Clinically Focused Physics Education
Principles to Practice

RSNA 2014 RC 823

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Course Website: http://www.sprawls.org/clinphys

To View on iPad: http://www.sprawls.org/ipad


EXIT
EXIT

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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Our Learning Objectives

- ***Describe*** *the general characteristics of mental knowledge structures of physics and technology that are required for effective clinical applications.*

Describe *the conditions and activities that contribute to the formation of effective knowledge structures.*

Identify *the different levels of learning that can occur and relate them to specific actions that can be performed and potential outcomes.*

Analyze *various learning activities for effectiveness and efficiency in producing desired outcomes with available human effort and resources.*

Identify *the opportunities to use digital technology to enhance human performance for both learners and learning facilitators*

Identify *resources that can be used to optimize the effective-efficiency relationship of learning activities.*

Provide ***effective learning activities.***

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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Our Learning Objectives

Clinical Radiology

DO

Effective Knowledge Structures

Levels of Learning

LEARN PHYSICS

Learning Activities **Effectiveness** and **Efficiency**

RESOURCES

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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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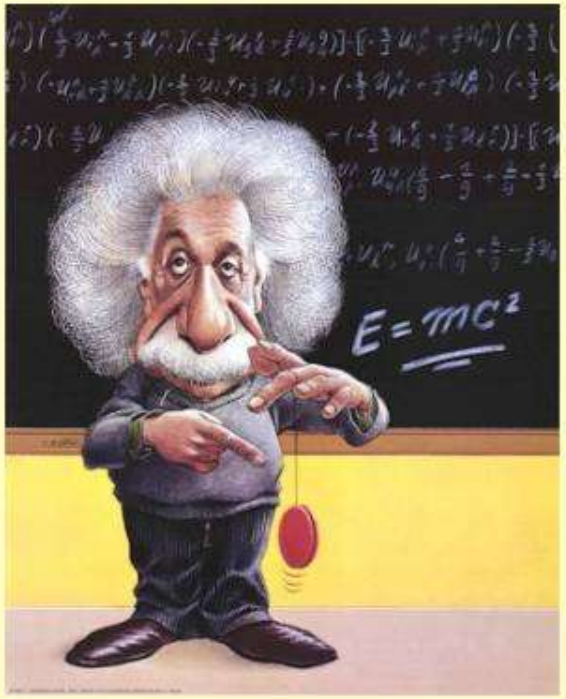
The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.



Be EFFICIENT in our teaching

Challenges Opportunities

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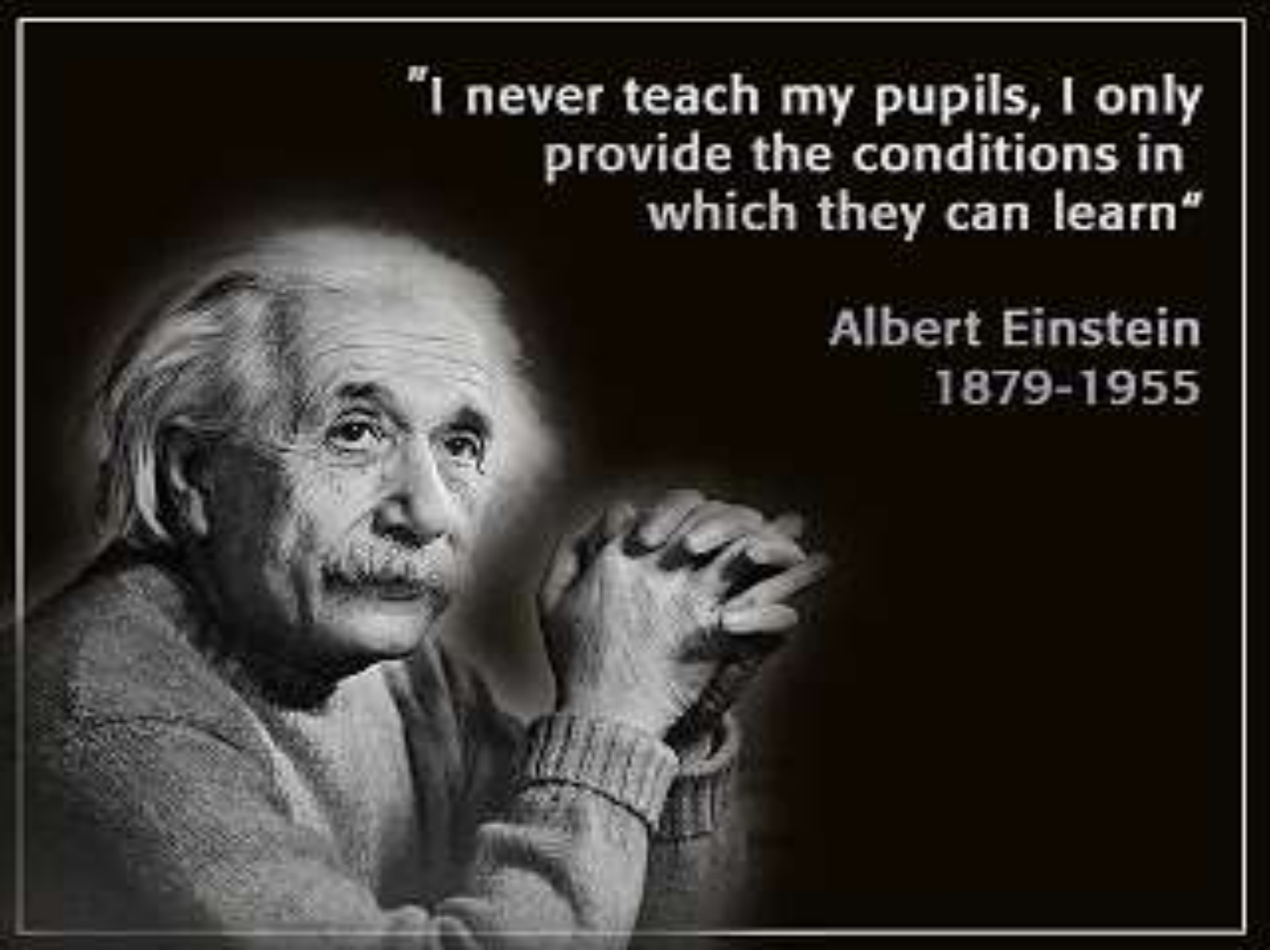
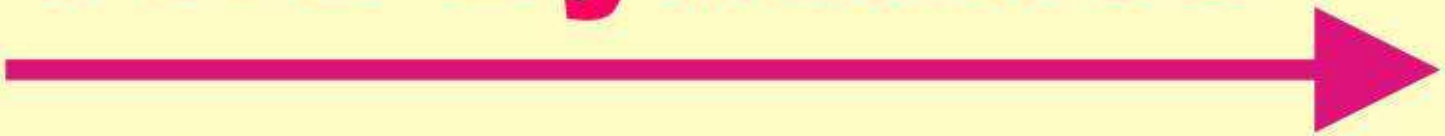

"I never teach my pupils, I only provide the conditions in which they can learn"
Albert Einstein
1879-1955

Five Dynamics



“ It’s a new ball game!”

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

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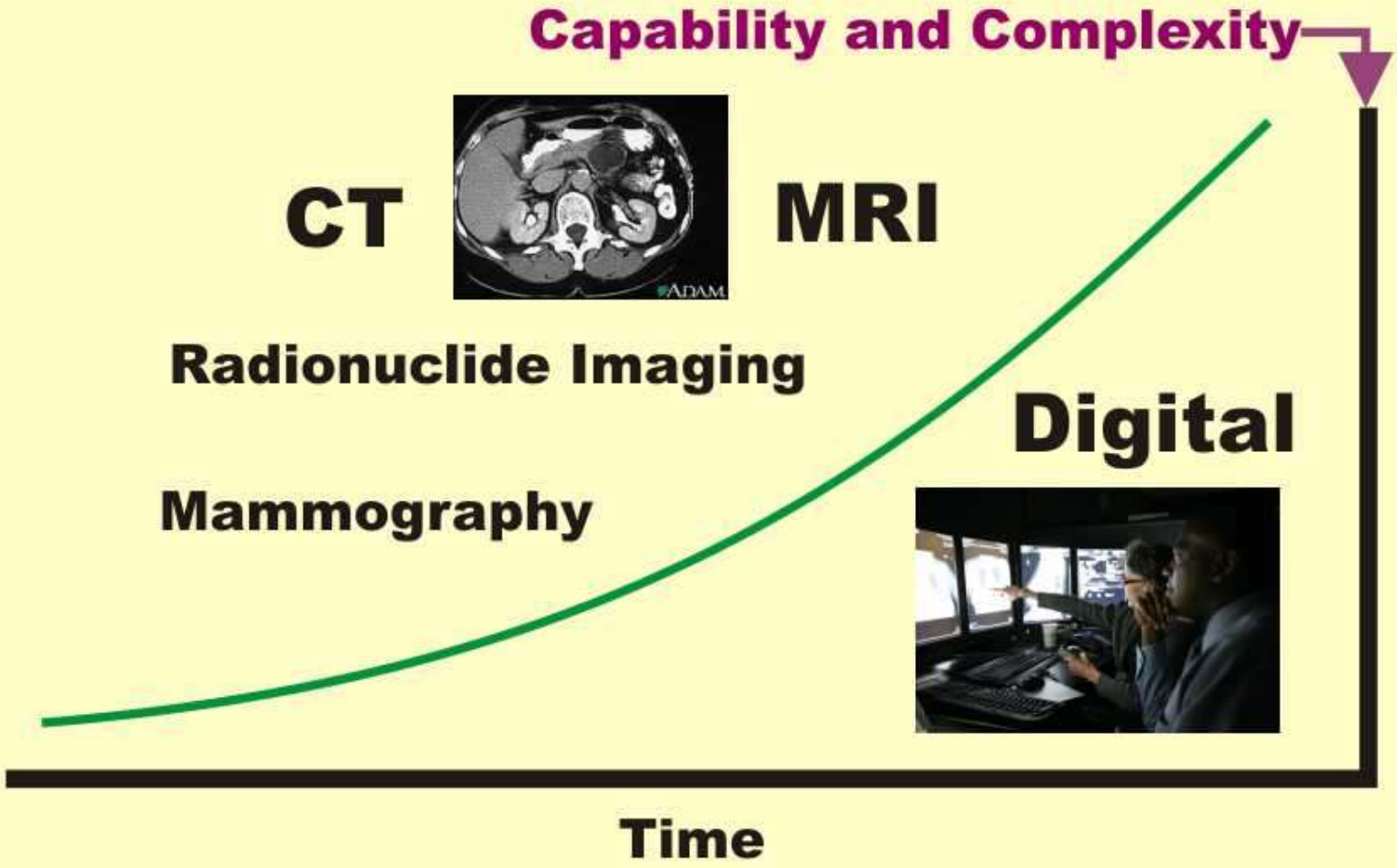
Continuing Growth in the Need for Physics Knowledge



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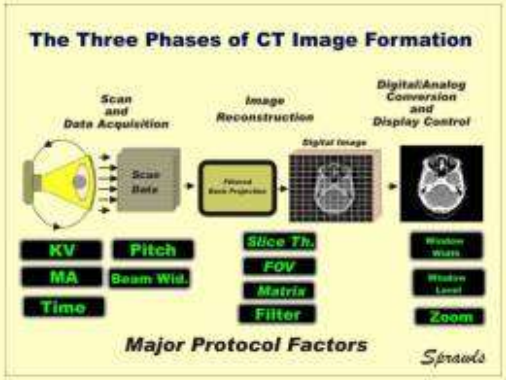
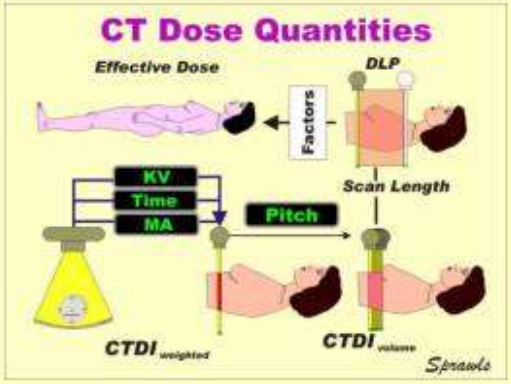
Capability & Complexity

(Computed Tomography)





Years

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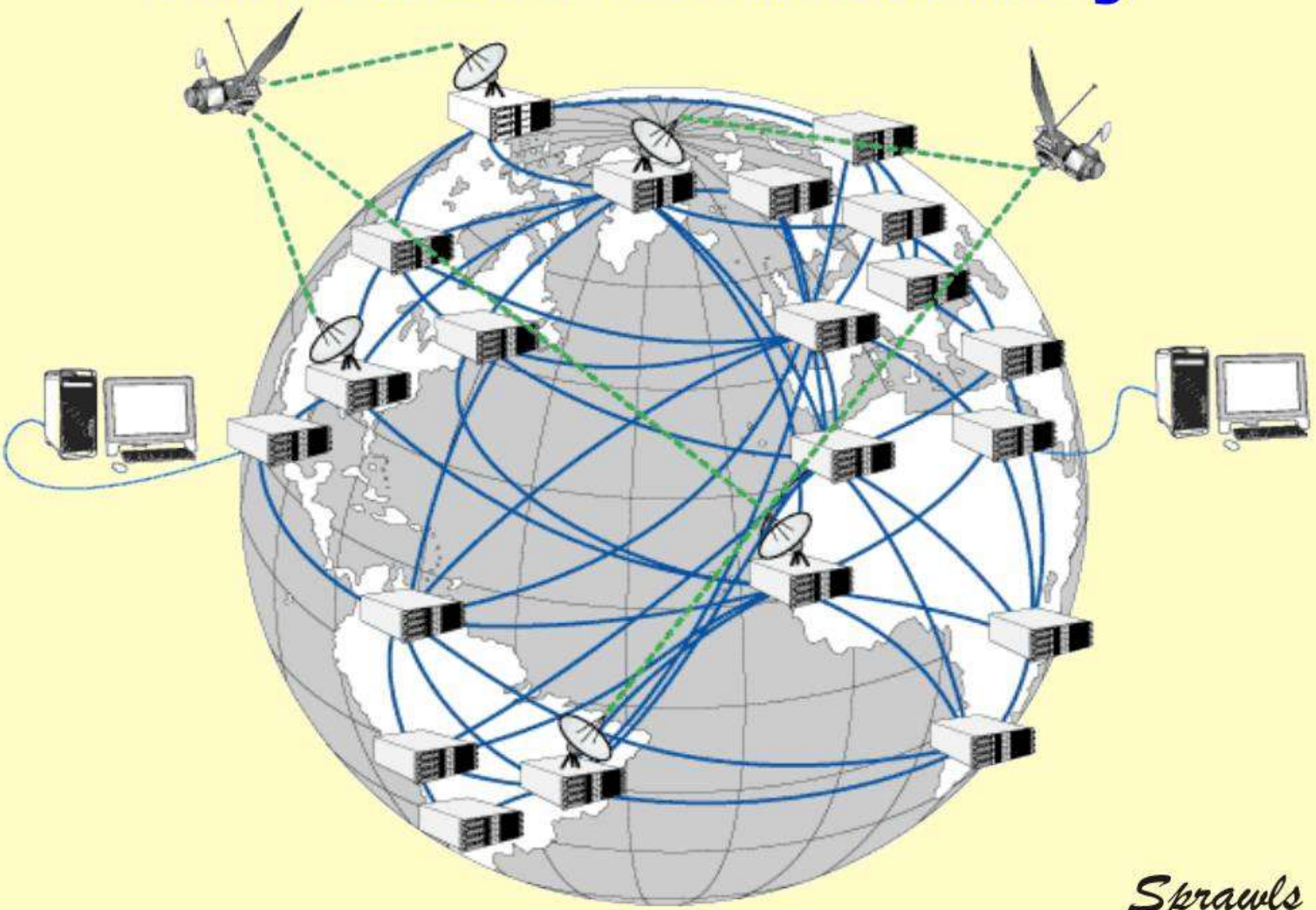
Increased Connectivity



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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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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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LEARNING is.....

Building a knowledge structure in the brain.

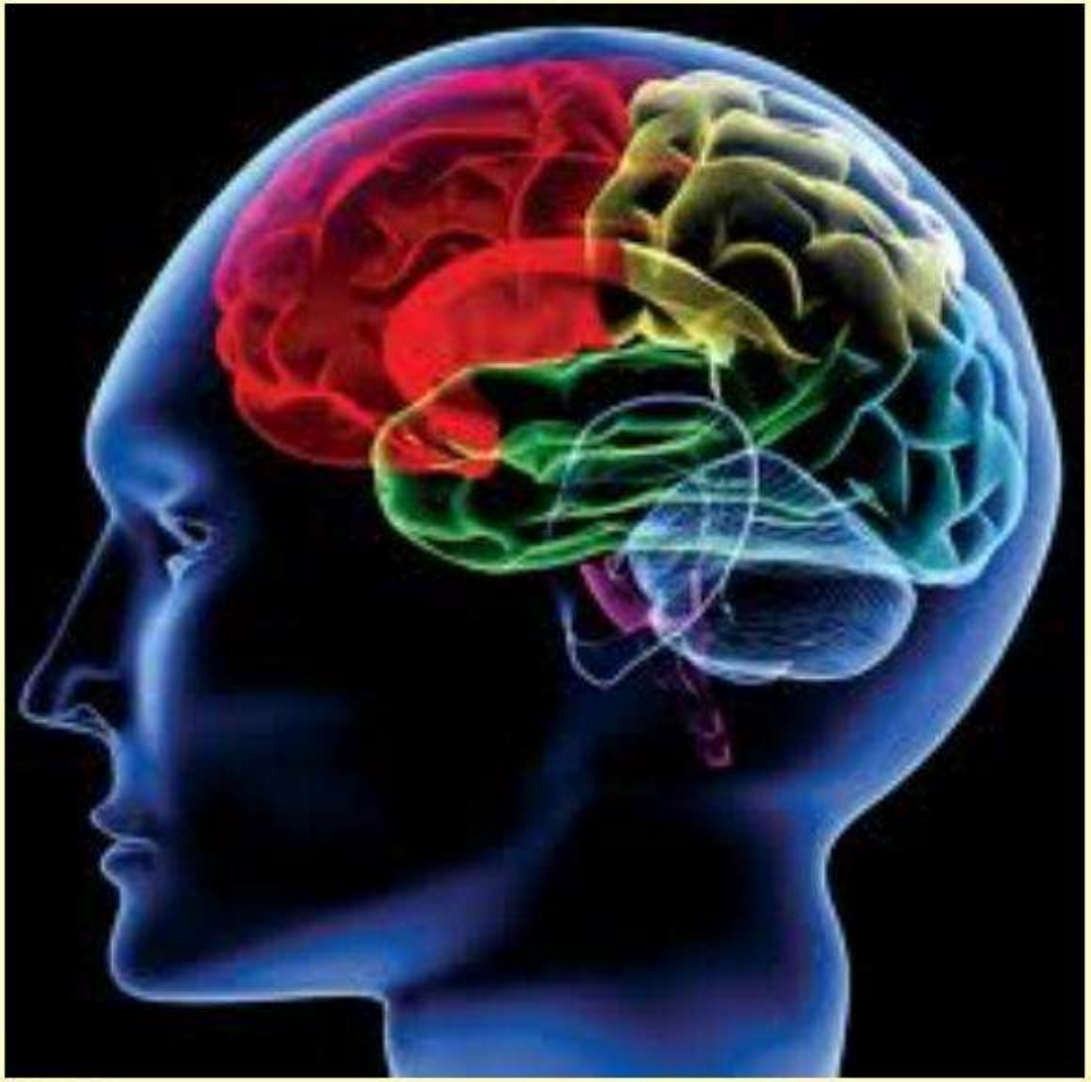

Image from the Web

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LEARNING PHYSICS is.....

Building a knowledge structure in the brain

by Encounter and Experience

Physical Universe

Sprawls

LEARNING PHYSICS is.....

Building a knowledge structure in the brain

by Encounter and Experience

Things That Are Visible

Physical Universe (Automobiles)

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LEARNING PHYSICS is.....

Building a knowledge structure in the brain

by Encounter and Experience

Physical Universe (Pets)

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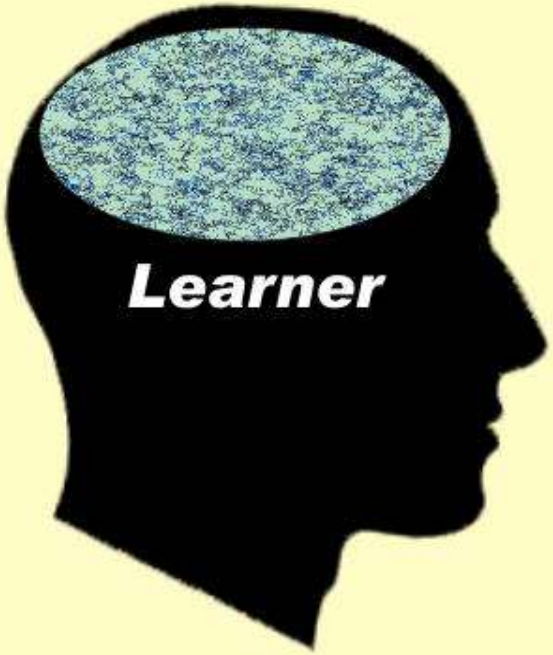
Learning Physics
is
Building a Knowledge Structure
in the Brain



Physical Universe

A mental representation of physical reality

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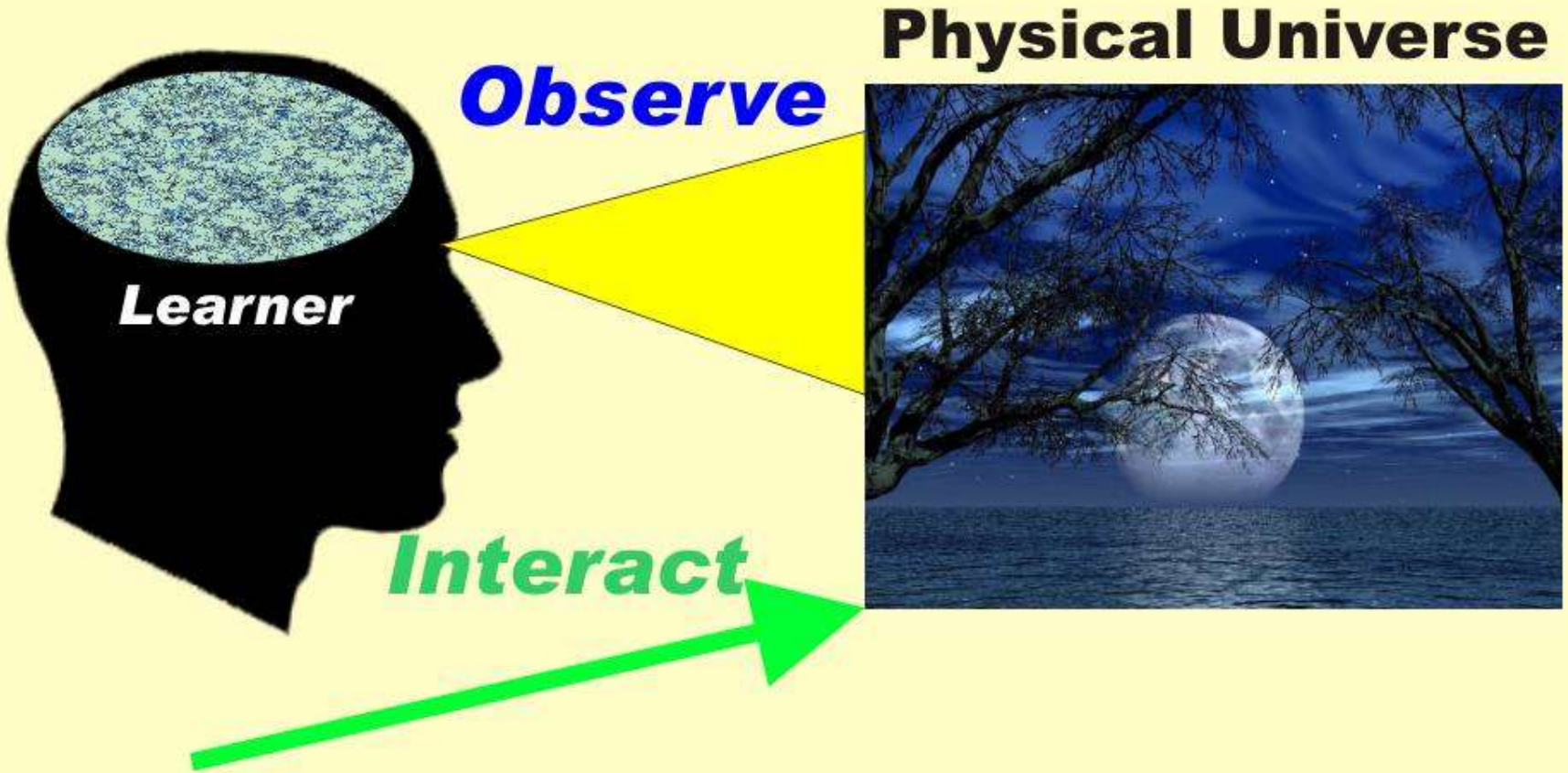
Learning is a Natural Human Process

We Learn by Experience



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LEARNING PHYSICS is.....

A Natural Human Process

....Like Breathing, Eating, etc

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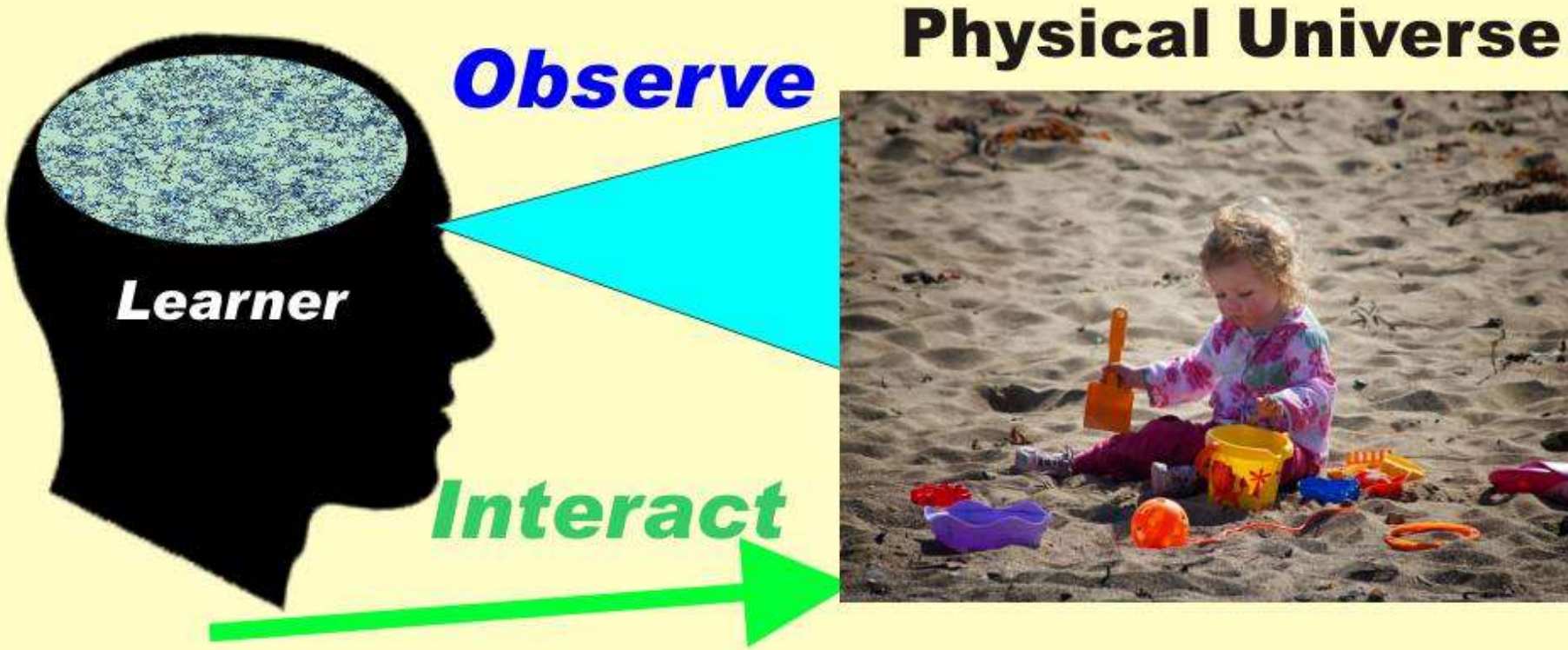
Learning is a Natural Human Process

We Learn by Experience



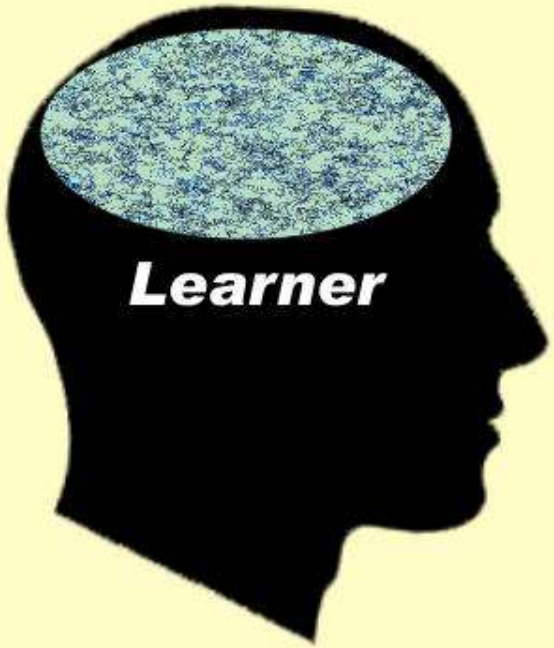
Our Early Physics Learning Activities

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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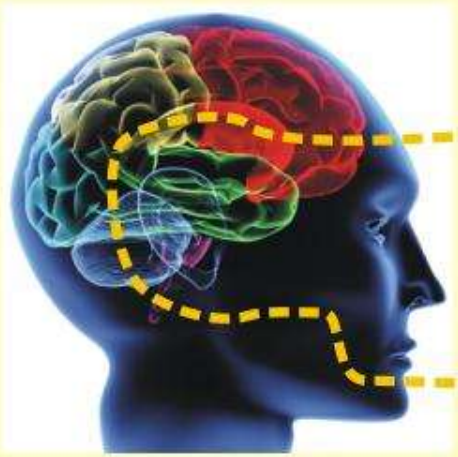
The Elements of
A Highly Effective Educational Session

The Brain

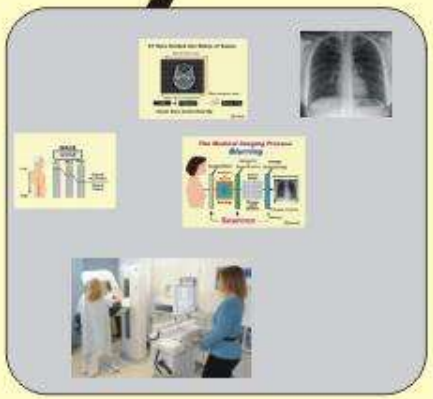


Connection

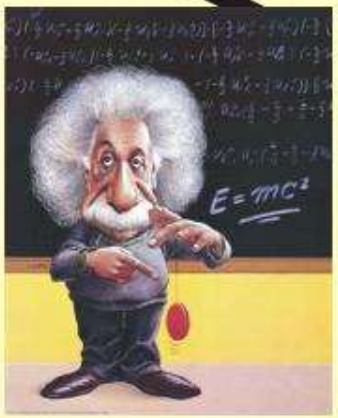
Observe

Interact

The Physical Universe
(Physics of Medical Imaging)



"Window"



Teacher /Guide

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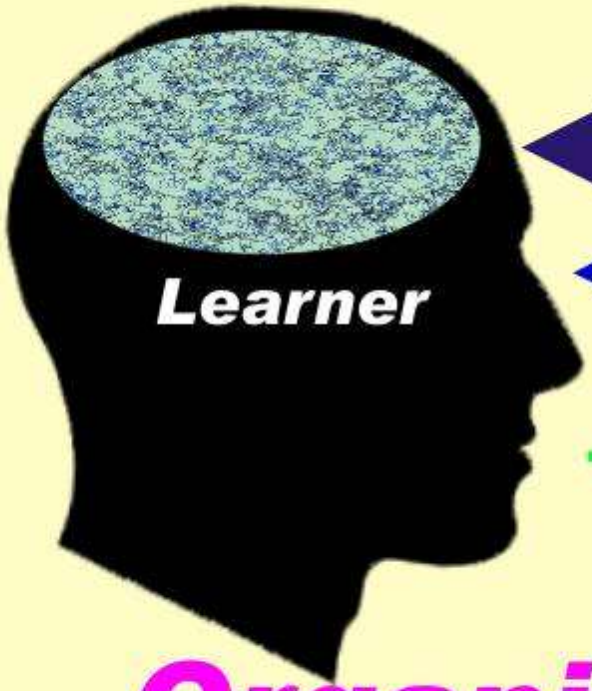
The Role of Formal Education

Connect

Physical Universe



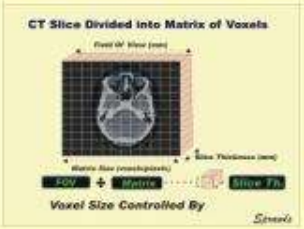
Observe

Interact

Organize and Guide

The Traditional Classroom

" A Box for Enclosing Students..."



And hiding them from the world about which they should learning.

The Barrier

Physics Education

Clinical Imaging

Efficiency

Location, Resources, Human Effort, Cost

Limited Experience

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Collaborative Teaching

Physicists
With Clinical Experience

Resources

Organize, Guide, Share Personal Experience

Physicists, Radiologists, Technologists

Local

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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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The Sprawls Resources

Sharing the Emory Experience with the World

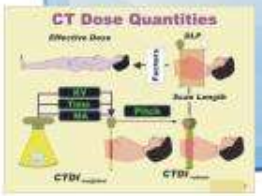
With Emphasis on the Developing Countries

Emory

www.sprawls.org/resources

Open Access

Educational Resources



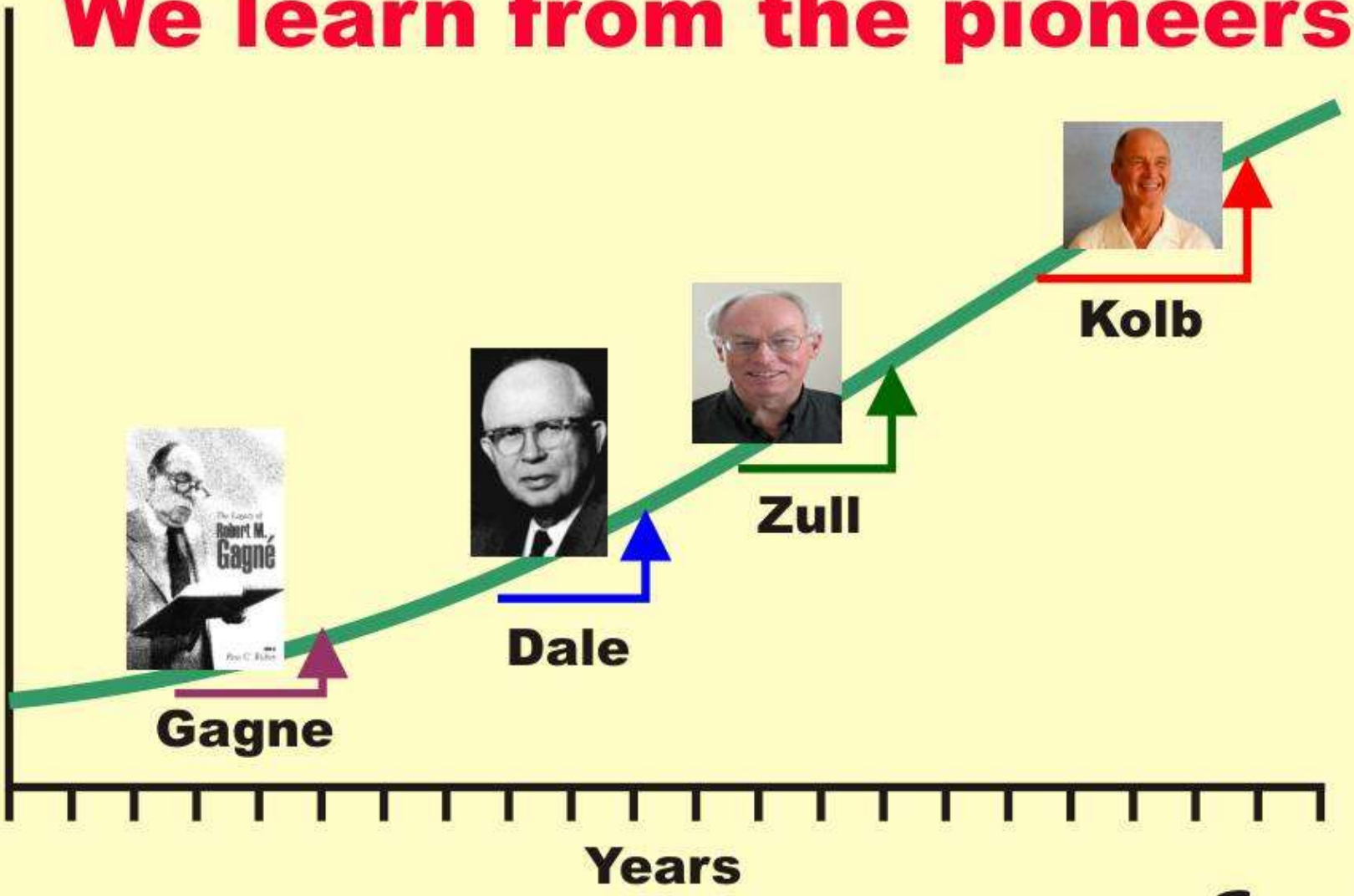
Visuals **Books** **Modules**

Global Impact

Enhancing Radiology Education in Every Country of the World

Knowledge of the Learning & Teaching Process

We learn from the pioneers



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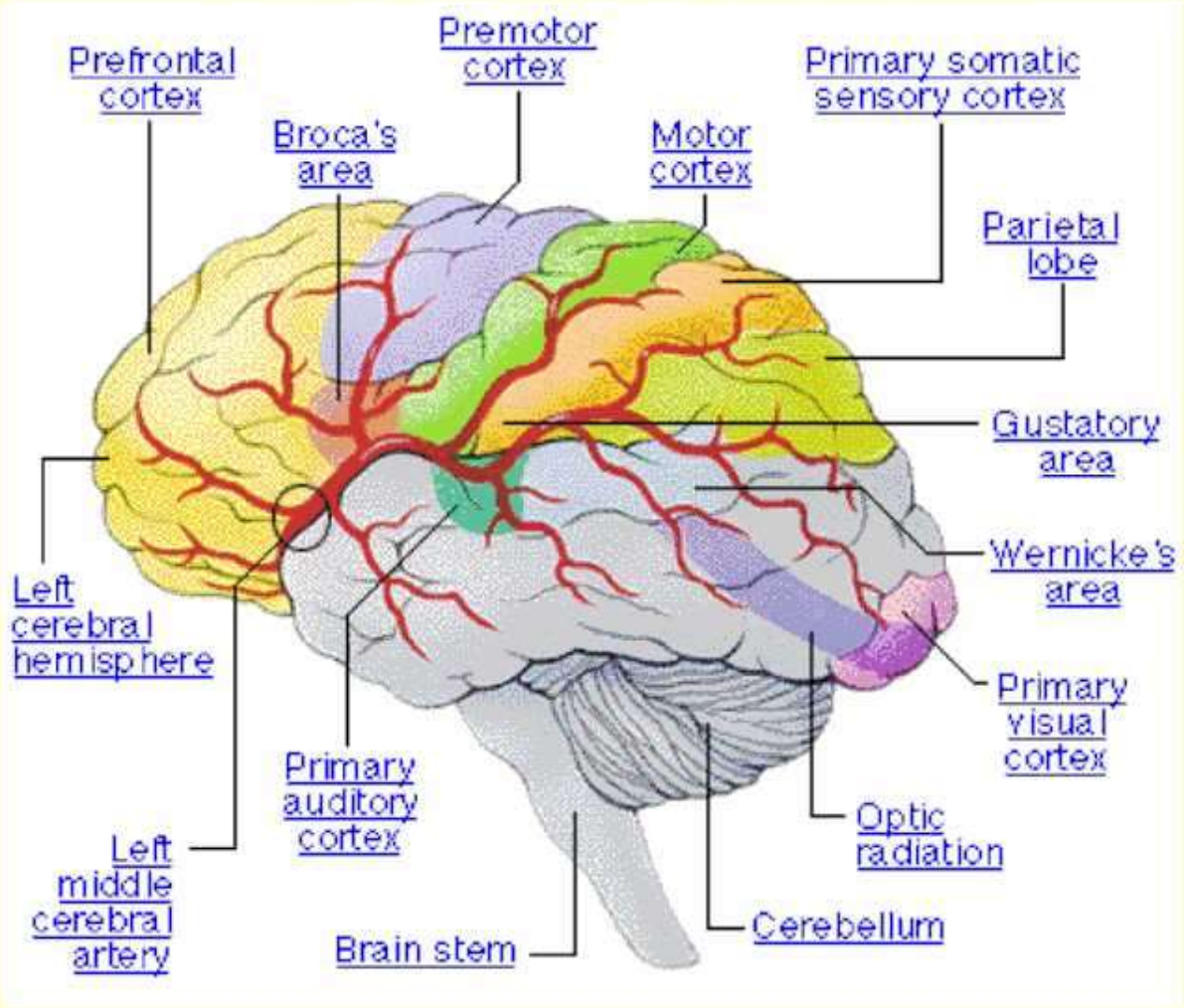
The Brain...



Structure and Function

Image: AMA

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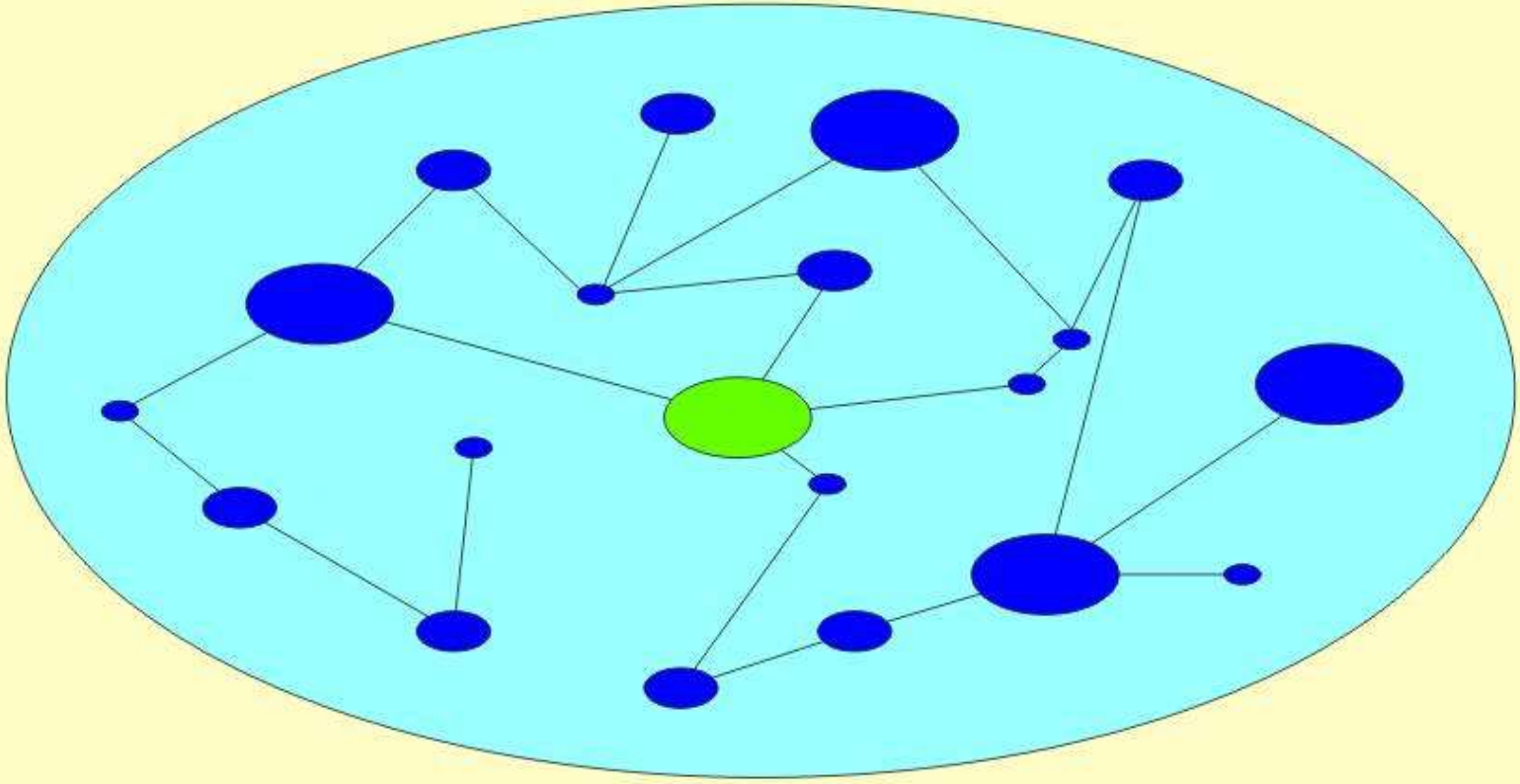
Knowledge Structures in the Brain

A Complex Network



Concepts **Facts**

Images **Language**

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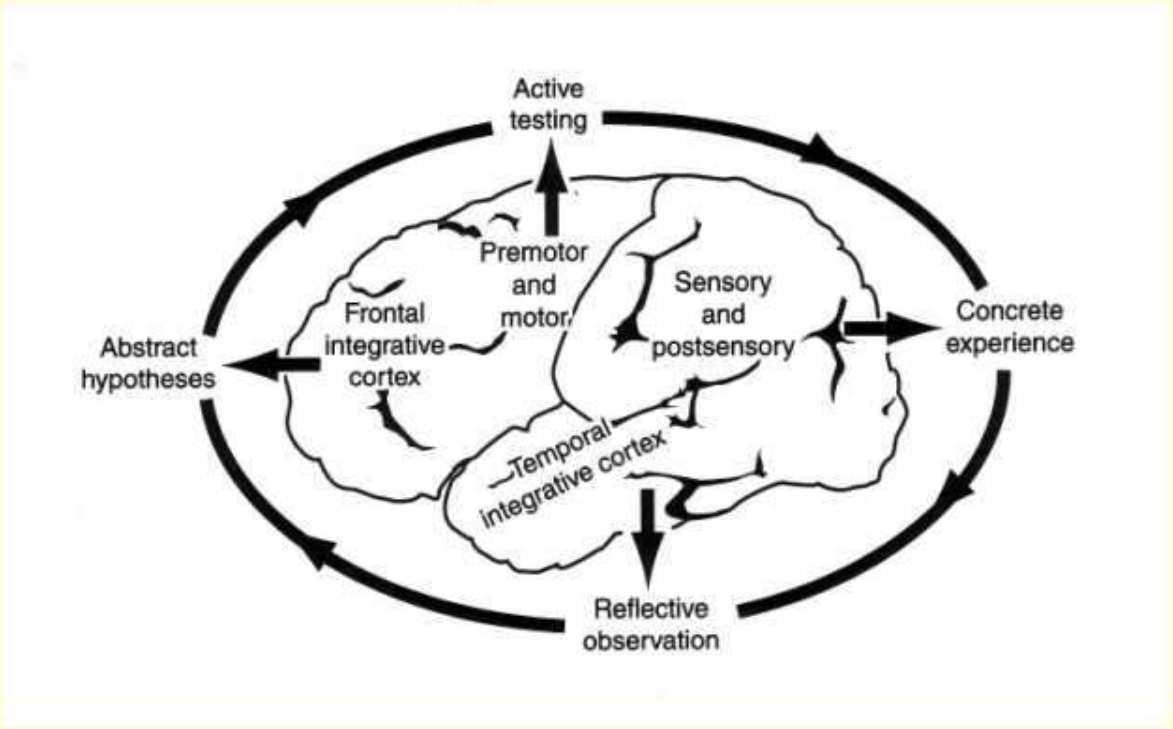
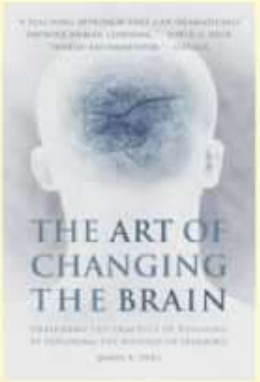
Zull's Model of Brain Function

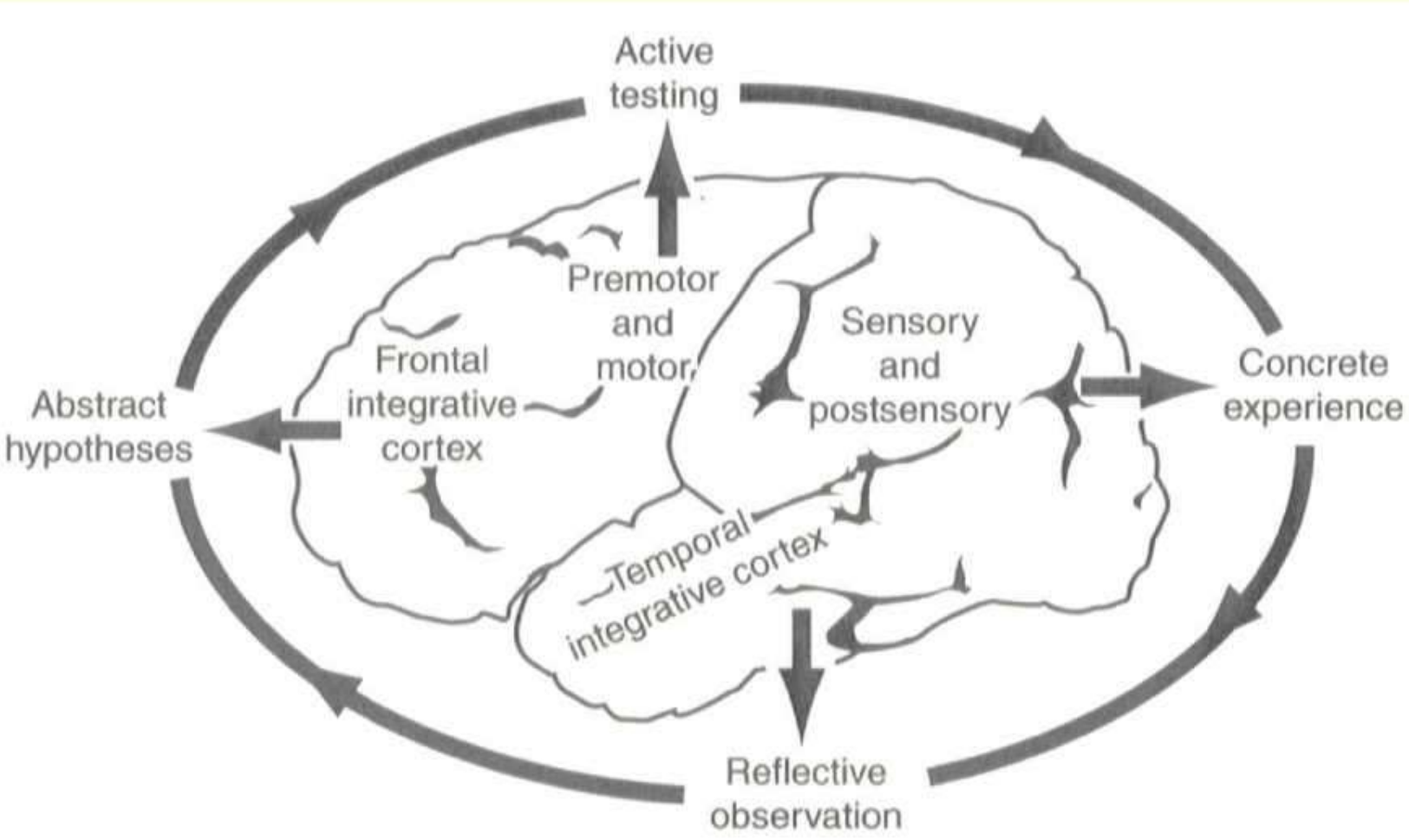


James Zull, Ph.D.
Professor of Biology
Professor of Biochemistry
Director of University Center for Innovation in Teaching and Education
Case Western Reserve

Reference:



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

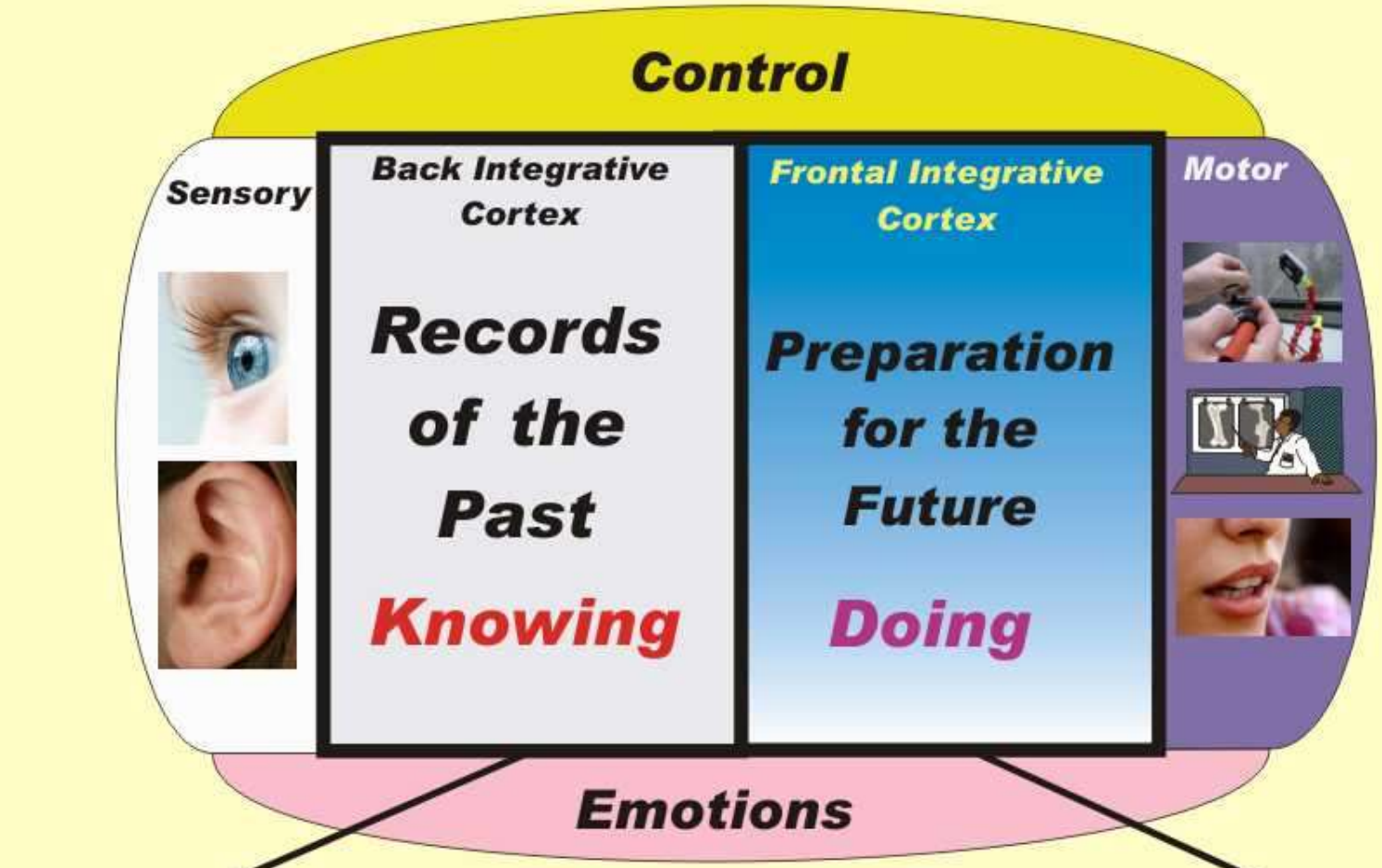
Doing

Motor

Emotions

Sprawls

Brain Functions for Learning Physics



Balanced Education

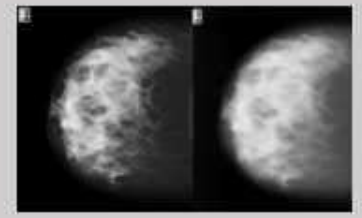
Sprawls

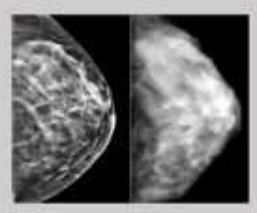
Forming Knowledge Structures

Physical Universe

Sensory

Back Integrative Cortex





Visible Physical Objects

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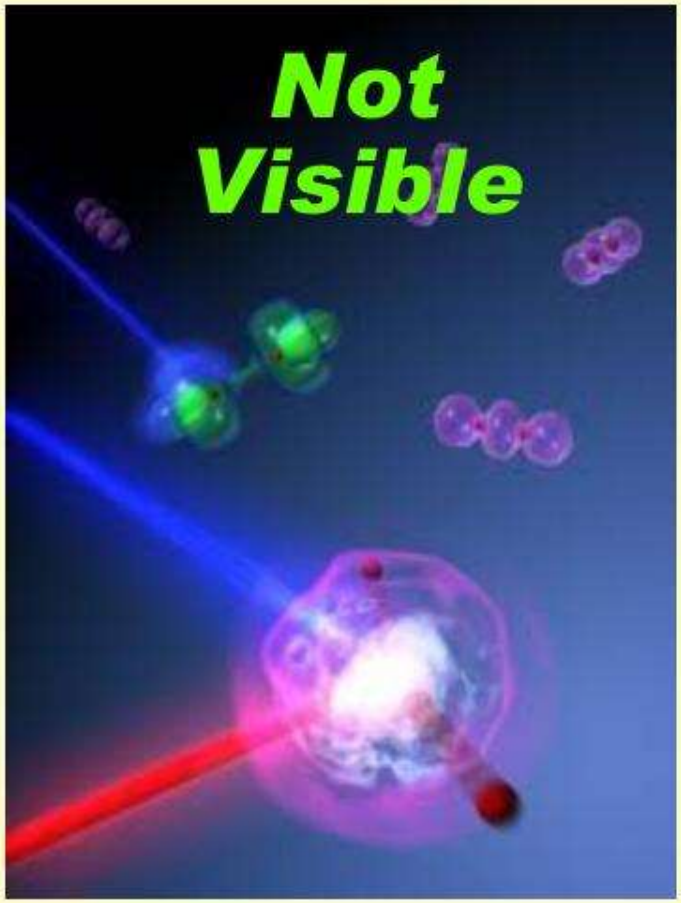
LEARNING PHYSICS is.....

Building a knowledge structure in the brain

by Encounter and Experience



"Window"

Physical Universe

Sprawls

LEARNING PHYSICS is.....

Building a knowledge structure in the brain

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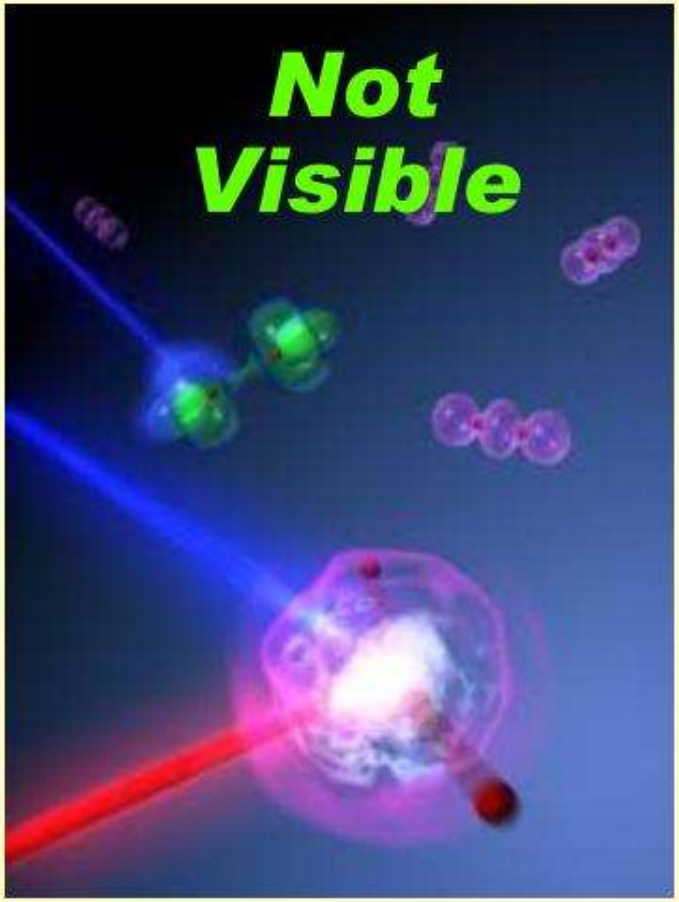
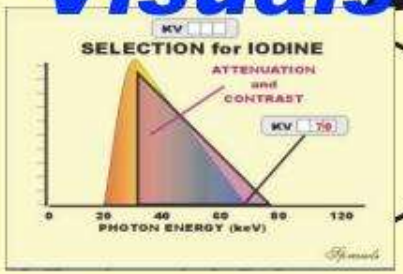


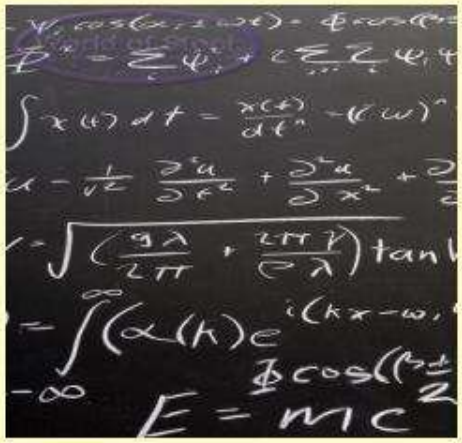
Physical Universe

Words

"Window"

Visuals





Equations

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The Physical Universe

The inverse square law is.....

Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th

X-ray beam now covers four times the area

The Inverse Square Law

$$\frac{I_1}{(I_2)} = \frac{(d_2)^2}{(d_1)^2}$$

I_1 is the initial intensity of radiation, d_1 is the initial distance, and d_2 is the final distance, and I_2 is the final intensity.

Verbal

Sensory

Mathematical

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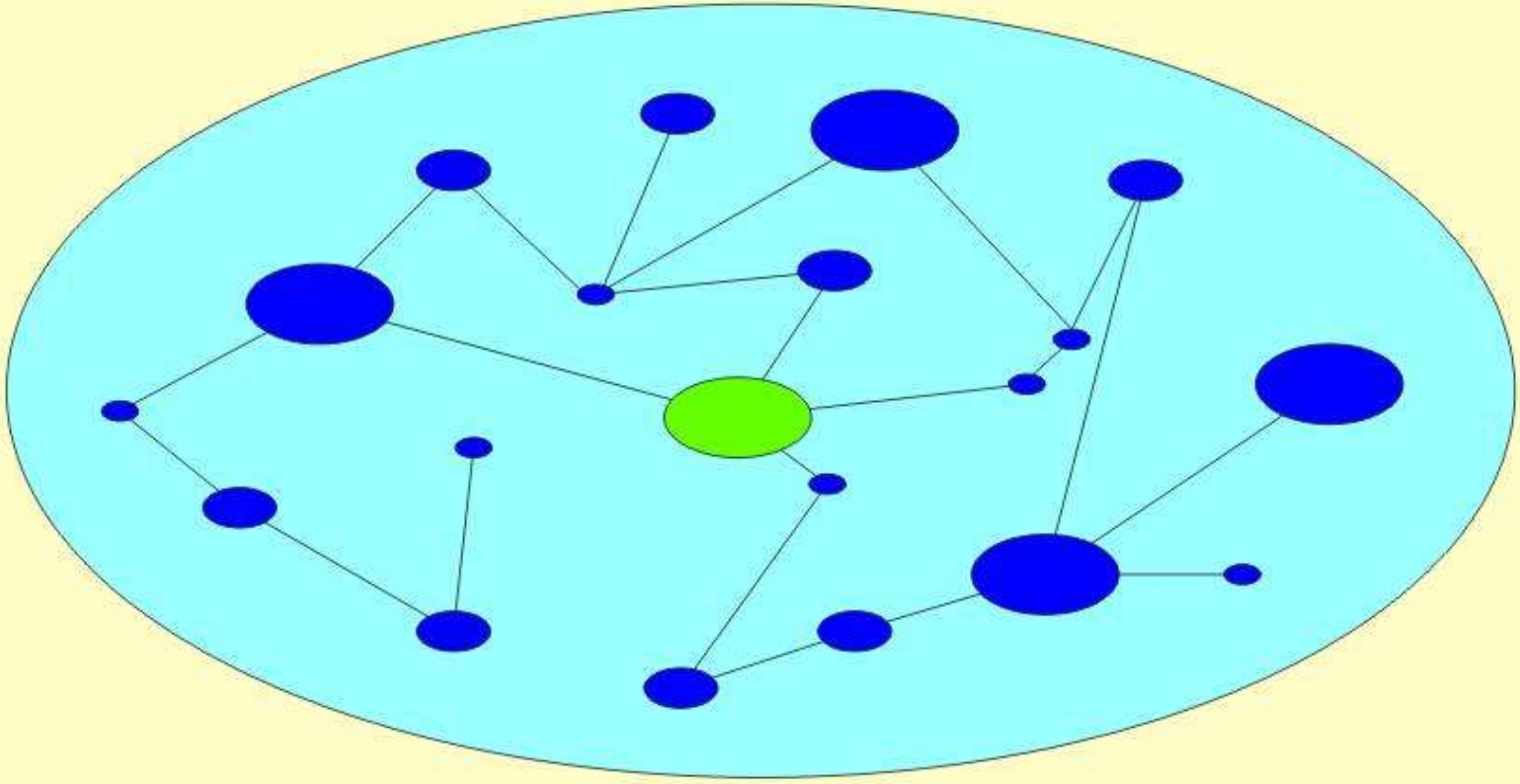
Knowledge Structures in the Brain

A Complex Network



Concepts **Facts**

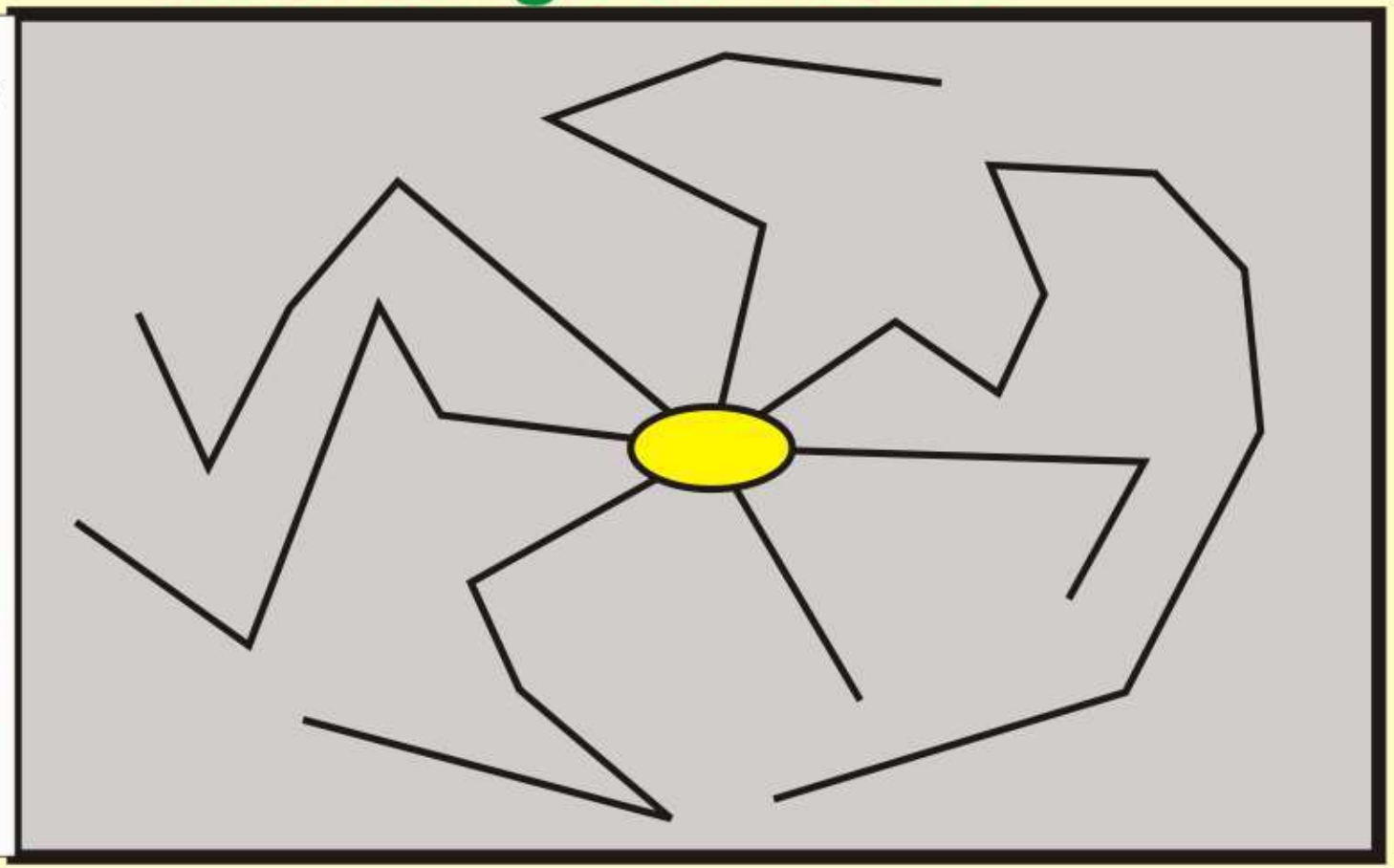
Images **Language**

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



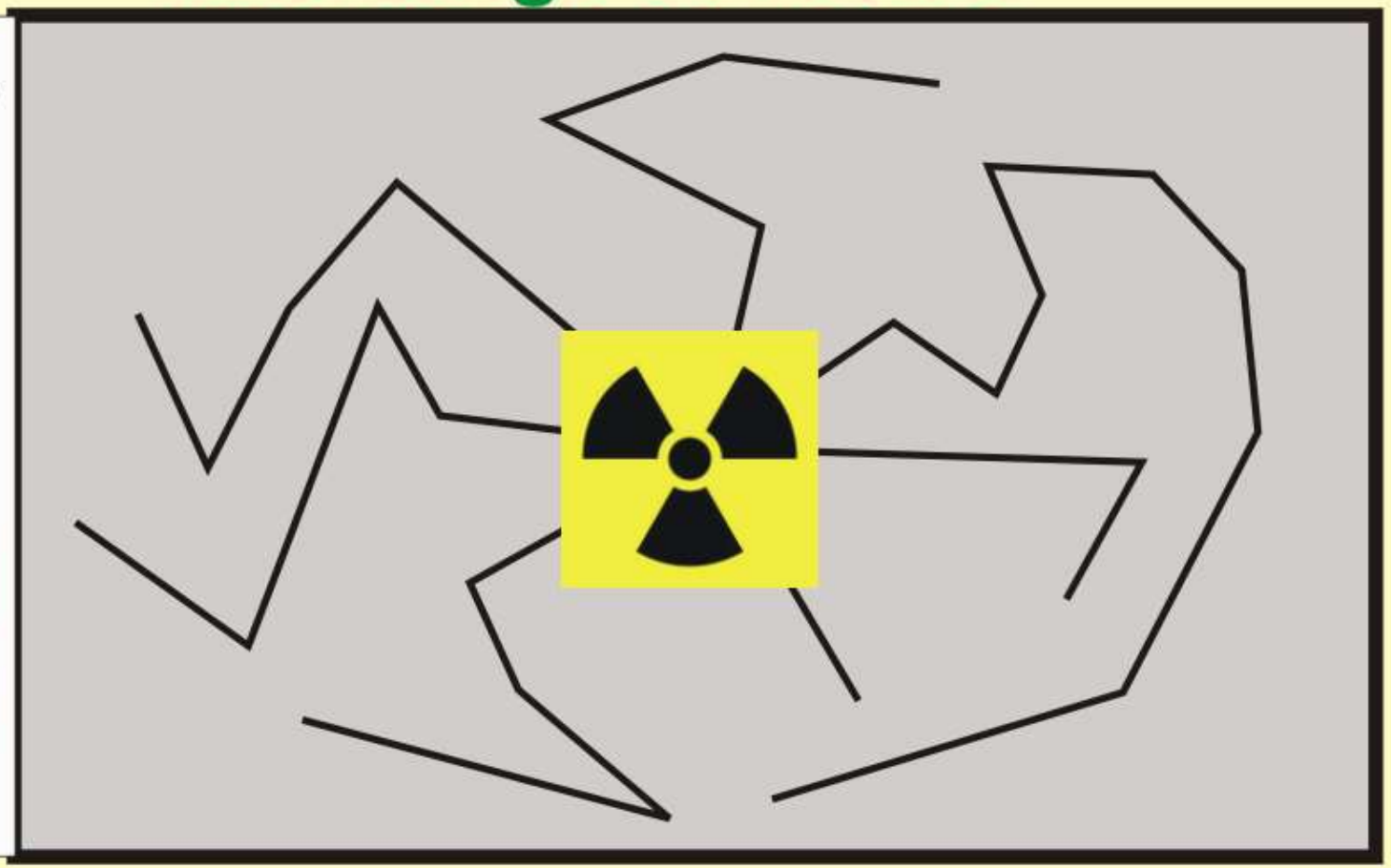
Meaning

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



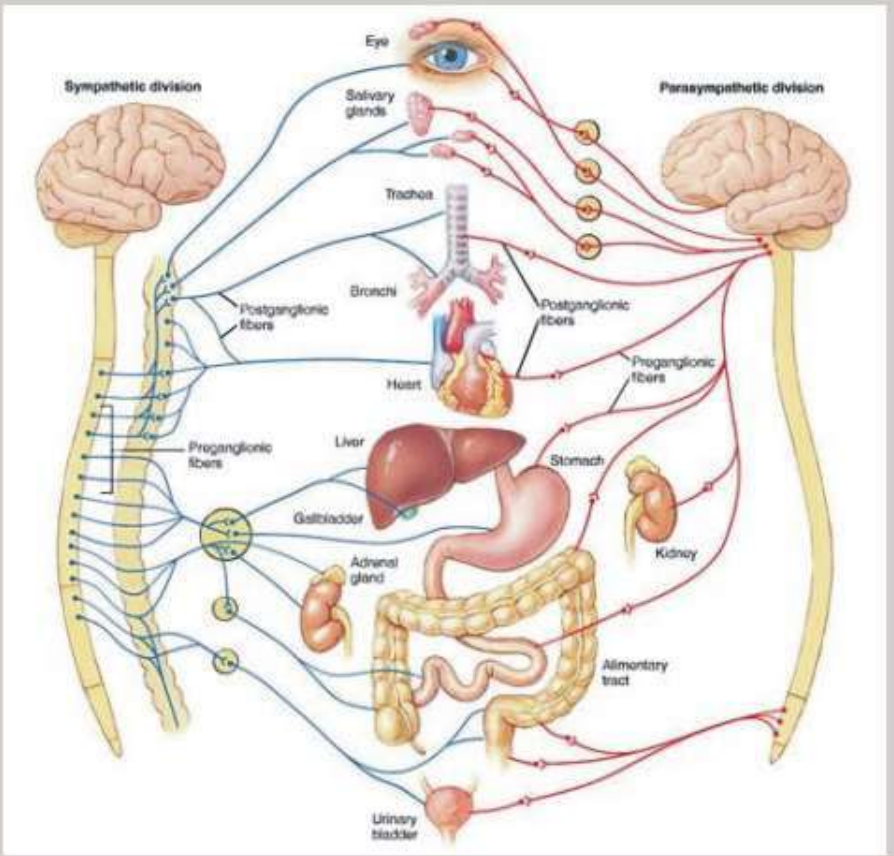
Meaning

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory



Medical Knowledge

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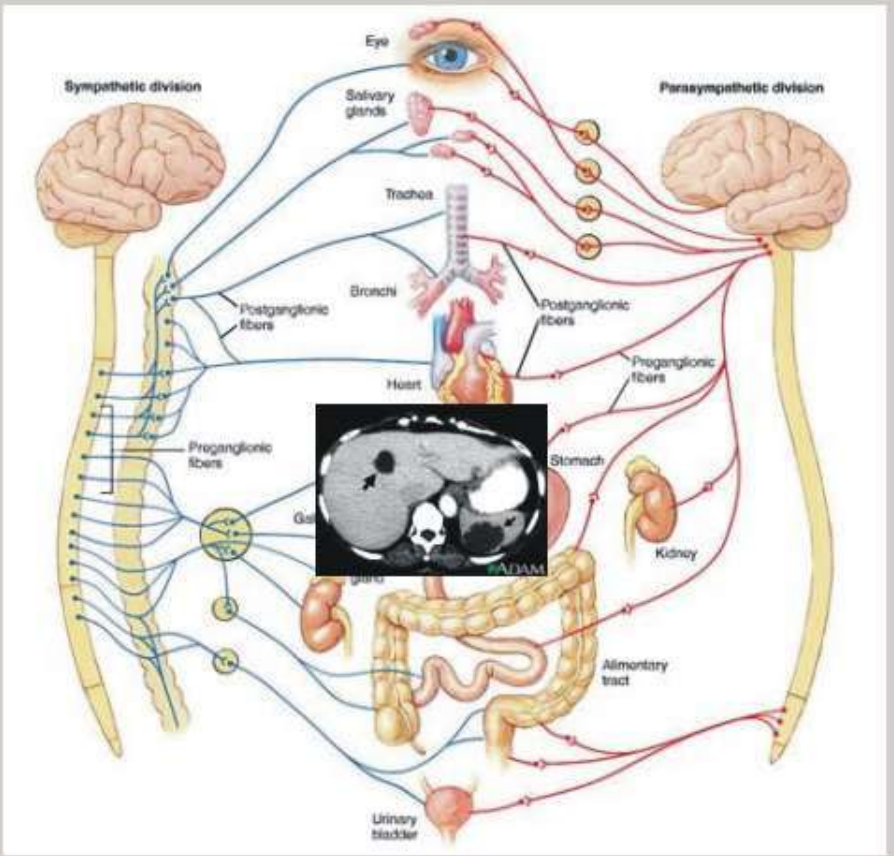
Back Integrative Cortex

Integrating experience into existing knowledge structure

Sensory

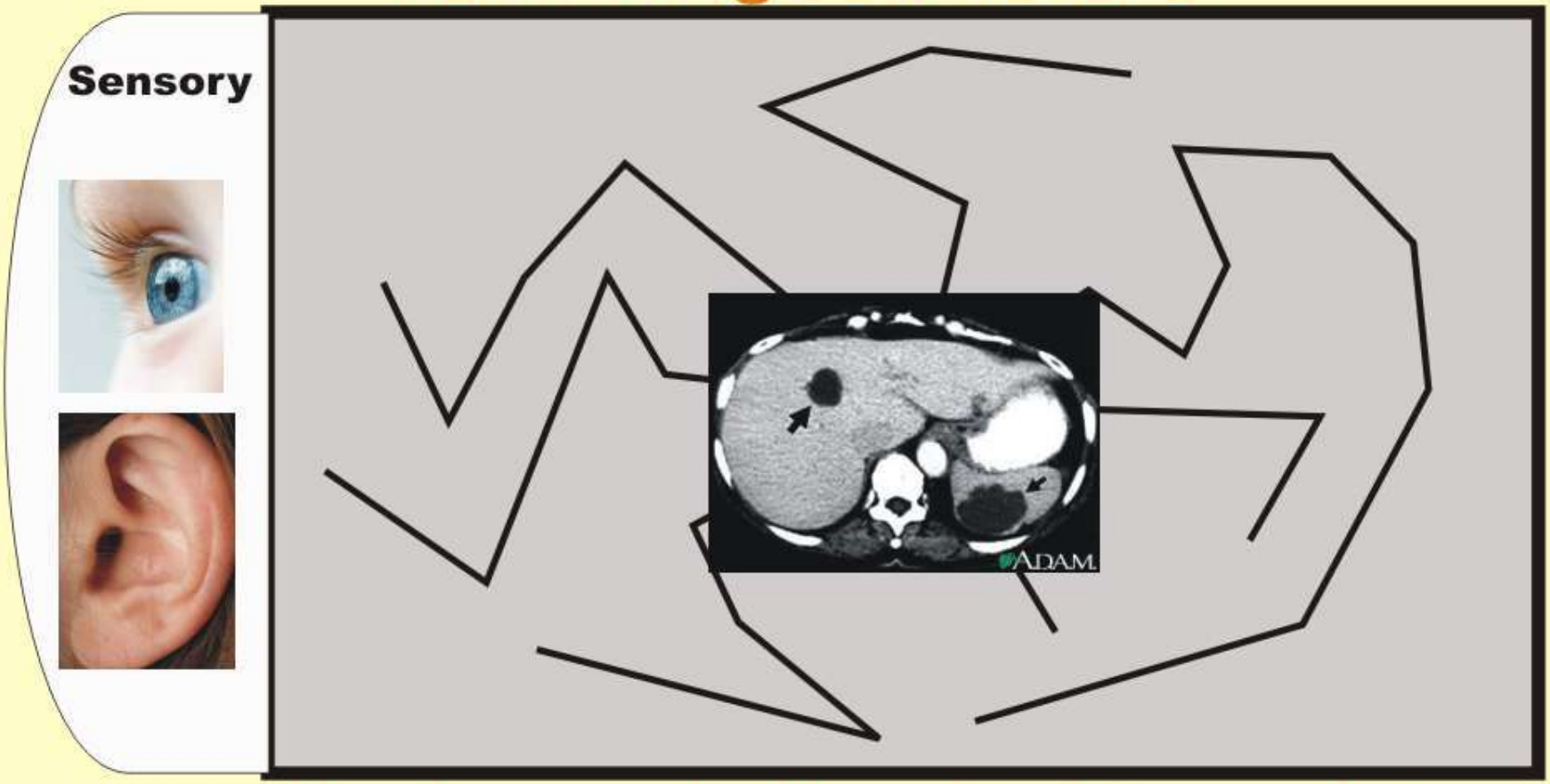


The image is the connection

Sprawls

Back Integrative Cortex

Integrating experience into existing knowledge structure



The image is the starting point for learning physics

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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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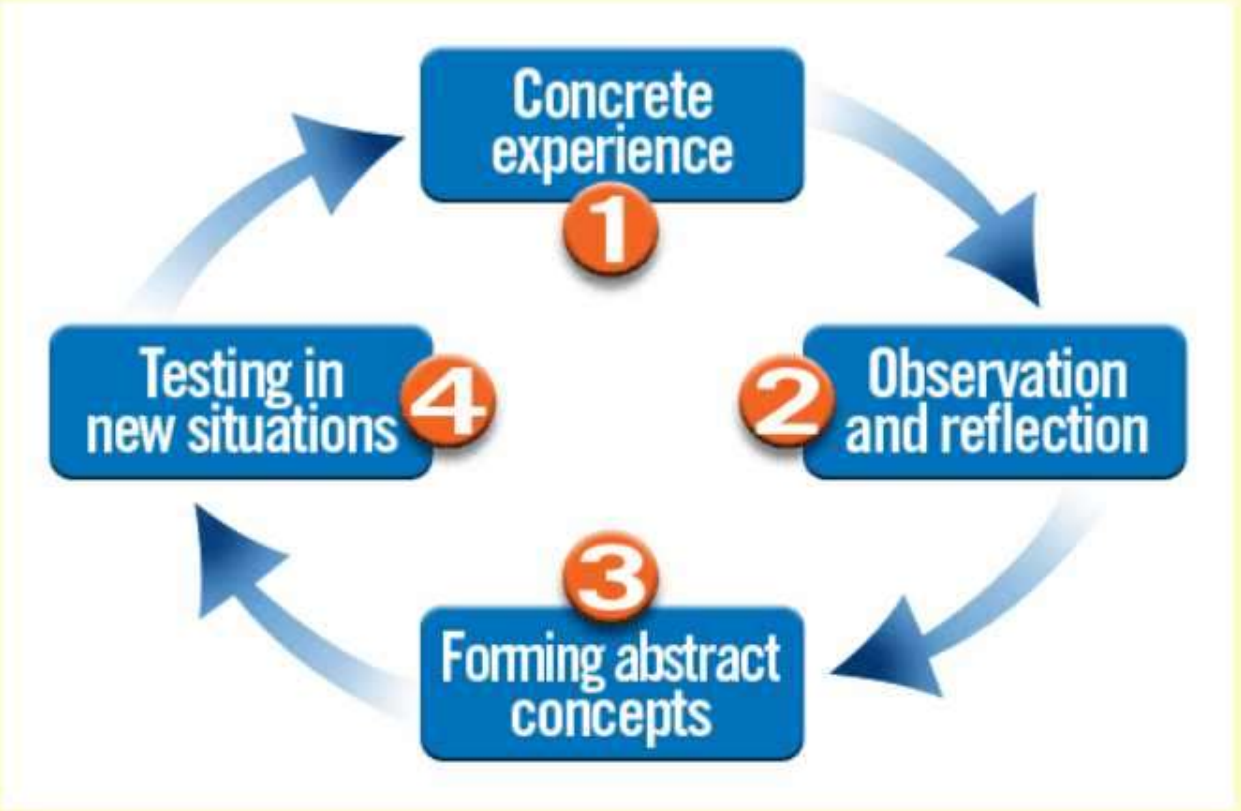
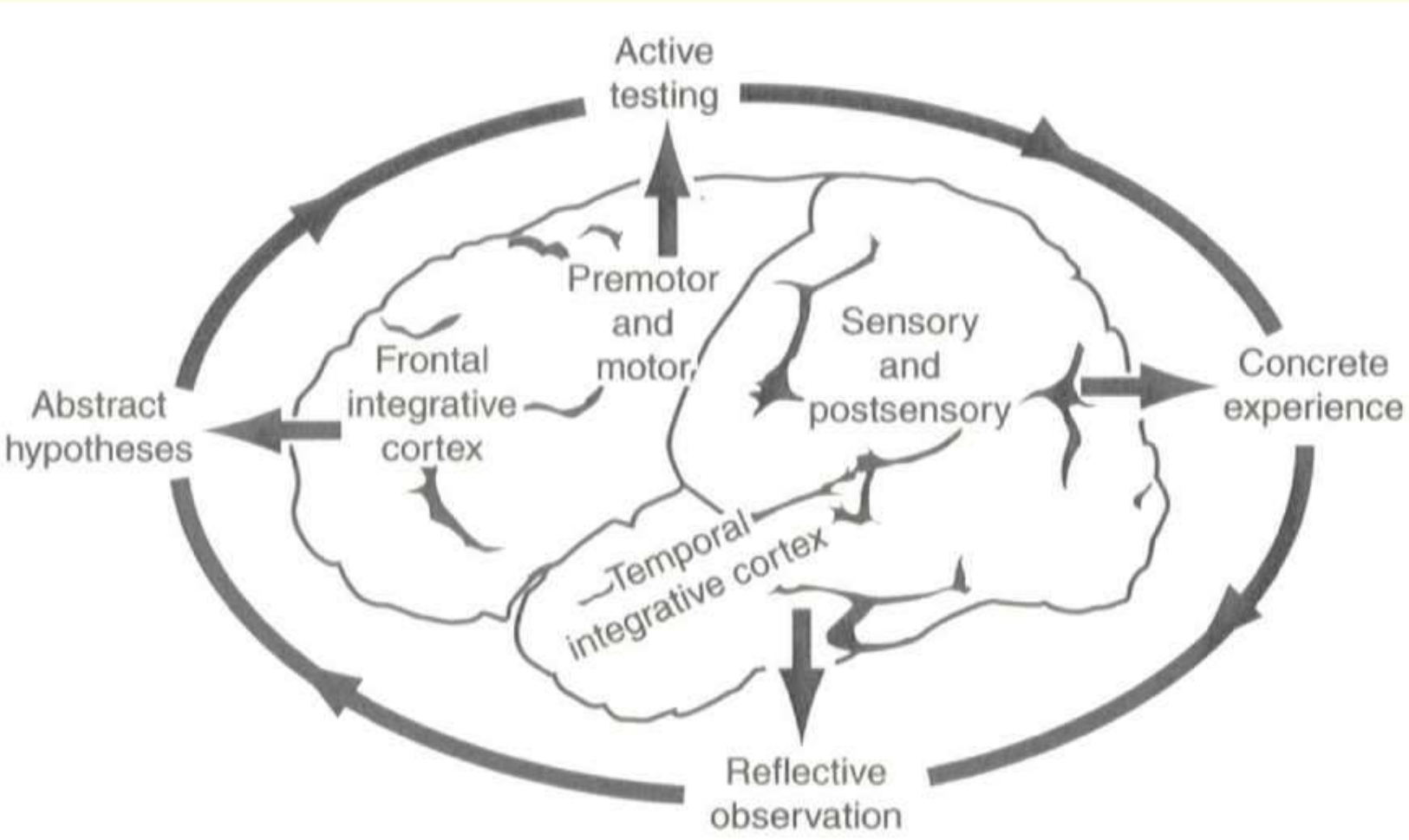
Kolb's Experiential Learning Model



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

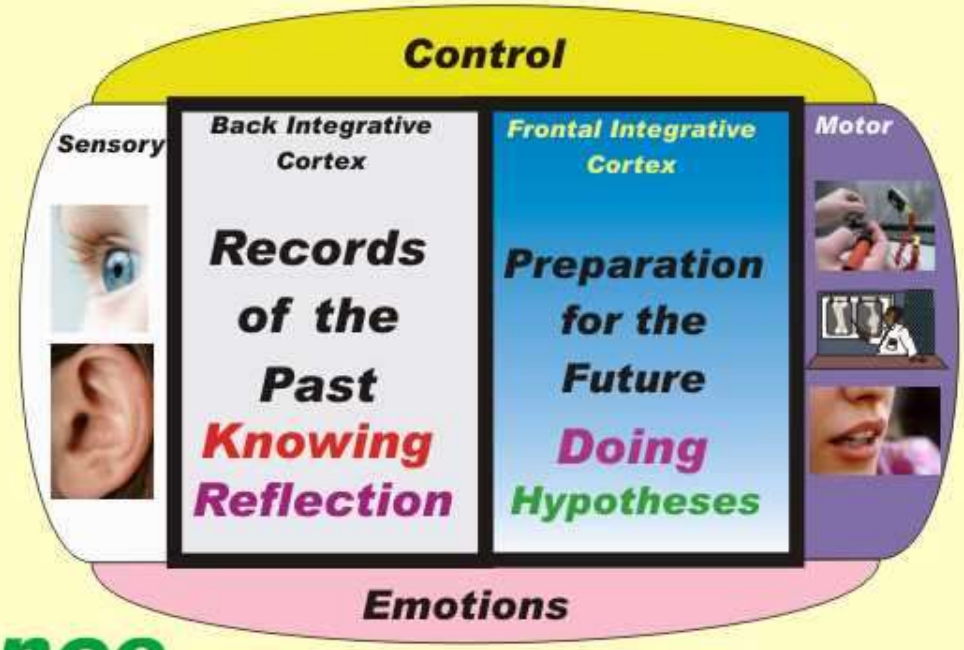
Website: http://www.learningfromexperience.com

Zull's Model of Brain Function



Brain Functions for Learning Physics

Active Experimentation and Testing



Sense and Experience Observe

Interact and Affect

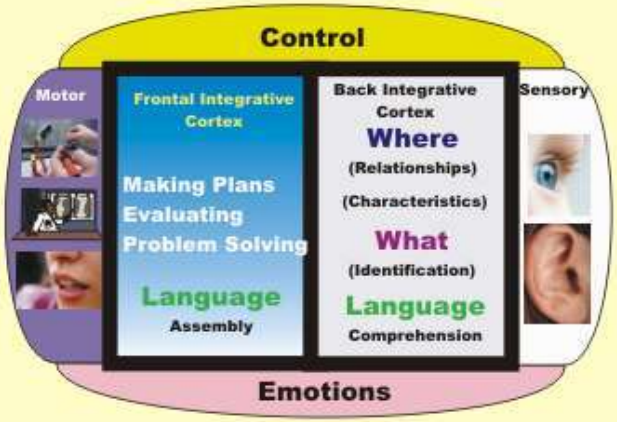
Physical Universe

Sprawls

Brain Functions for Learning Physics

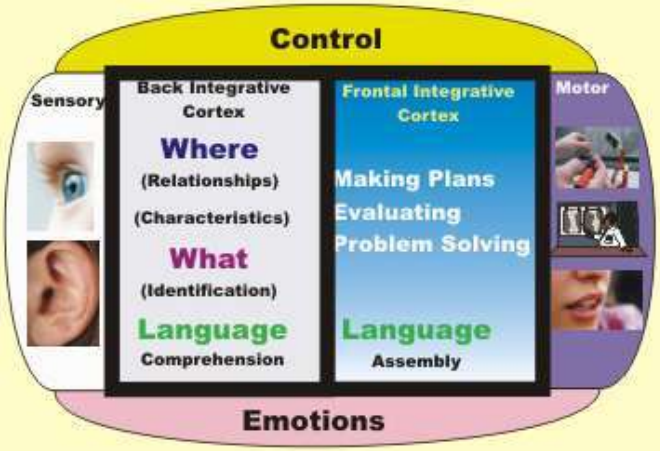
Two brains are better than one!

Collaborative Learning



Ben

?



Jerry

Problem Solving

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Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning

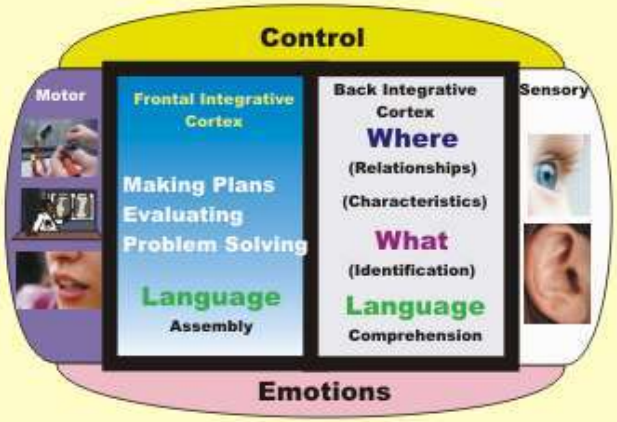
Problem Solving

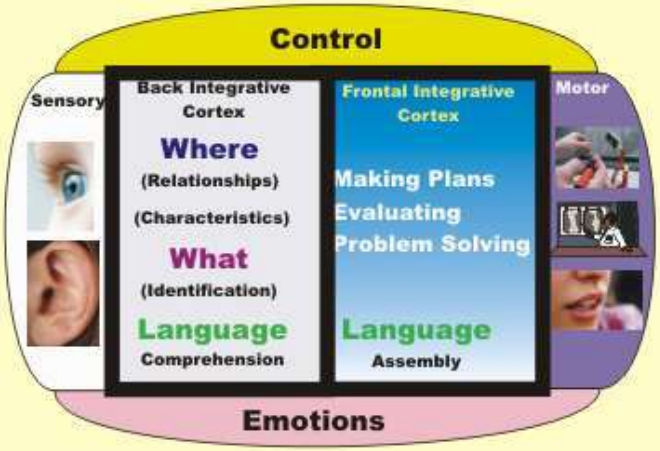
Sprawls

Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning





Views
Perspectives
Experiences

Views
Perspectives
Experiences

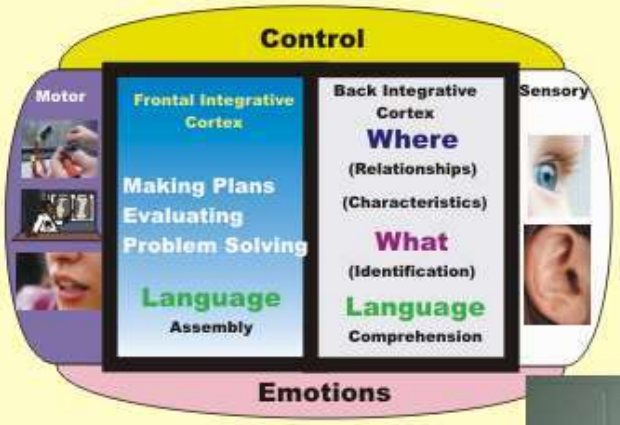
Problem Solved!

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

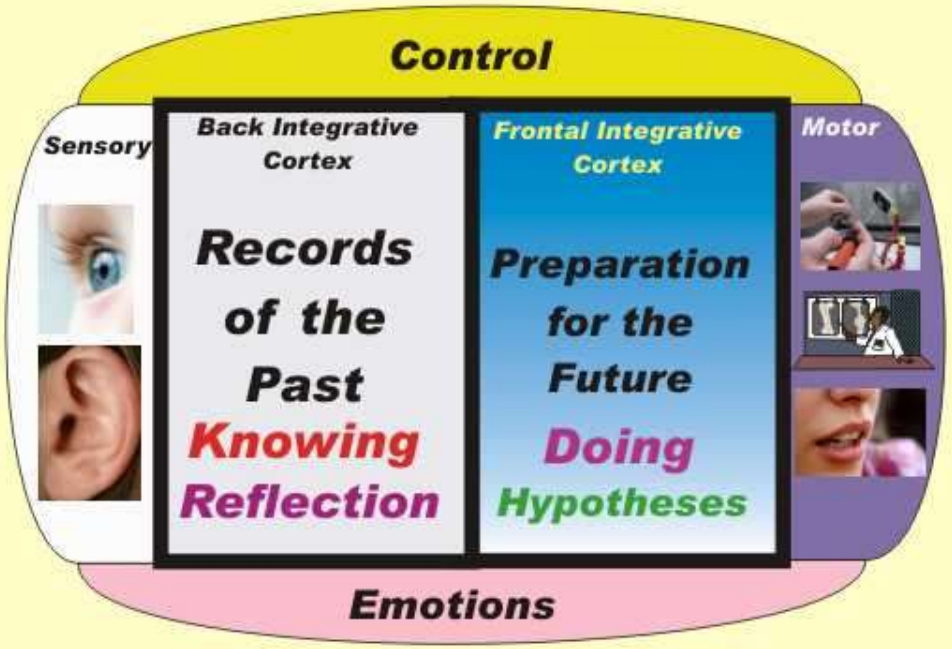
Two brains are better than one!

Collaborative Learning

Problem Solving
Analysis and Evaluation
Developing Plans

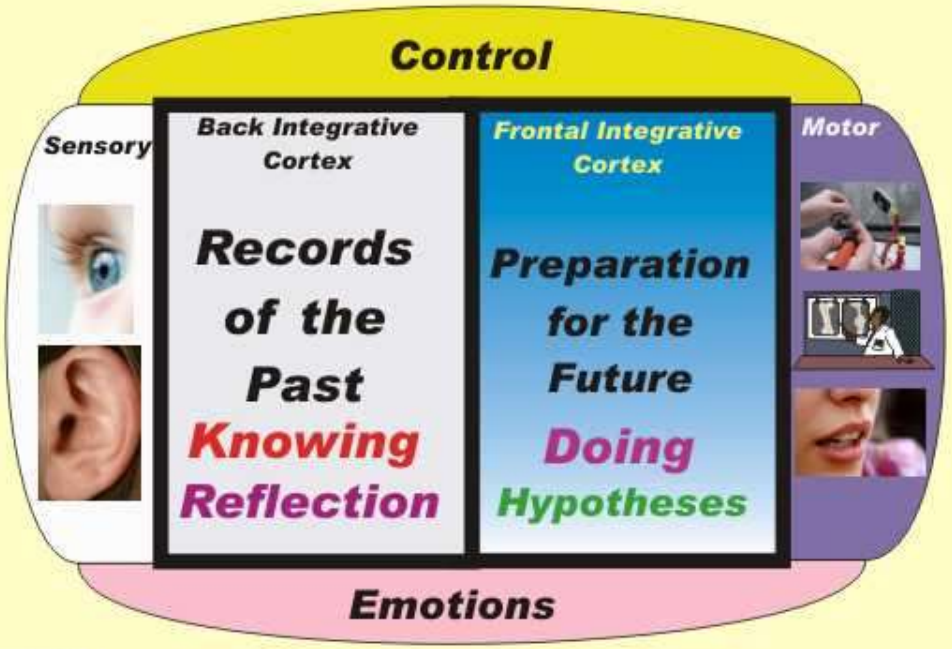
Sprawls

The Learning Environment



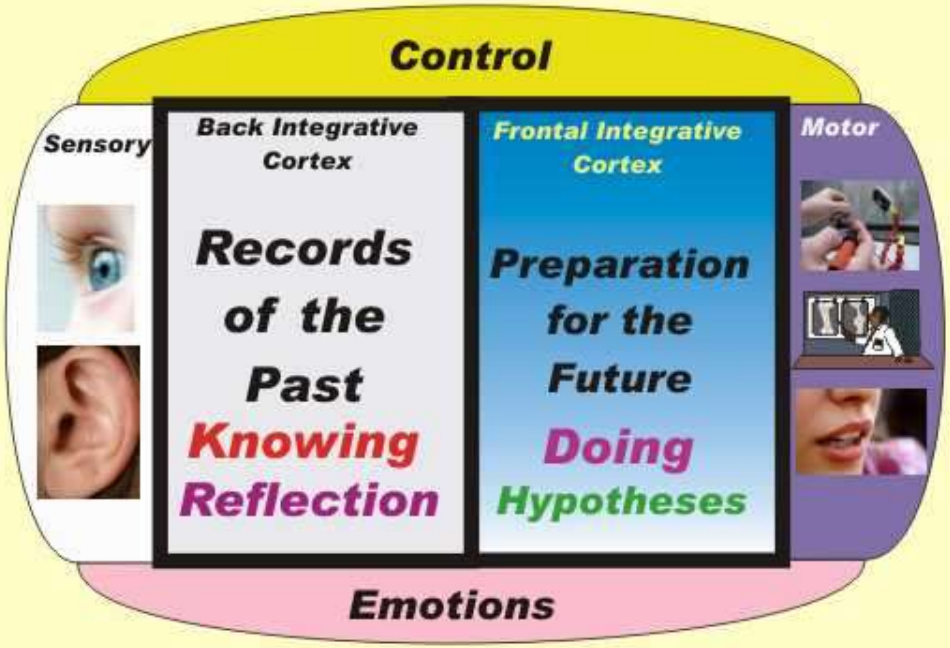
Sprawls

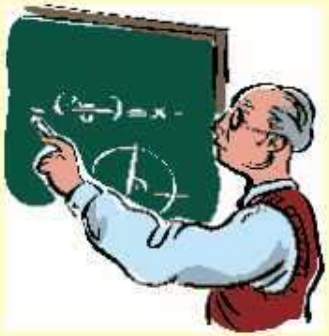
Rich Learning Environments



Sprawls

Challenging Learning Environments





Sprawls

Effective Learning

Rich Learning Environment

New and Different

Integrate into Existing Knowledge

Reflection →

Sprawls

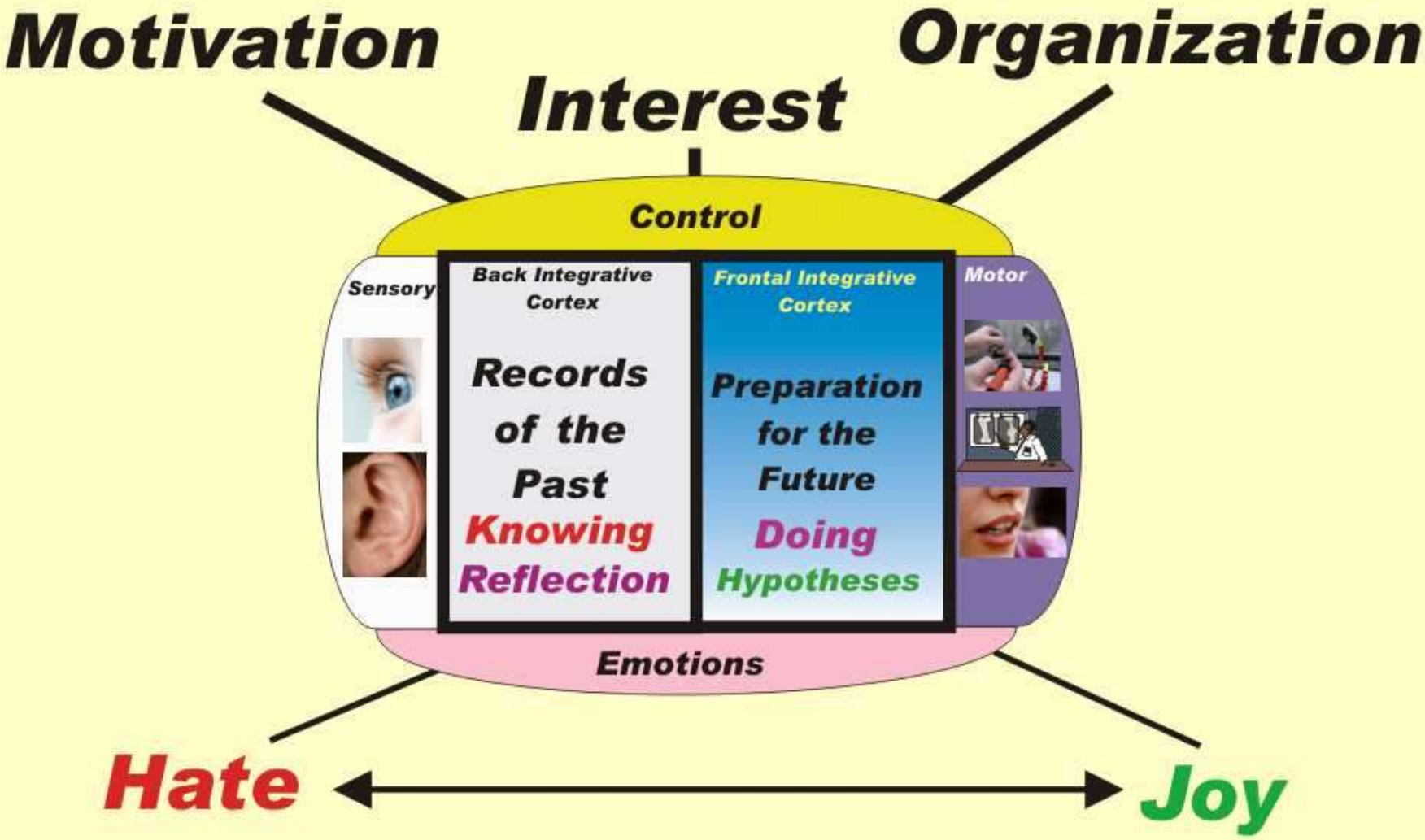
Effective Learning

Interact **Review** **Reflect**

Developing useful knowledge for the future

Sprawls

Brain Functions for Learning Physics



Sprawls

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

PROBLEM SOLVING

RULE LEARNING

CONCEPT LEARNING

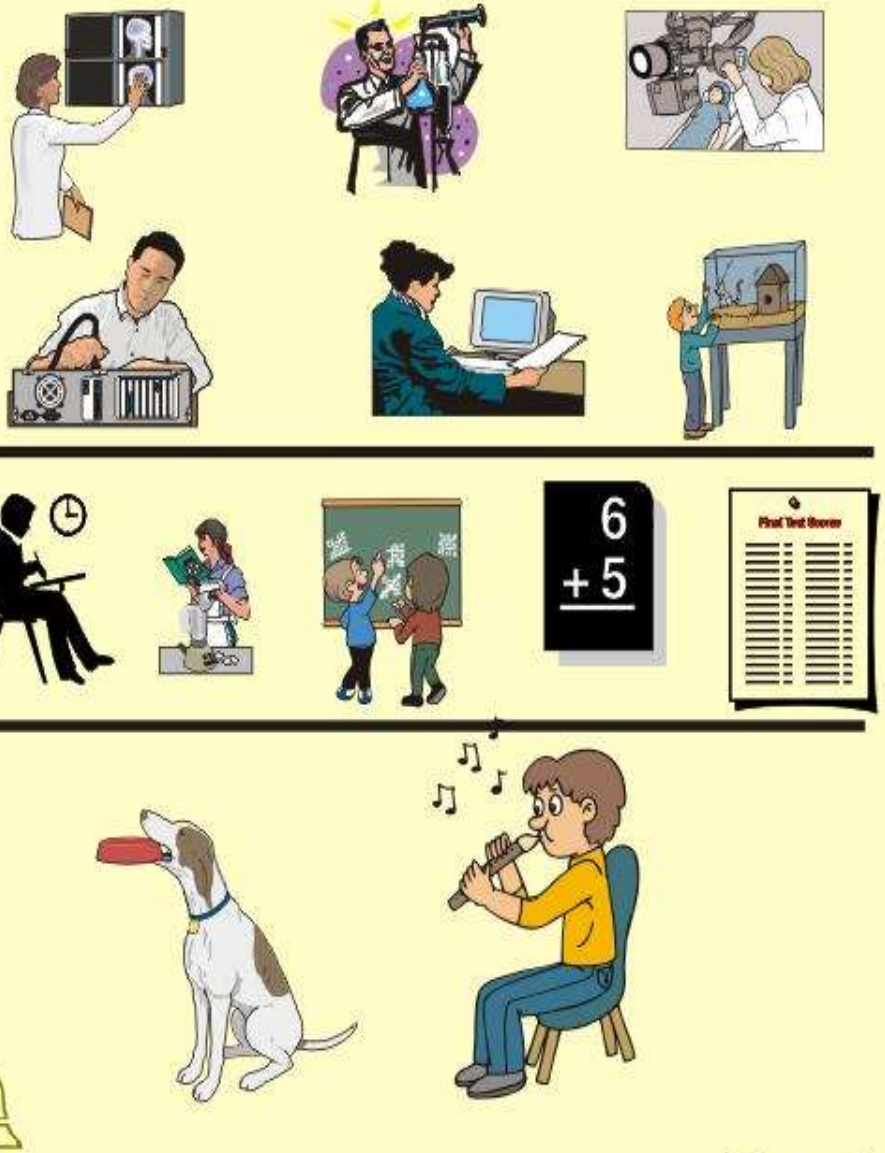
DISCRIMINATION LEARNING

VERBAL ASSOCIATION

CHAINING

STIMULUS RESPONSE

SIGNAL LEARNING



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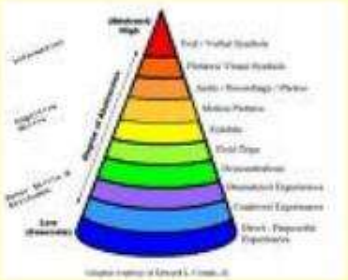
Edgar Dale (1900-1985)

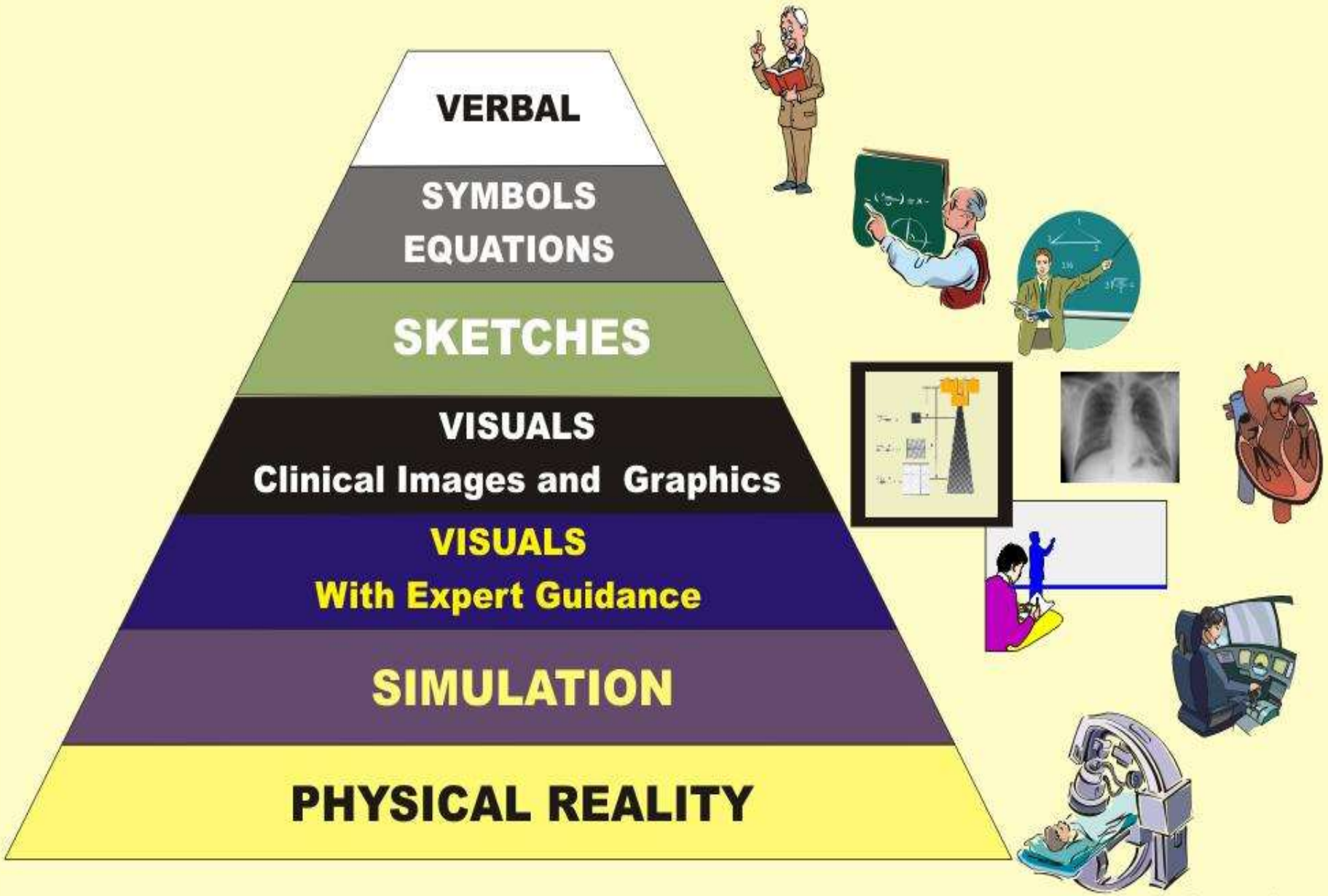
Educationalist who developed the famous

Cone of Experience theory

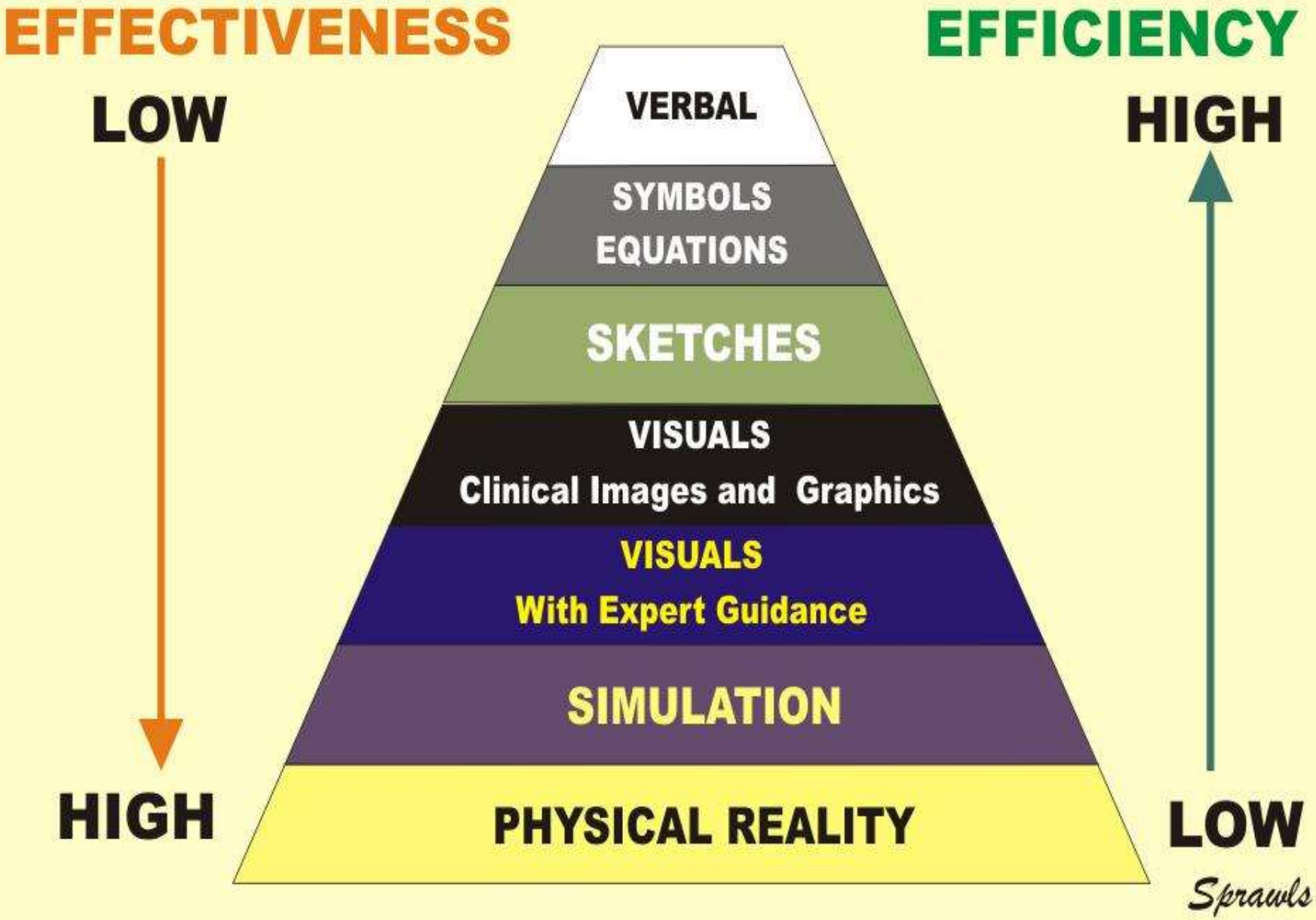


Sprawls

Cone of Experience for Medical Imaging Education

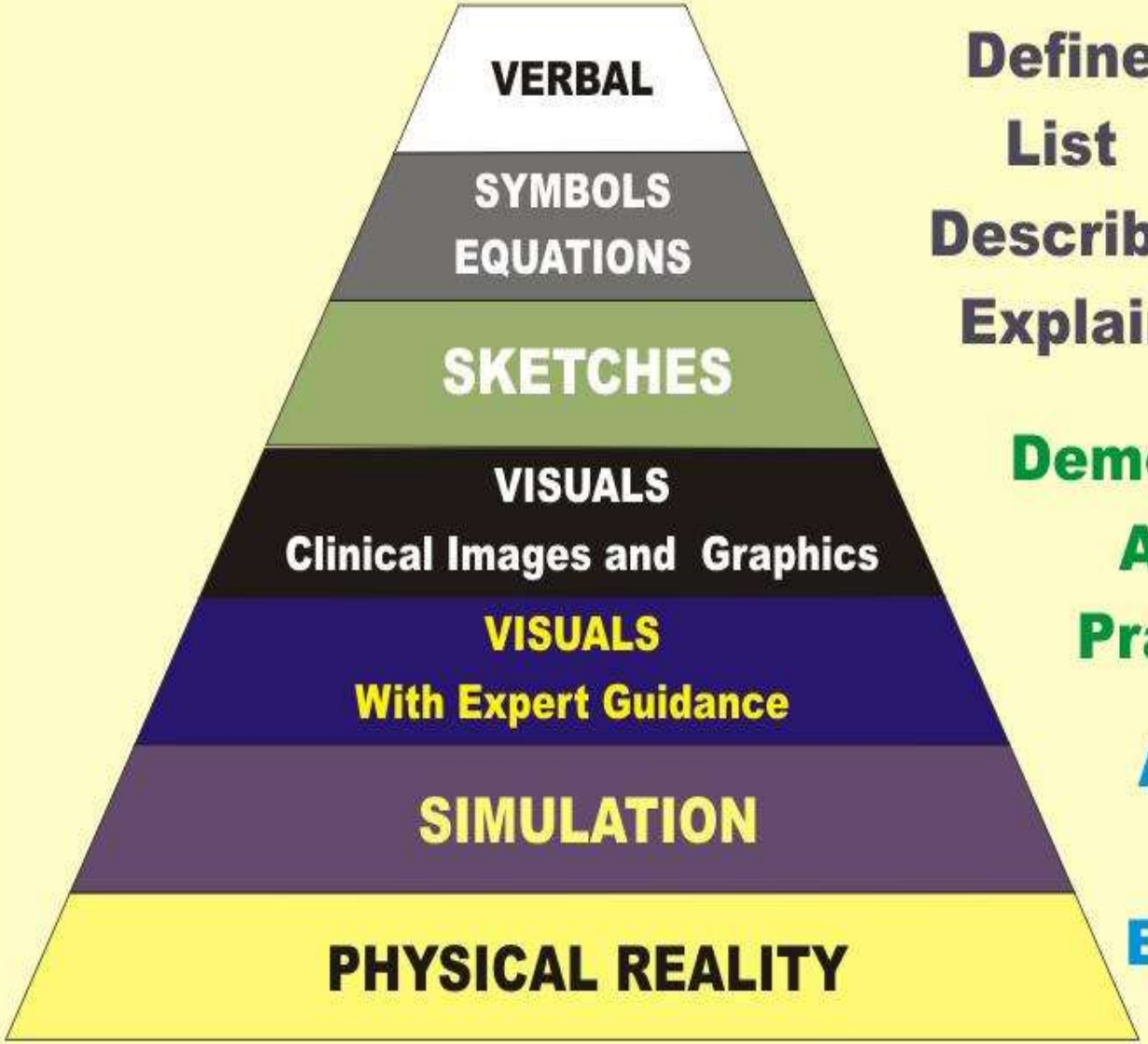


Cone of Experience for Medical Imaging Education



Sprawls

Cone of Experience for Medical Imaging Education



LEARNING OUTCOMES

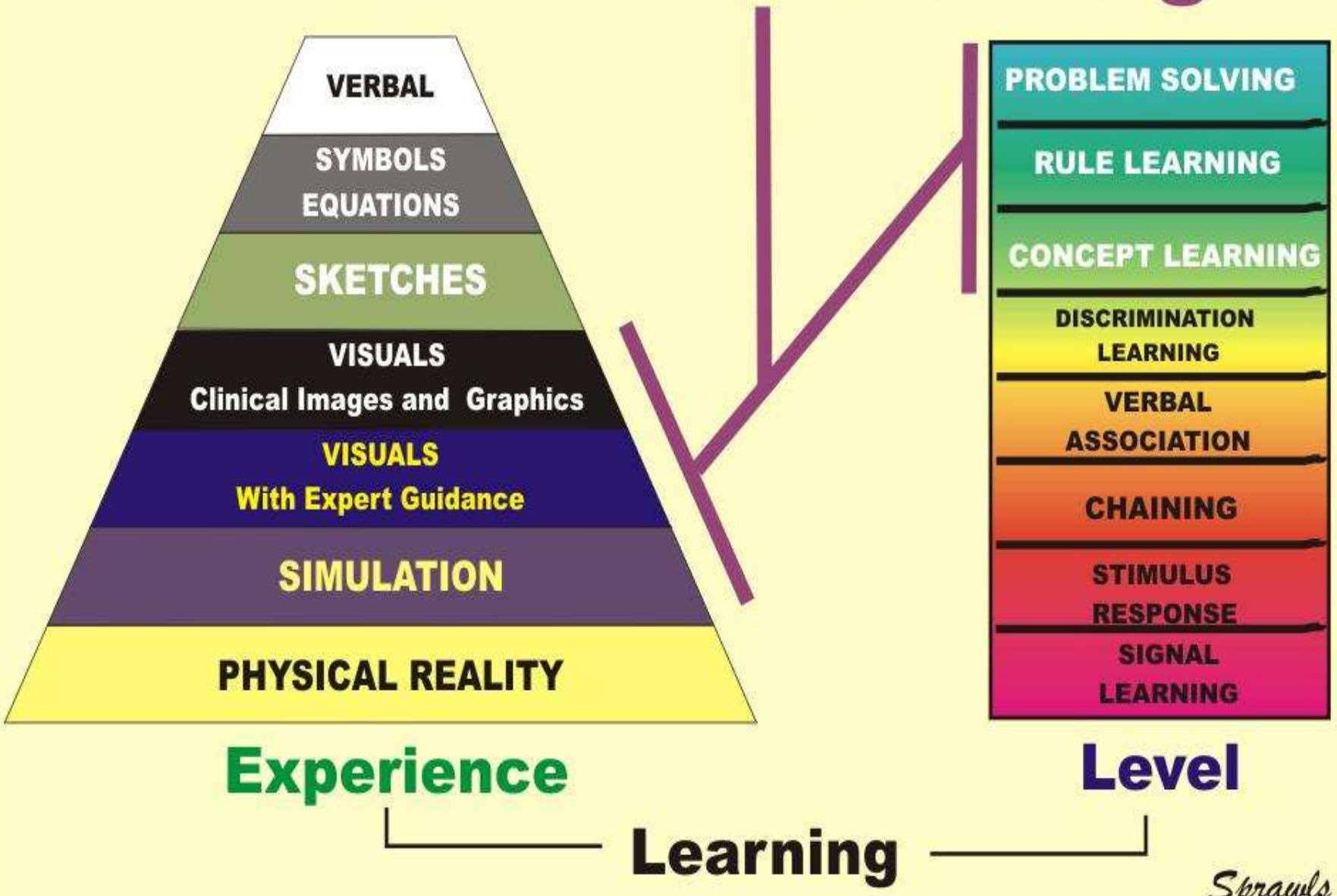
Define
List
Describe
Explain

Demonstrate
Apply
Practice

Analyze
Create
Evaluate

Sprawls

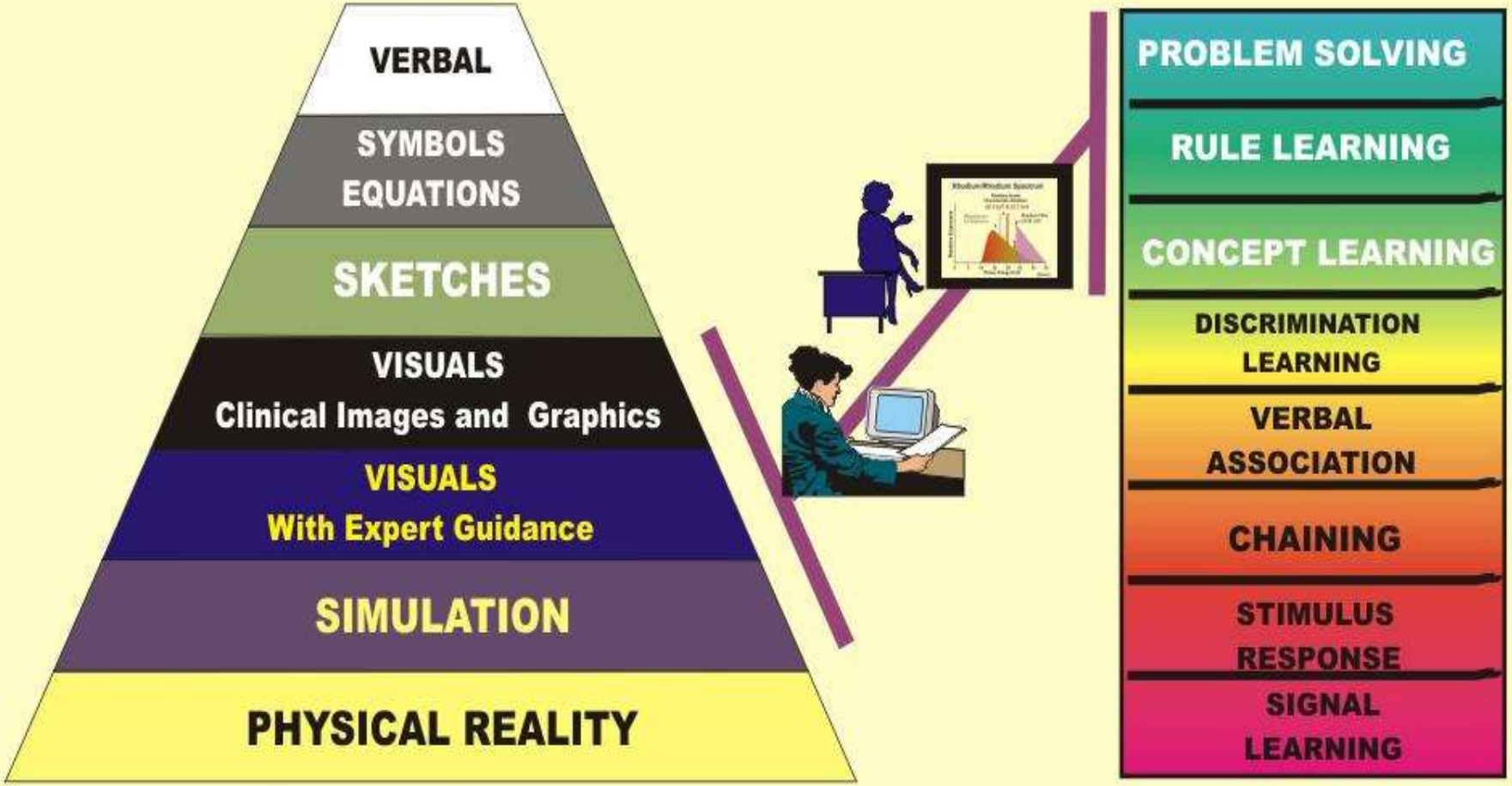
Effective Learning



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

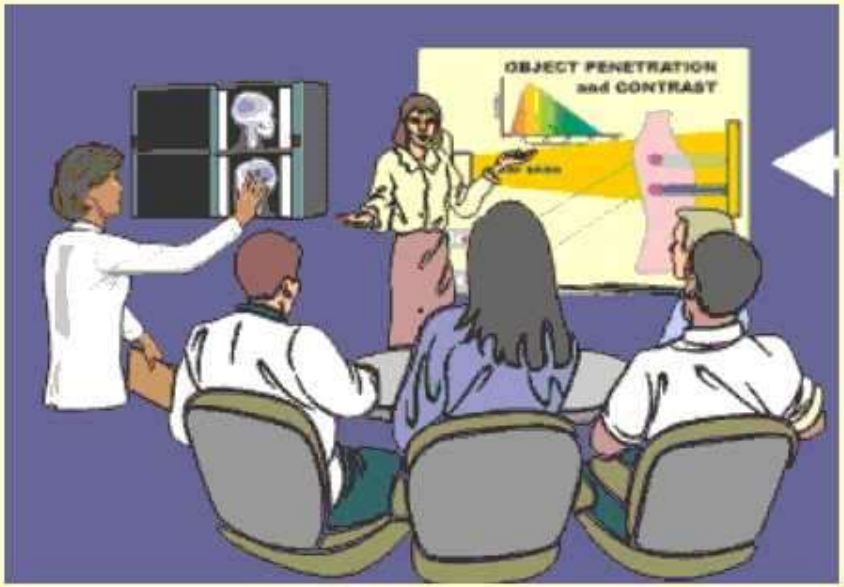
Visuals **Images** **Online Modules**

Resources and References

Sprawls

Rich Classroom and Conference Learning Activities

Learning Facilitator "Teacher"



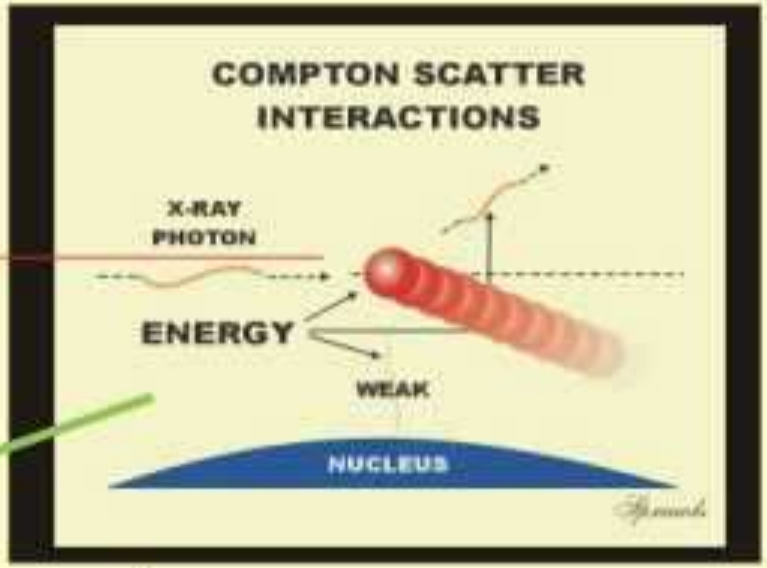
Visuals

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



Learning Guide

Learner

Visuals for Classroom

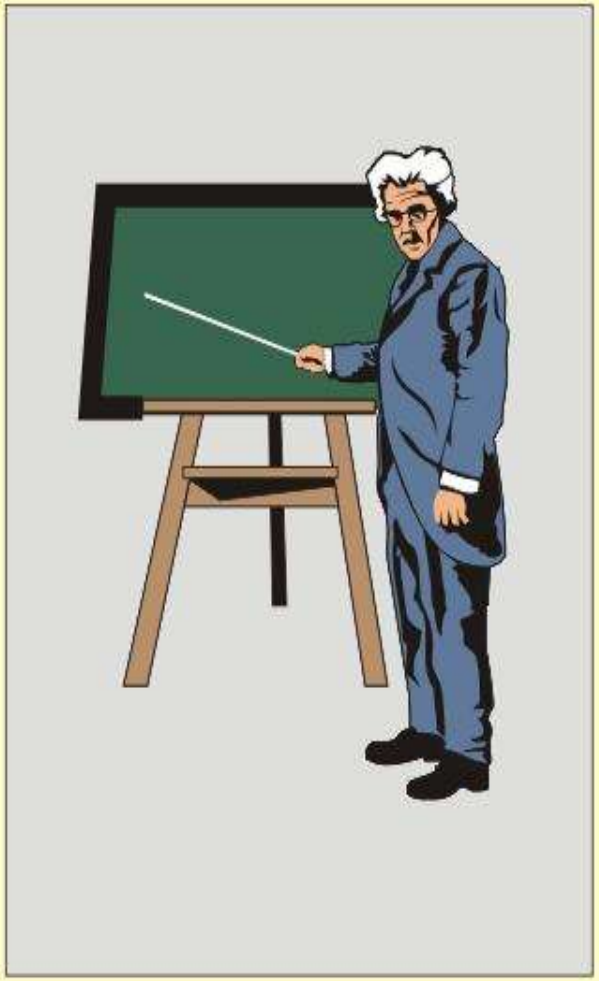
Notes
and
Text

Online
Resources

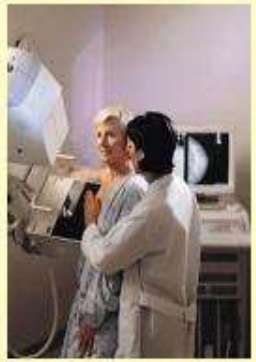
Sprawls

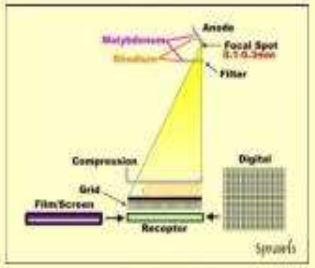
WINDOW
or
BARRIER

THE LEARNERS



PHYSICAL UNIVERSE



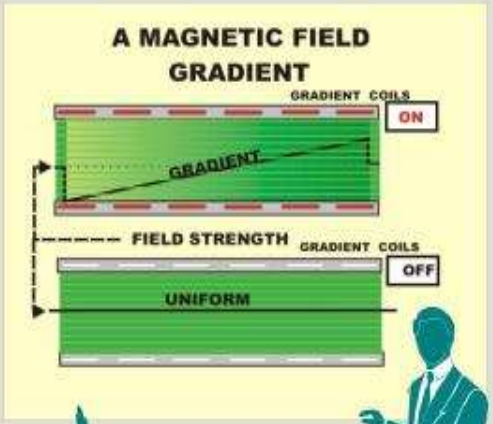


Sprawls

WINDOW or BARRIER

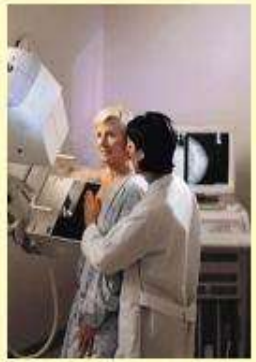
THE LEARNERS

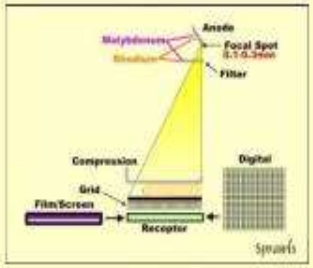
Visuals



Physicists

PHYSICAL UNIVERSE





Sprawls

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.

Sprawls

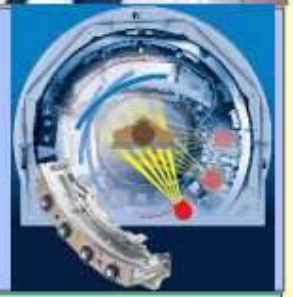
Computed Tomography

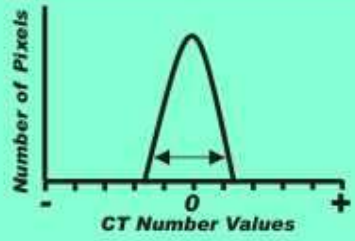
Image Characteristics and Quality

Radiation Dose

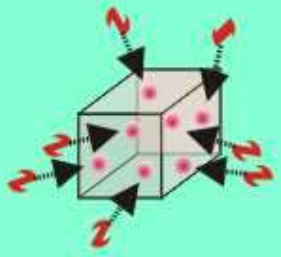
Imaging Protocols

Technology





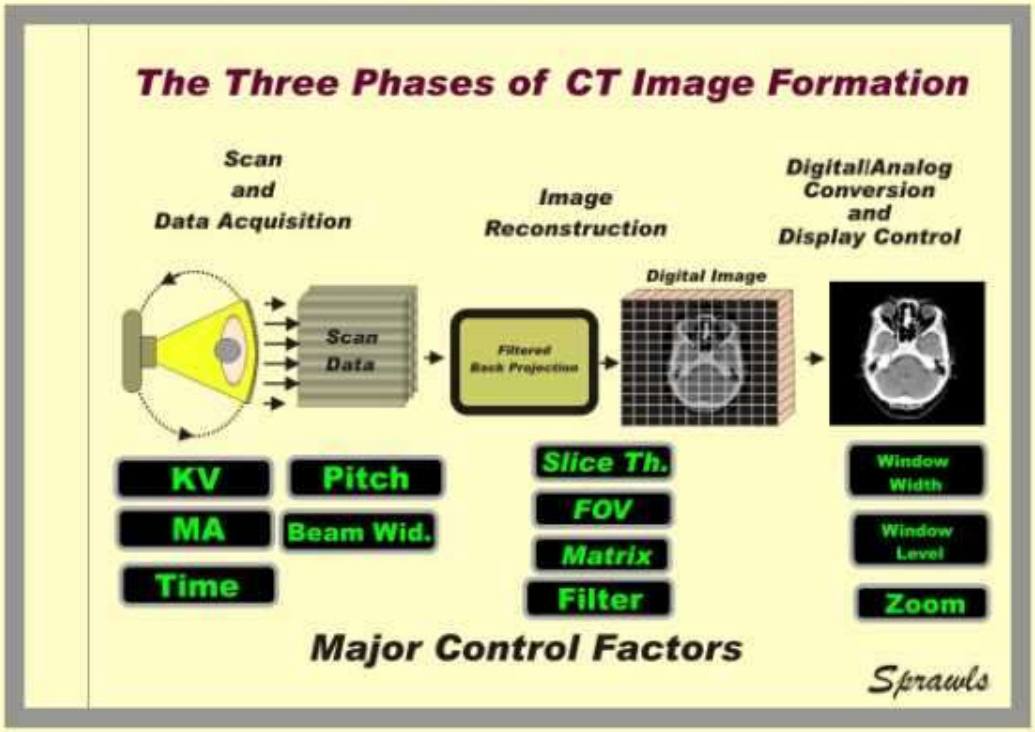
Science



Sprawls

Visuals for Learning and Teaching

The Imaging Process



Clinical Images

Sprawls

Visuals

to be used by

Physicists in Classroom and Conference Discussions

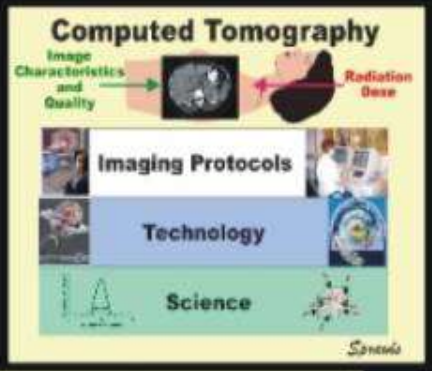
SPRAWLS EDUCATIONAL FOUNDATION
Open Resources for Learning and Teaching
The Physical Principles of Medical Imaging

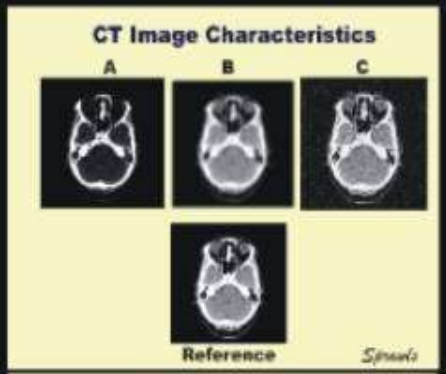
Visuals
for
Classroom, Conference, and Collaborative Learning

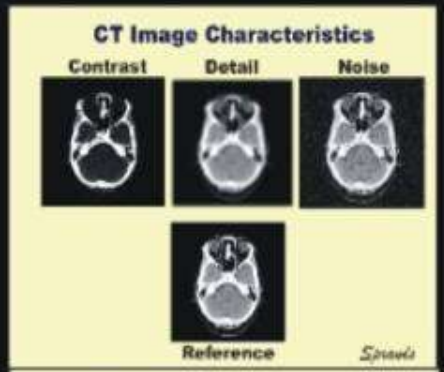
RIGHT CLICK on each visual to download and use in PowerPoint or other display programs.

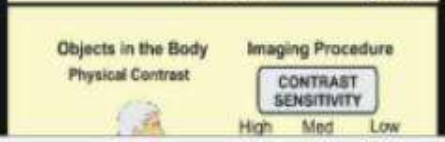
Computed Tomography Image Quality Optimization and Dose Management

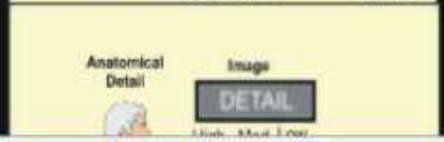
Companion Module
http://www.sprawls.org/resources/CTIQDM/











Modules for Self Study
and
Collaborative Learning in the Clinic

How to Use This Resource

Table of Contents and List of Topics

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
Measuring CT Image Noise	Controlling Image Noise	Voxel Size Compromise

How to Use This Resource

Table of Contents and List of Topics

Mammography Physics and Technology
for effective clinical imaging

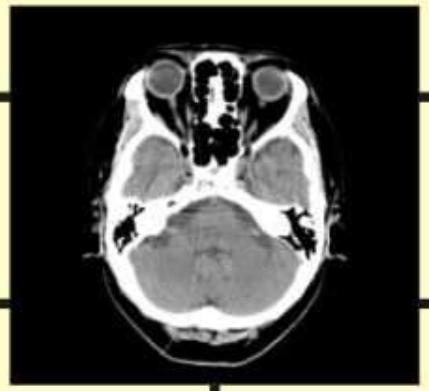
Perry Sprawls, Ph.D.

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

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

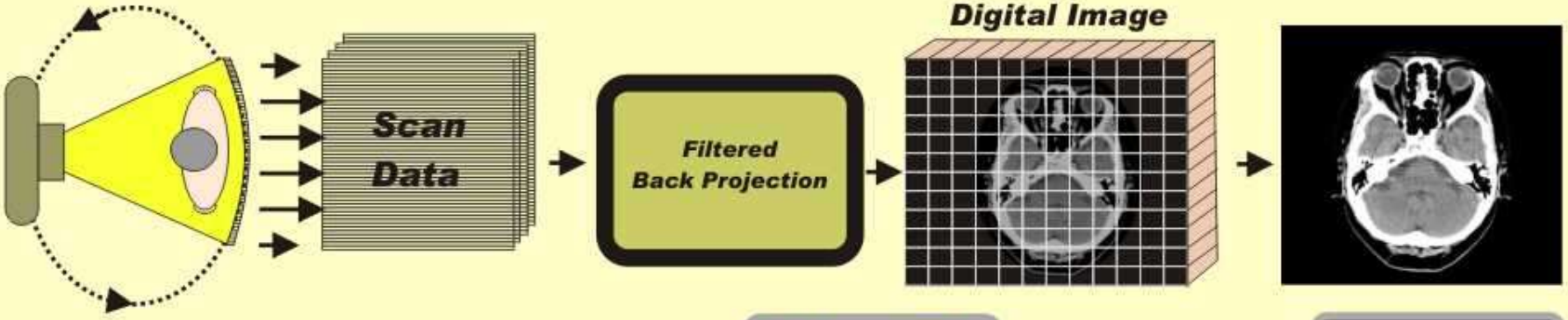
Sprawls

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

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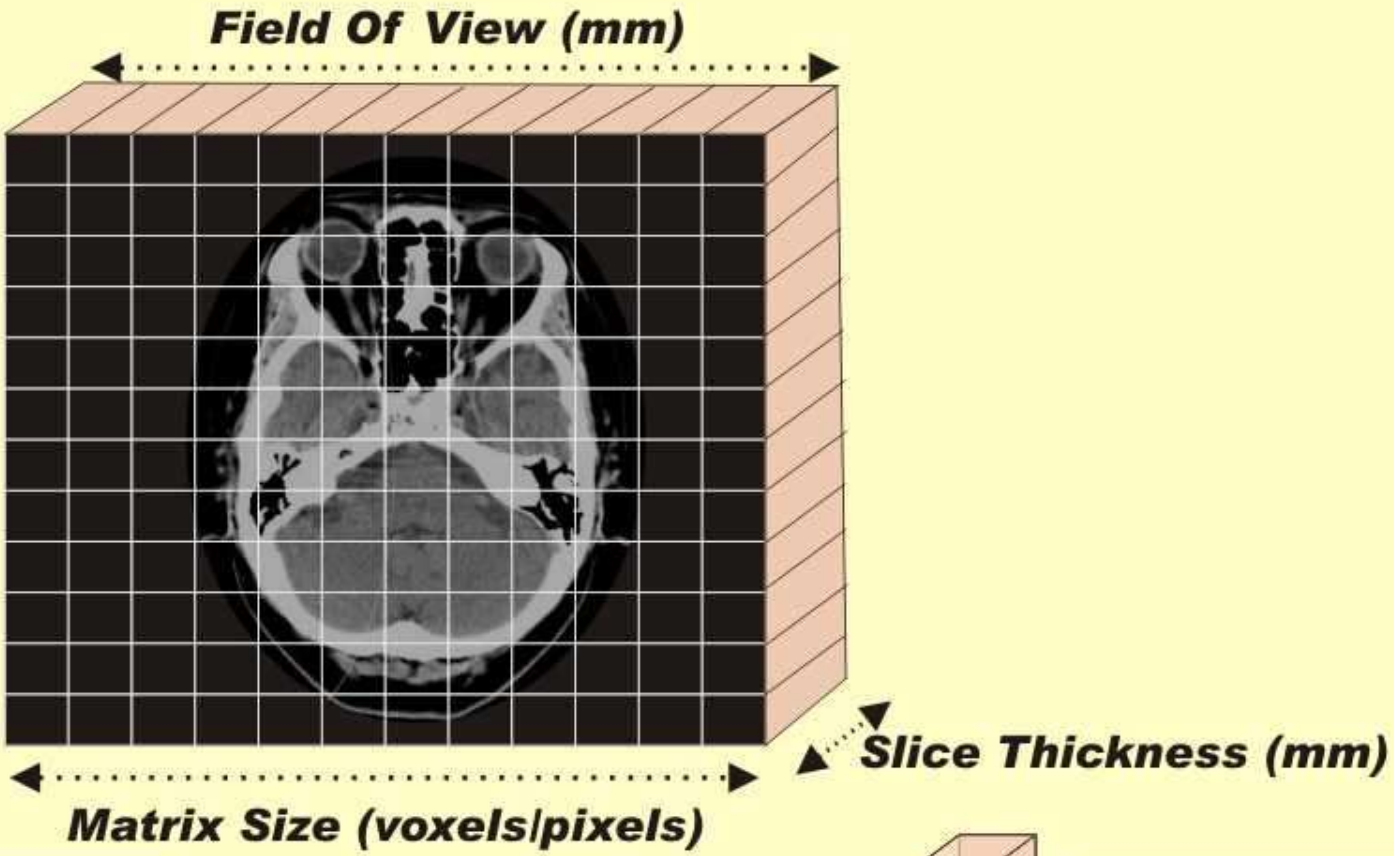
CT Slice Divided into Matrix of Voxels

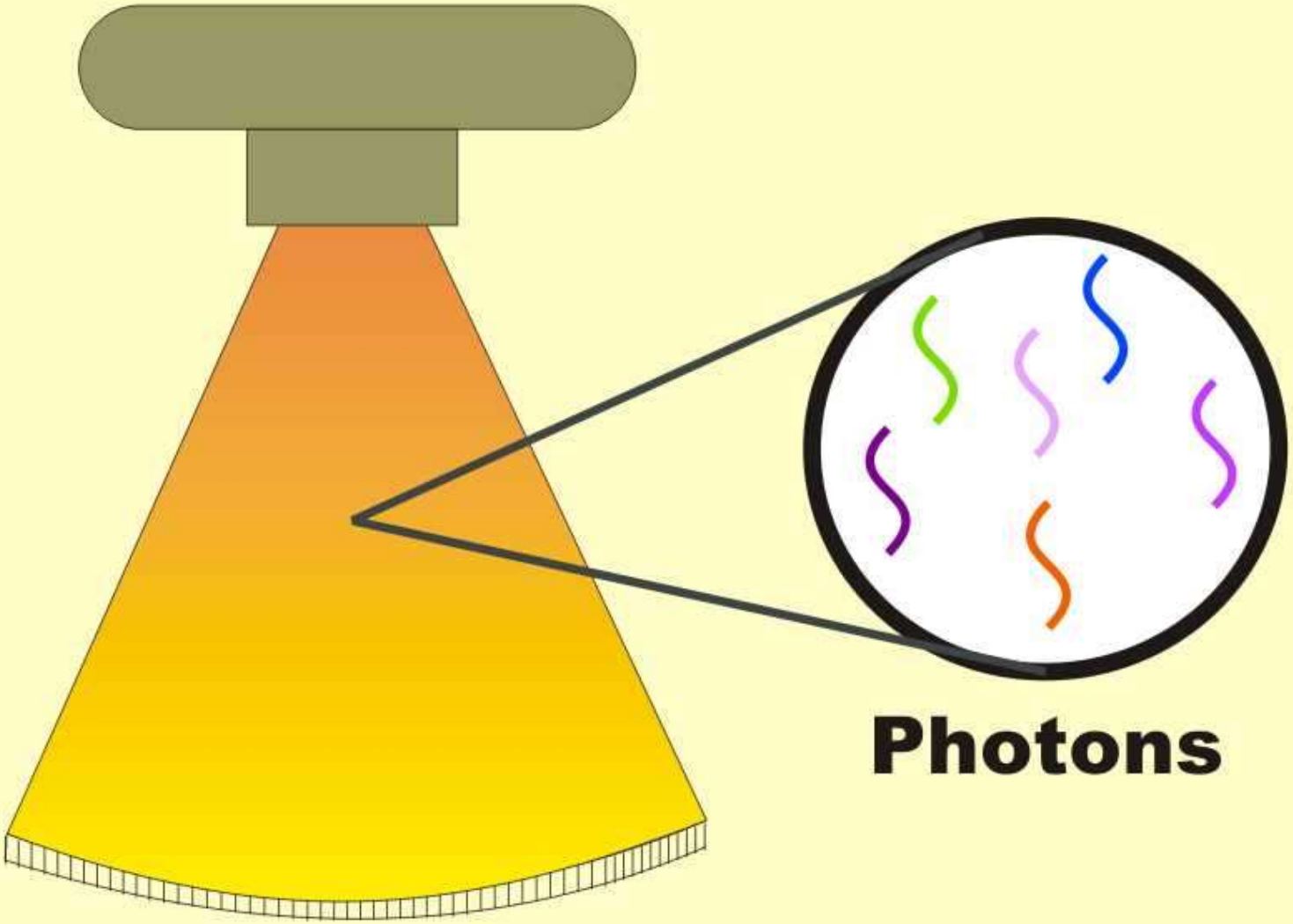


FOV ÷ Matrix ····· Slice Th.

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

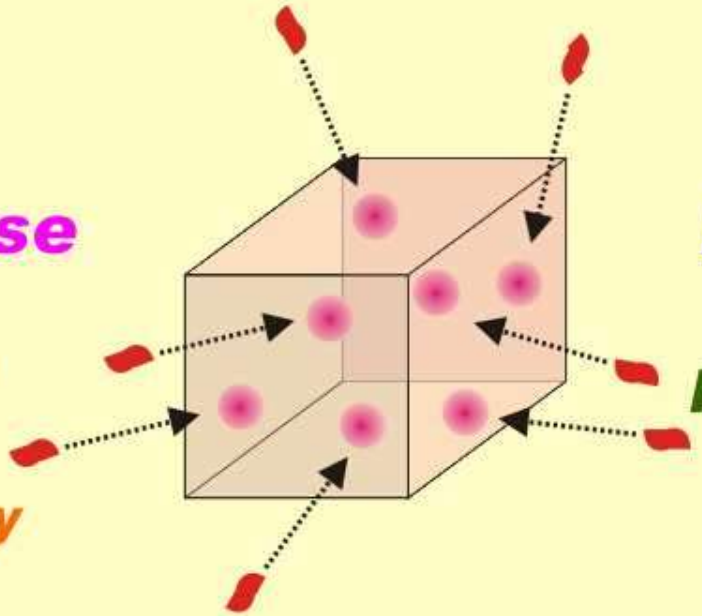


Image Noise

determined by

Number of Photons

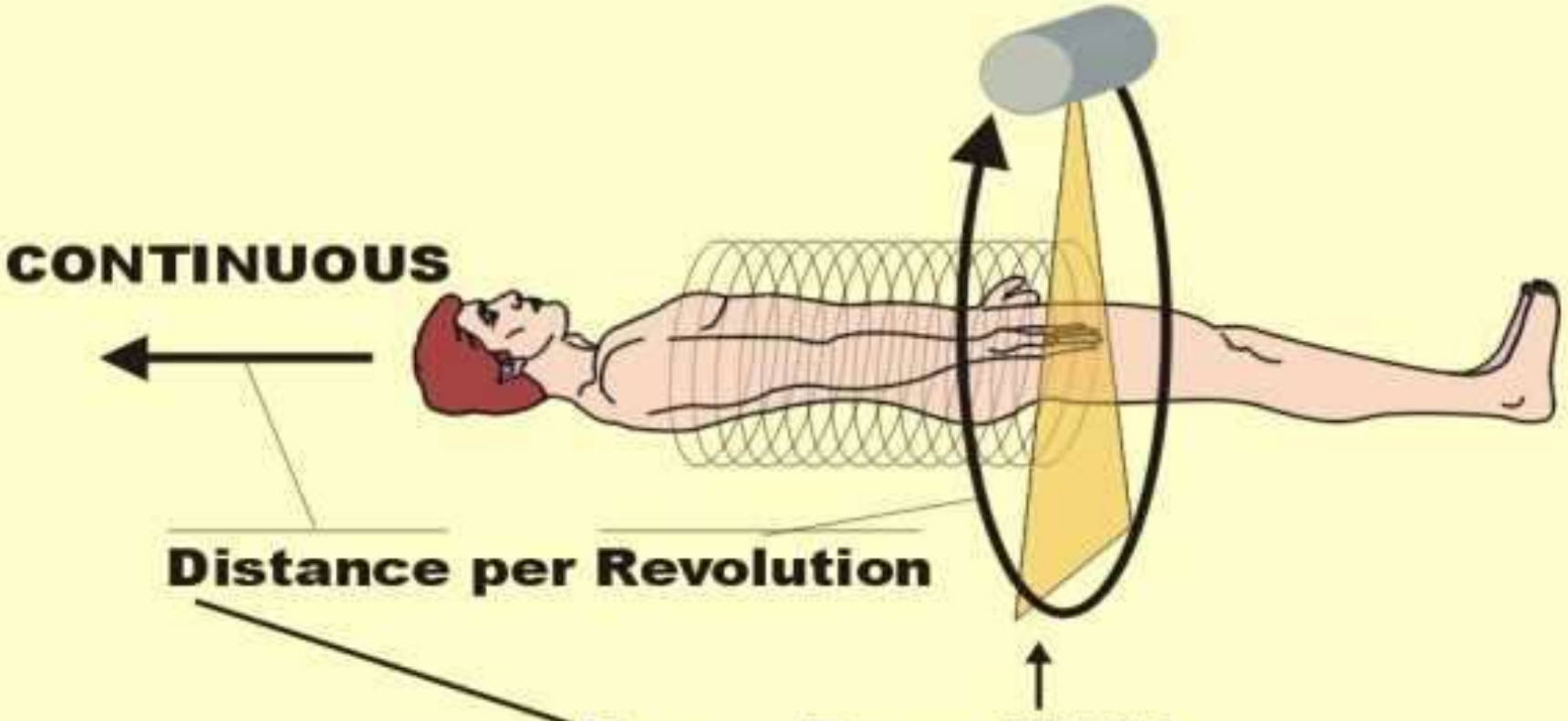
per voxel

Dose is increased by increasing number of photons.

Noise is reduced by increasing number of photons.

Sprawls

SPIRAL SCAN



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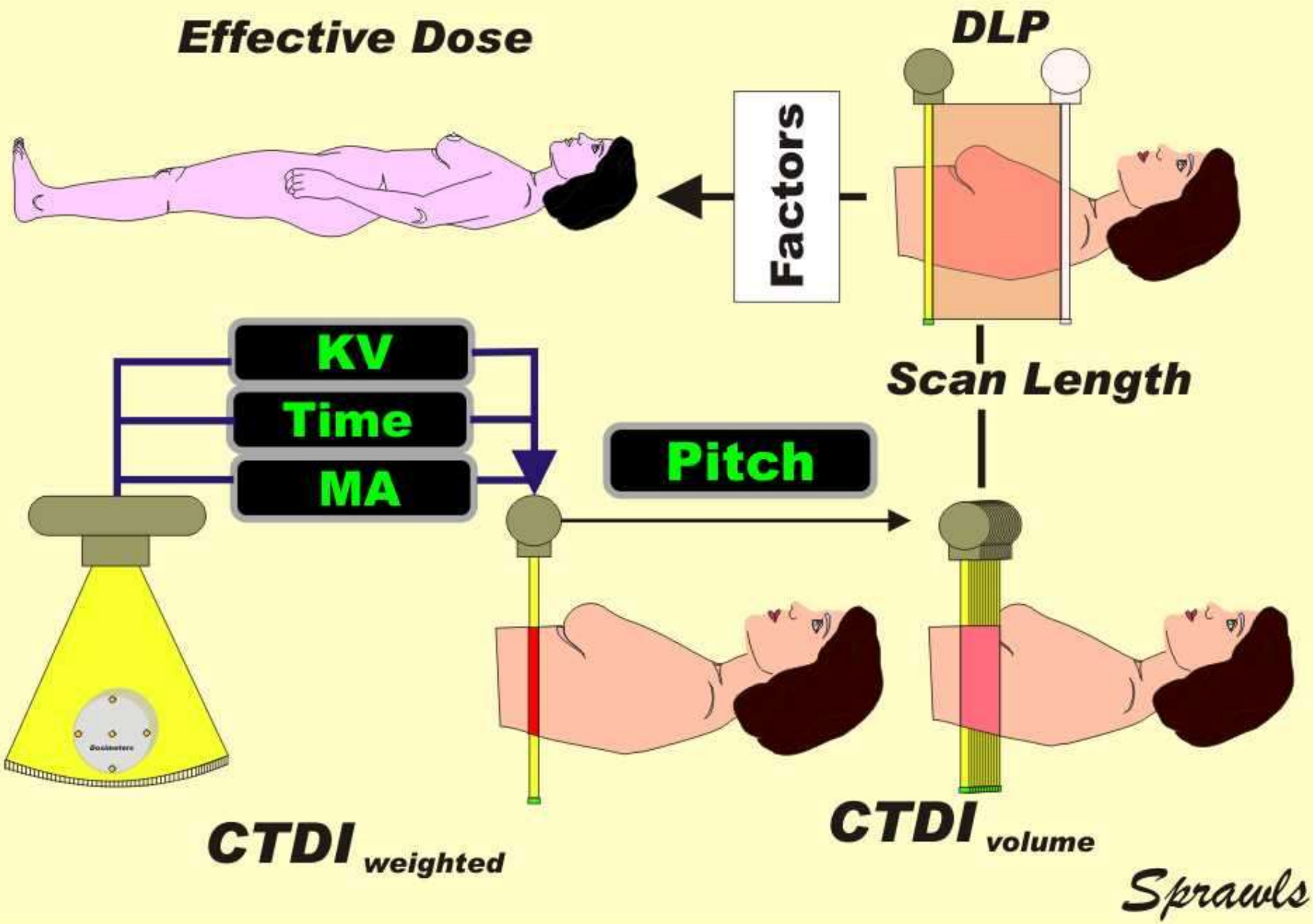
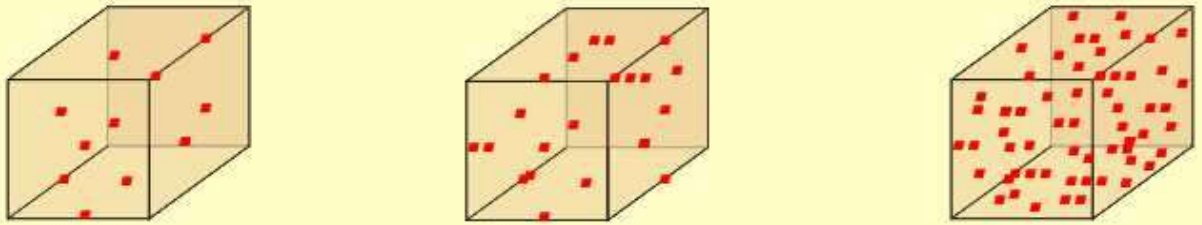
CT Dose Quantities



Decreasing Noise

Requires Increased Photons Absorbed Per Voxel



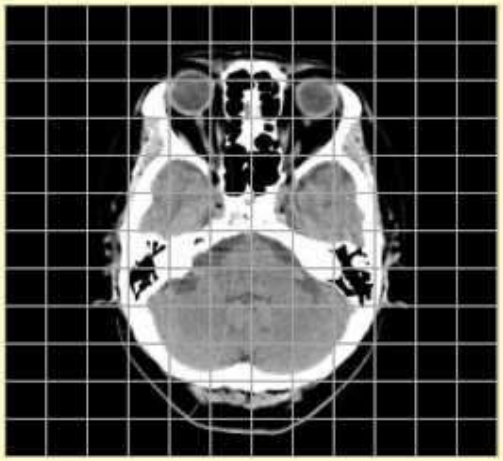
Produces Increasing Dose

Sprawls

Effect of Matrix Size on Image Noise

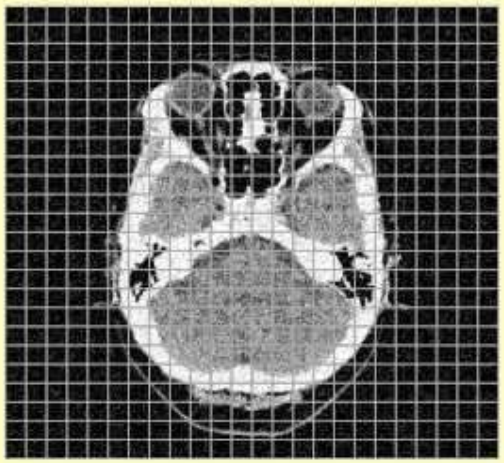
Small **Matrix** ***Large***

Large Voxels



Low Noise

Small Voxels

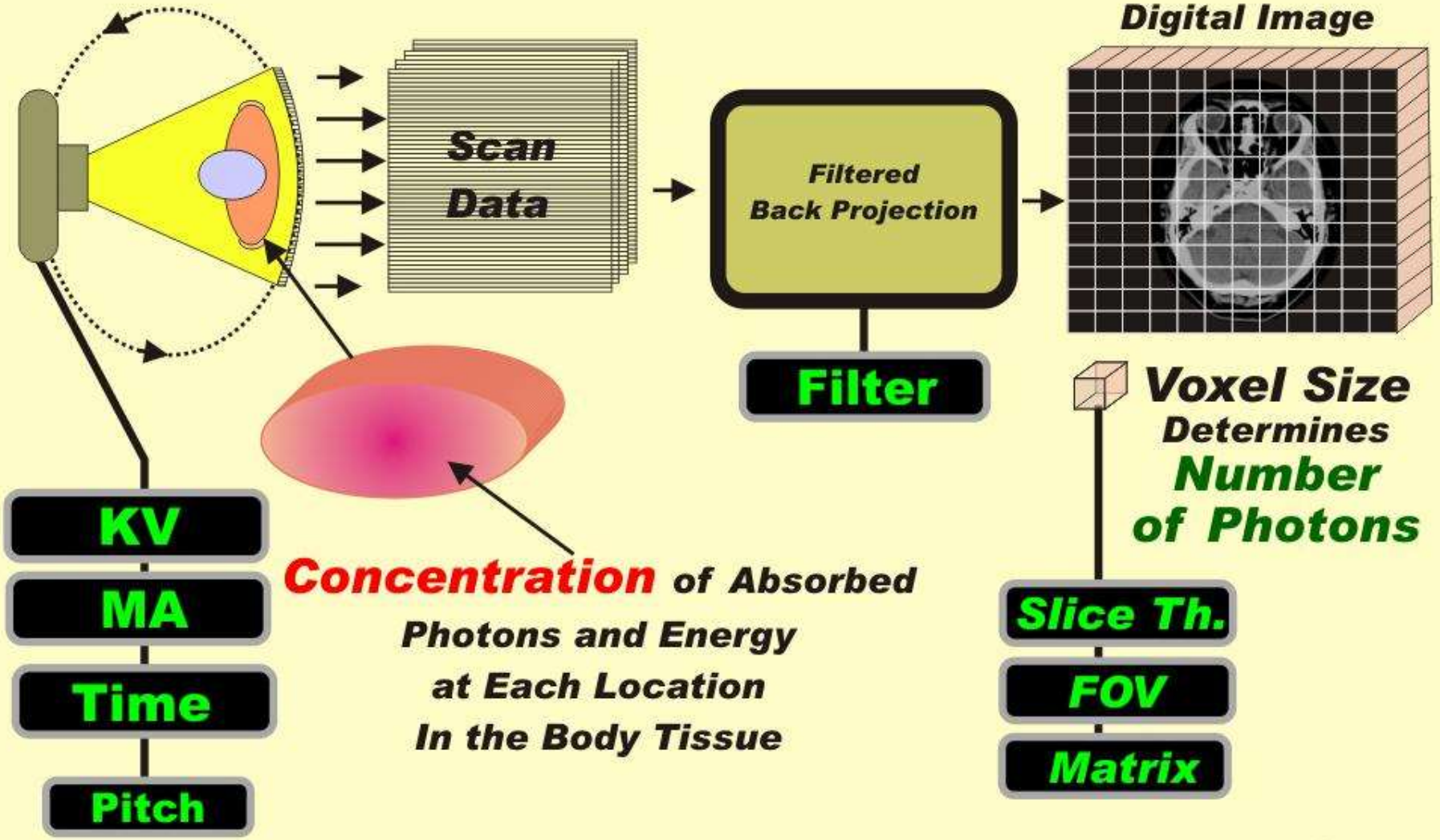


High Noise

The same radiation dose for both images.

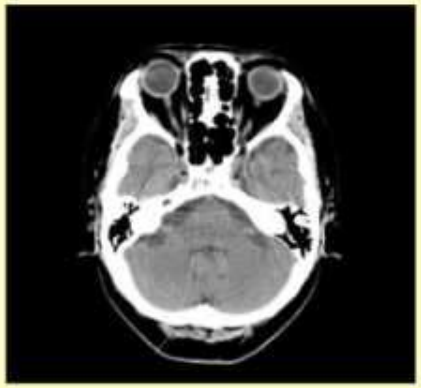
Sprawls

Factors That Determine Image Noise



Sprawls

Two Major Image Quality Goals



High Detail

Low Noise

Voxel Size

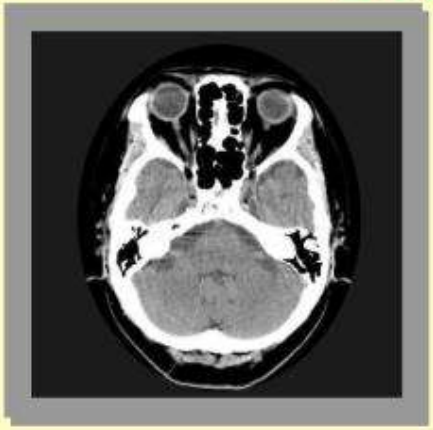
FOV | **Matrix** | **Slice Th.**

Protocol Factors

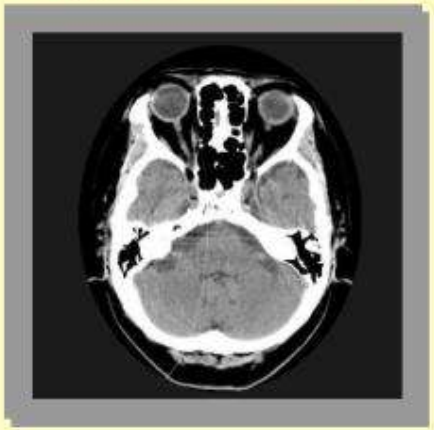
Sprawls

Relationship of Radiation Dose to Image Detail

Lower Dose



Higher Dose

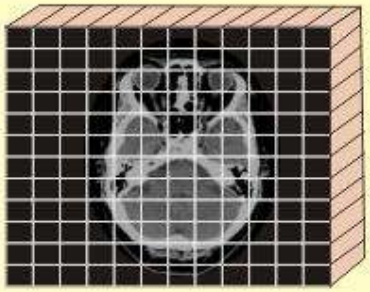


When detail is increased by

- Decreasing **Slice Th.**
- Increasing **Matrix**
- Decreasing **FOV**

Noise Increases

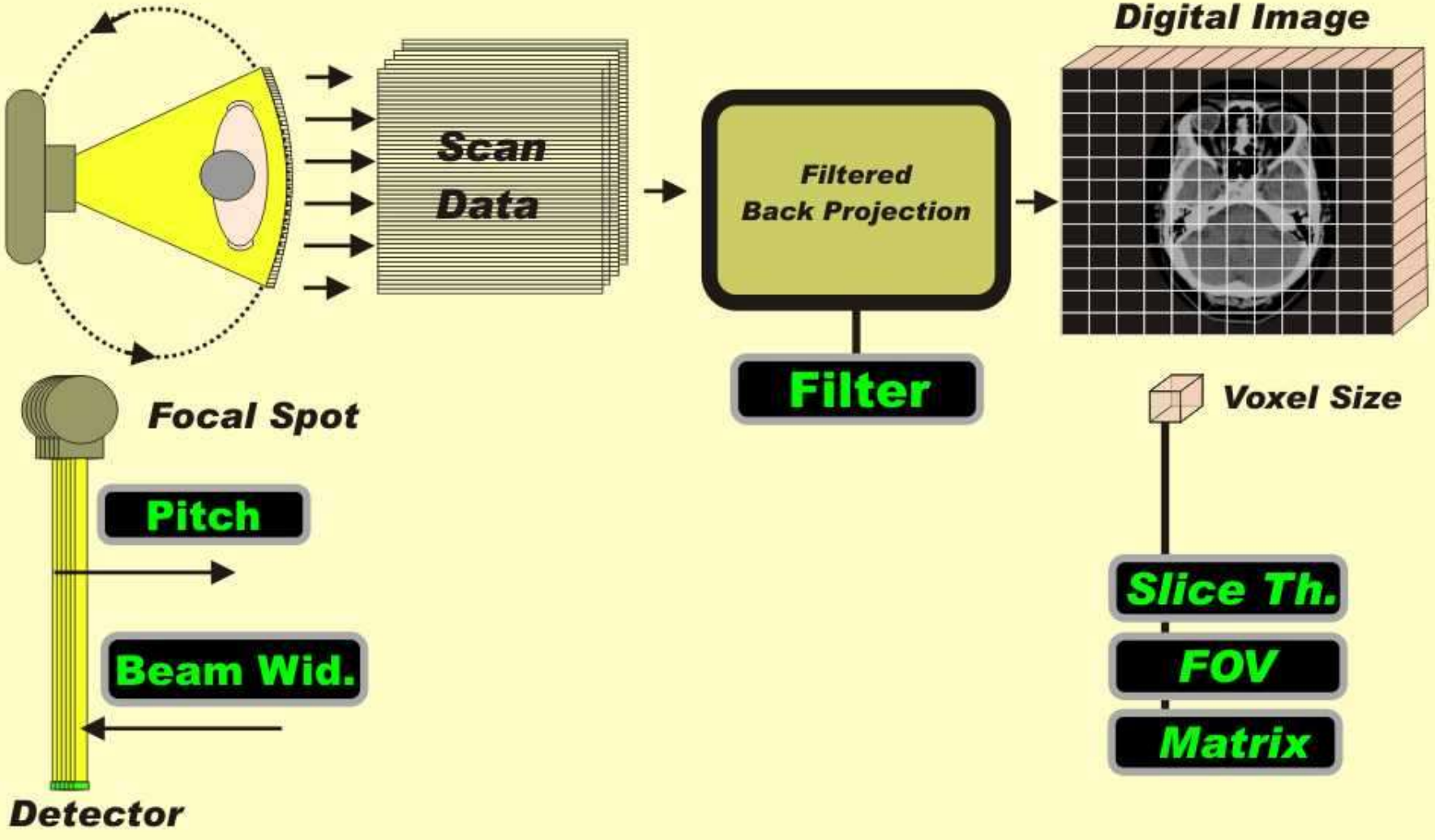
Because of decreased voxel size



Dose must be increased to reduce noise.

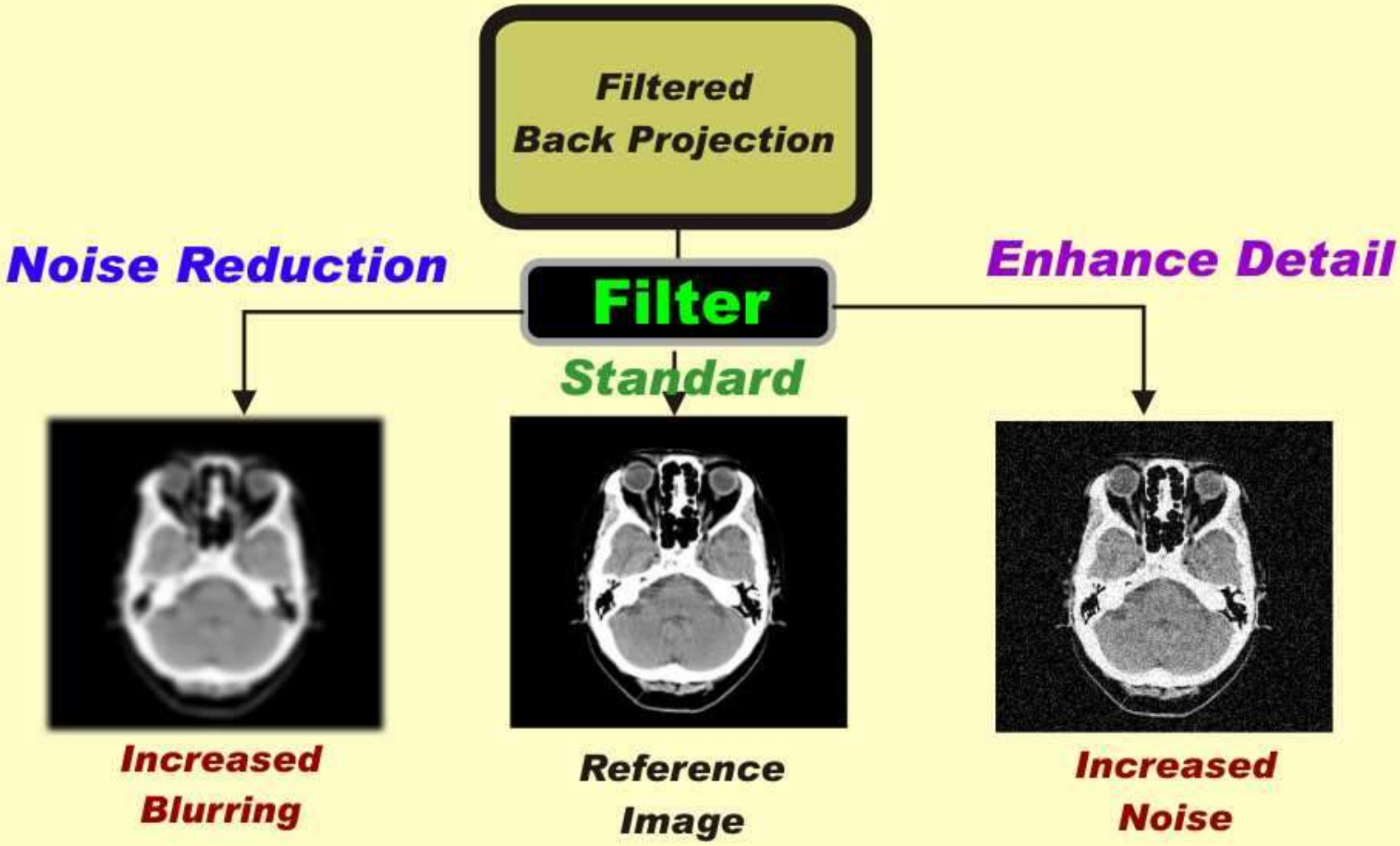
Sprawls

Factors That Determine Image Detail (Sources of Blurring)



Sprawls

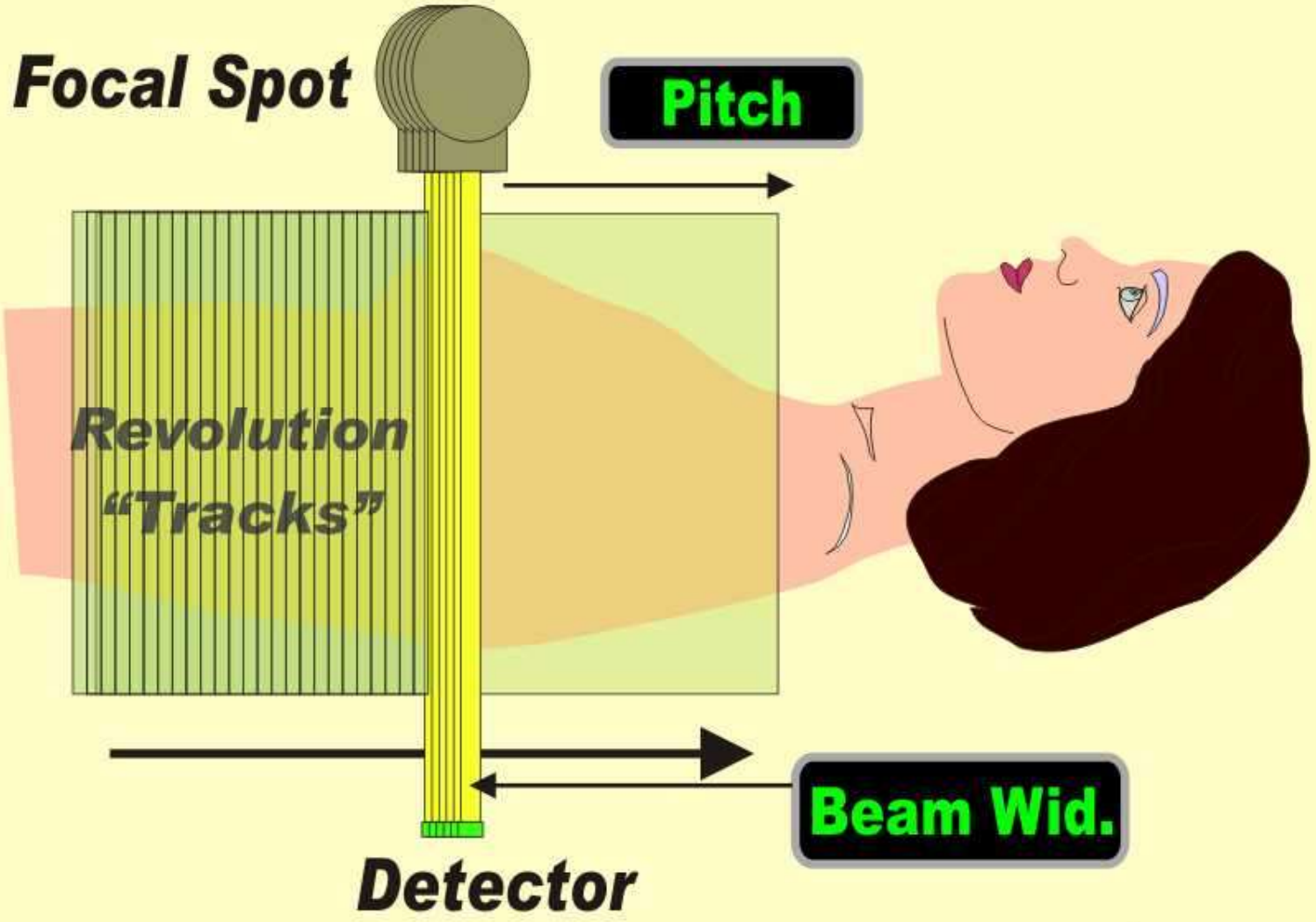
Reconstruction Filter Kernels



(Effects exaggerated for illustration here)

Sprawls

Scan Data Set



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

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.

Sprawls

Digital Resources to Enrich Learning Activities

The Web

Connecting and Sharing

Textbooks
Modules

Visuals

Clinical
Images

Modules

References
Teaching Files

Classroom

Clinical
Conference

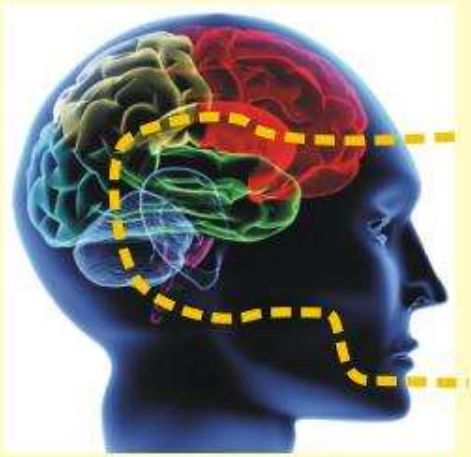
Small
Group

"Flying Solo"

Sprawls

The Elements of
A Highly Effective Educational Session

The Brain



Follow Up

Review

Refresh

Reflect

Recall

Remember

Re-inforce

The Physical Universe

(Physics of Medical Imaging)

Web-based Resources

(www.sprawls.org/ipad)

Sprawls

Clinically Focused Physics Education
Principles to Practice

RSNA 2014 RC 823

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Course Website: http://www.sprawls.org/clinphys

To View on iPad: http://www.sprawls.org/ipad