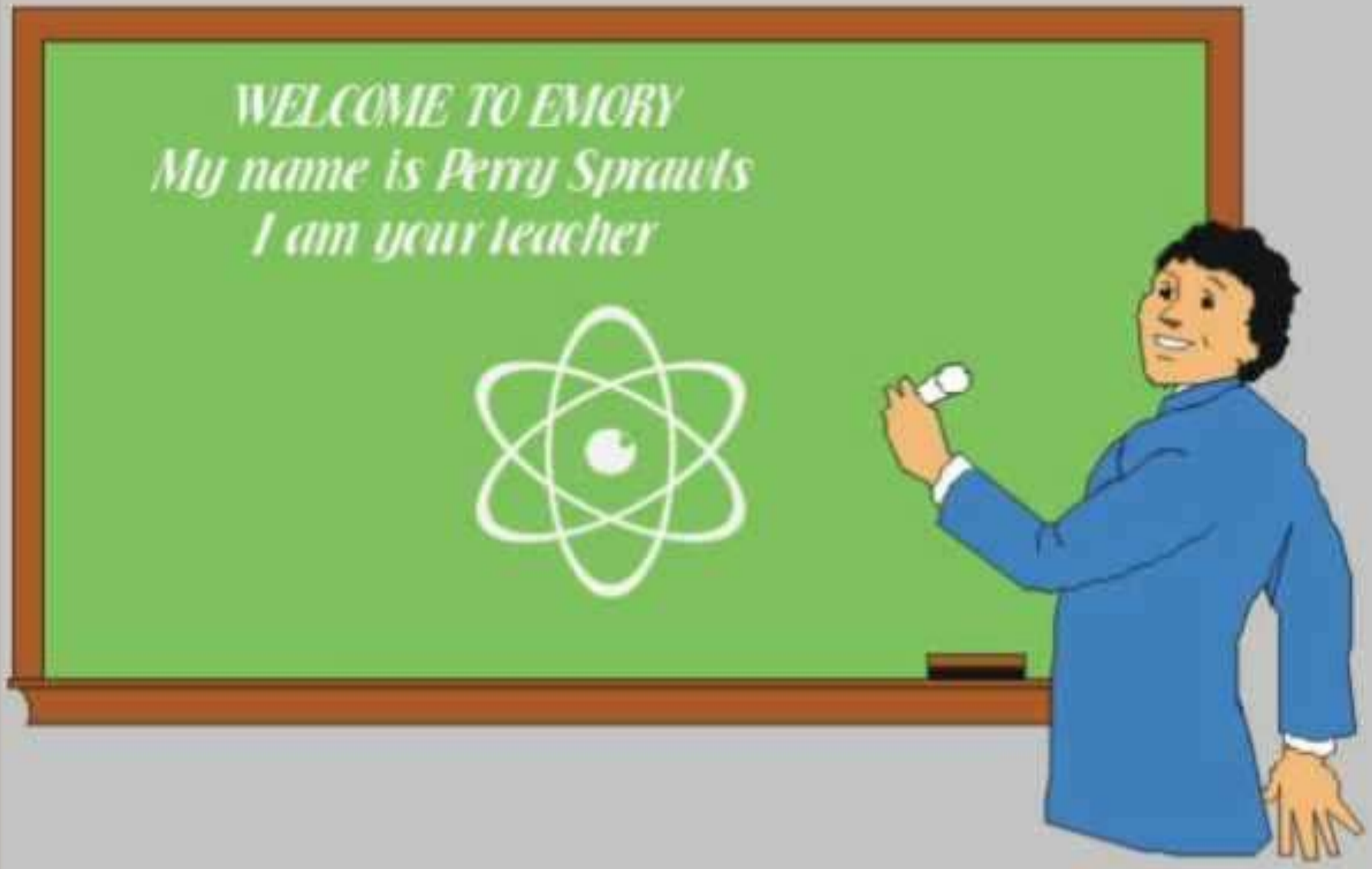
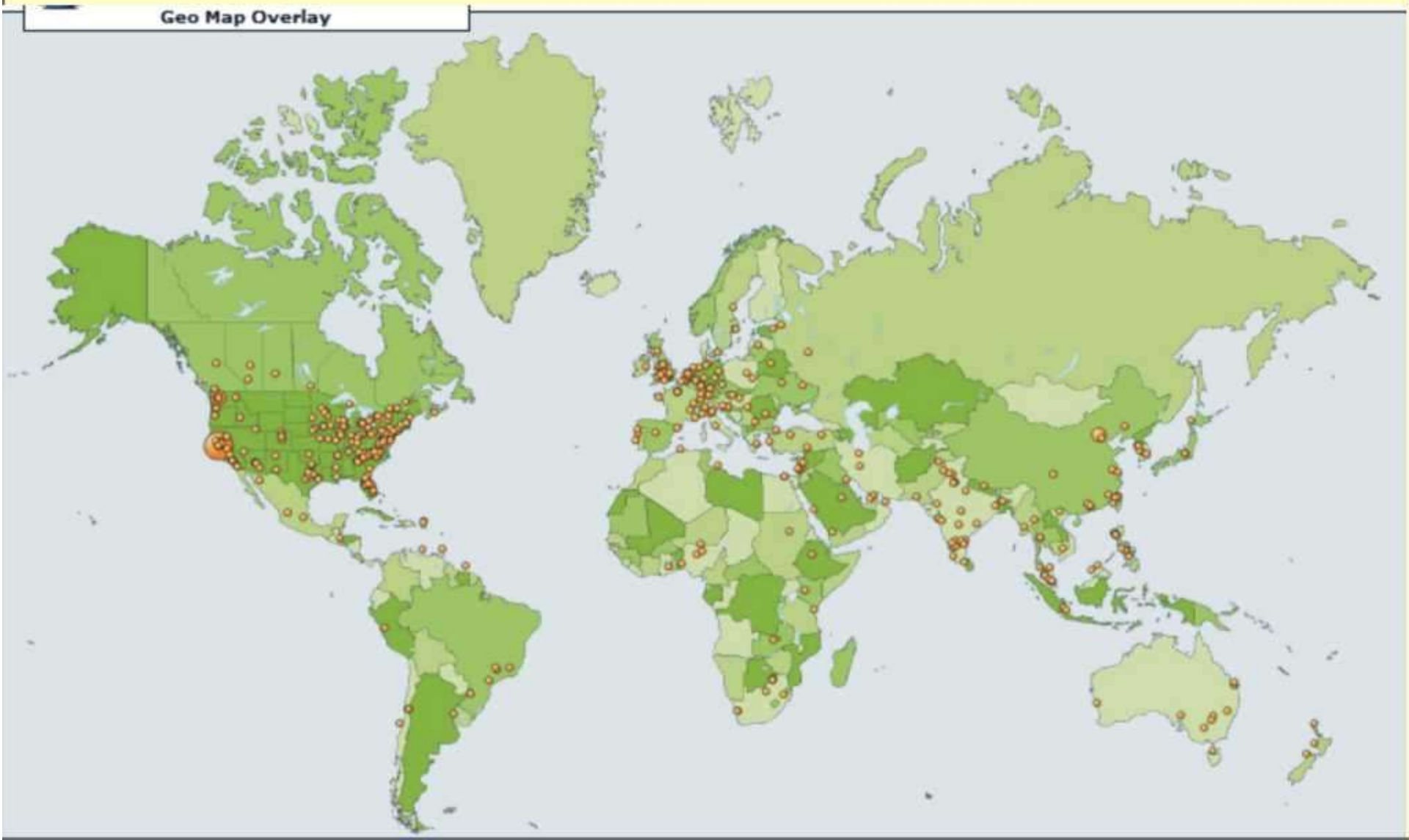
1960



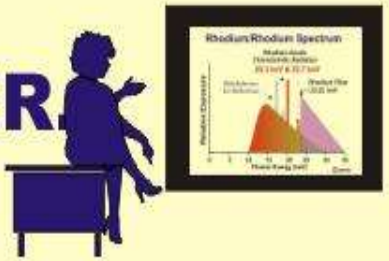
Sprawls Resource Users

Week of July 17-23, 2012



The Values We Hold

The PHYSICIST is the TEACHER.



TECHNOLOGY is the TOOL that can be used for effective and efficient teaching.

Technology should be used to enhance human performance of both learners (residents, students, etc.) And teachers

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Effective
Medical Imaging Physics Education

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