Challenges and Opportunities in Medical Physics

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The Future of Health Care -Objectives

- Predictive
- Preemptive
- Personal
- Participatory

Elias Zerhouni MD

NIH Director –2007

Imaging as a Tool to Realize Healthcare Objectives

- Predictive –Screening, Early Intervention
- Preemptive –Monitoring
  At-Risk Populations
- Personal –Phenotypic Expression
  of Genetic Characteristics
- Participatory –Databases and
  Digital Health Records

Basic Science: Imaging as a Tool to Understanding

Cell migration	Cell differentiation
Tissue inflammation	Malignant processes
Genetic basis of disease	Genomic-based treatments
Signal transduction	Signaling pathways
Temporal & spatial interactions	Drug actions
Tissue self-assembly	Regenerative medicine

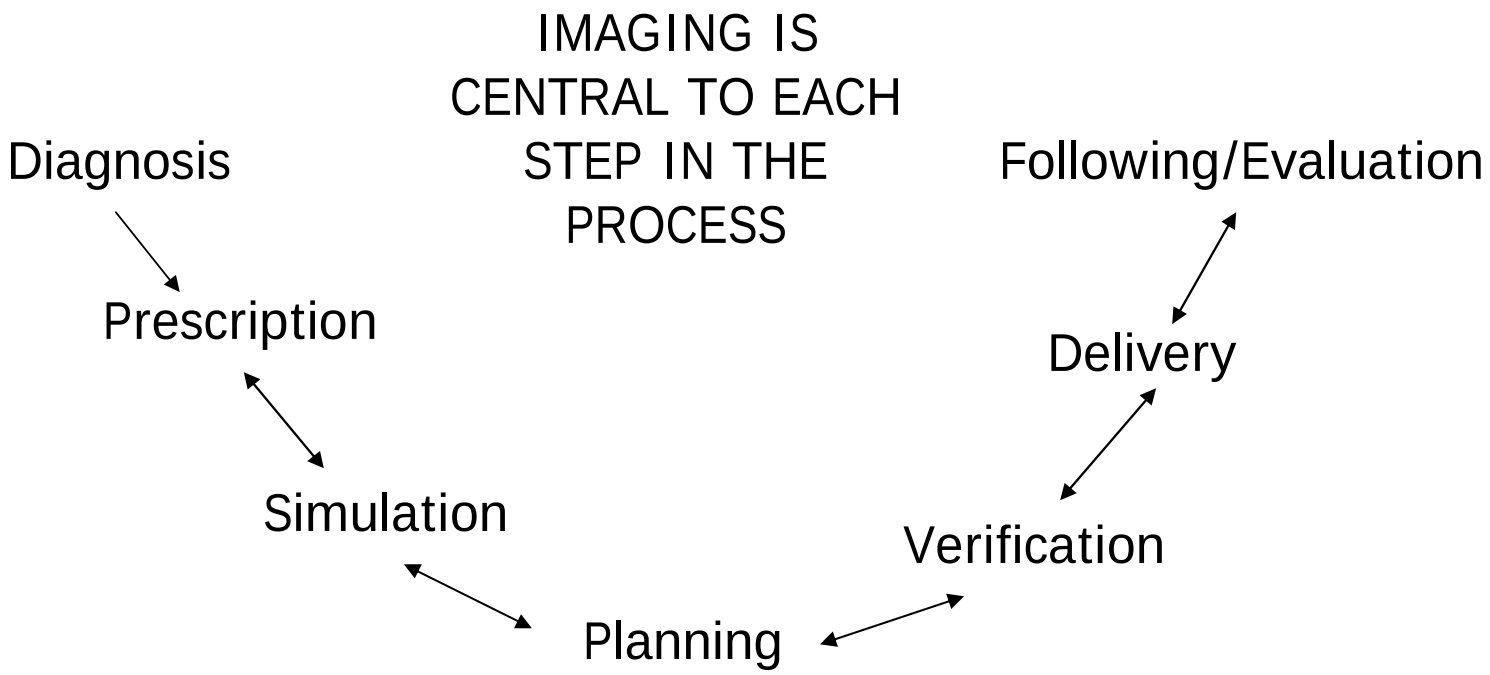
Interventional Techniques Employing Image Guidance

- Angiography
- Ablation
- Embolization
- Biopsy
- Cholecystectomy
- Sinus IGS
- Craniofacial IGS
- Catheter Placement

Imaging in Radiation Oncology

- Detection
- Diagnosis
- Staging
- Prescription
- Simulation
- Planning
- Verification
- Delivery
- Intra-treatment Response
- Response and Follow-up

The Process of Radiation Treatment



Imaging Modalities in Radiation Therapy

- Radiography/Fluoroscopy
- CT Fan-Beam
- PET
- MRI
- Optical
- MV Portal
- CT Cone-Beam
- SPECT
- Microwave
- Ultrasound

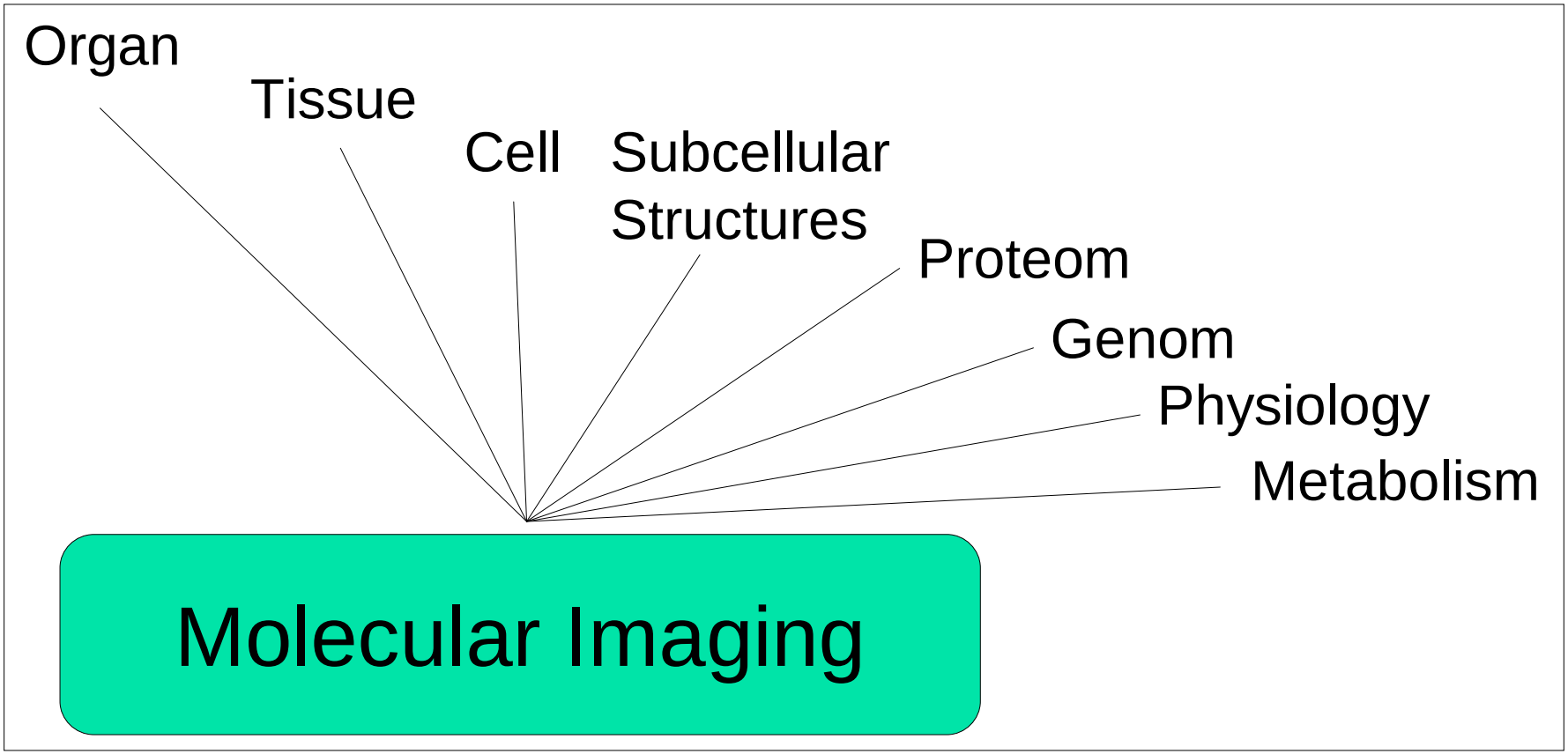
Future of IGRT

- Hybrid imaging systems
  - CT-PET
  - CT-SPECT
  - CT-MRI
  - X Ray-US
  - Optical-MRI

Future of IGRT

- Complex systems simplified to turn-key
  - Further integration of imaging and treatment systems
  - Reduced cost
  - Improved efficiency
  - New knowledge of molecular mechanisms of cancer
  - Development of molecular imaging and therapeutic agents

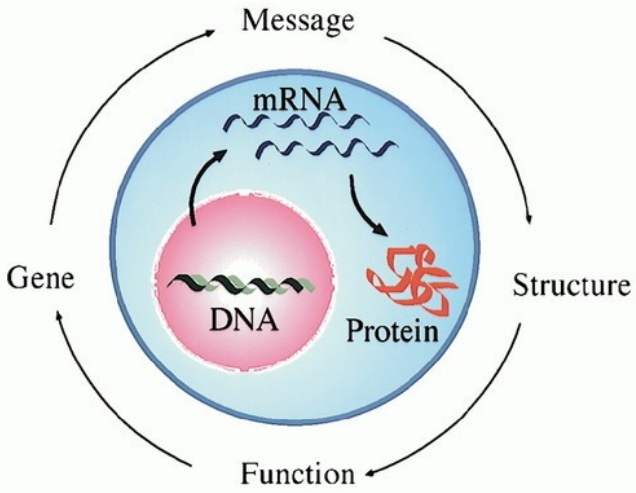
Molecular Imaging



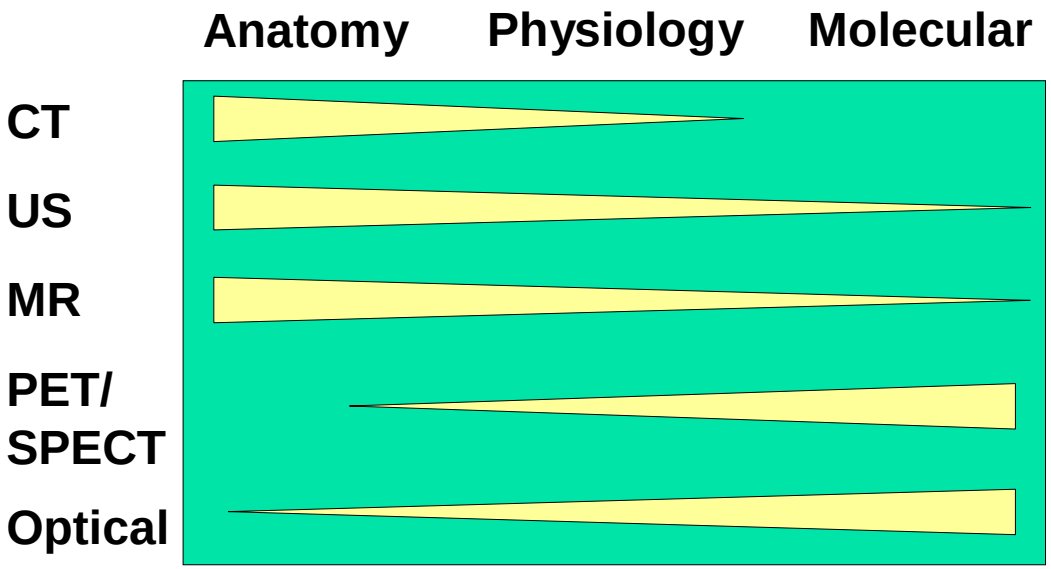
Molecular Imaging investigates the molecular signature of diseases through *in-vivo characterization and measurement of biologic processes at the cellular and molecular level*

Weissleder et al., Radiology 219 (2001)

Intracellular Targets for Molecular Imaging

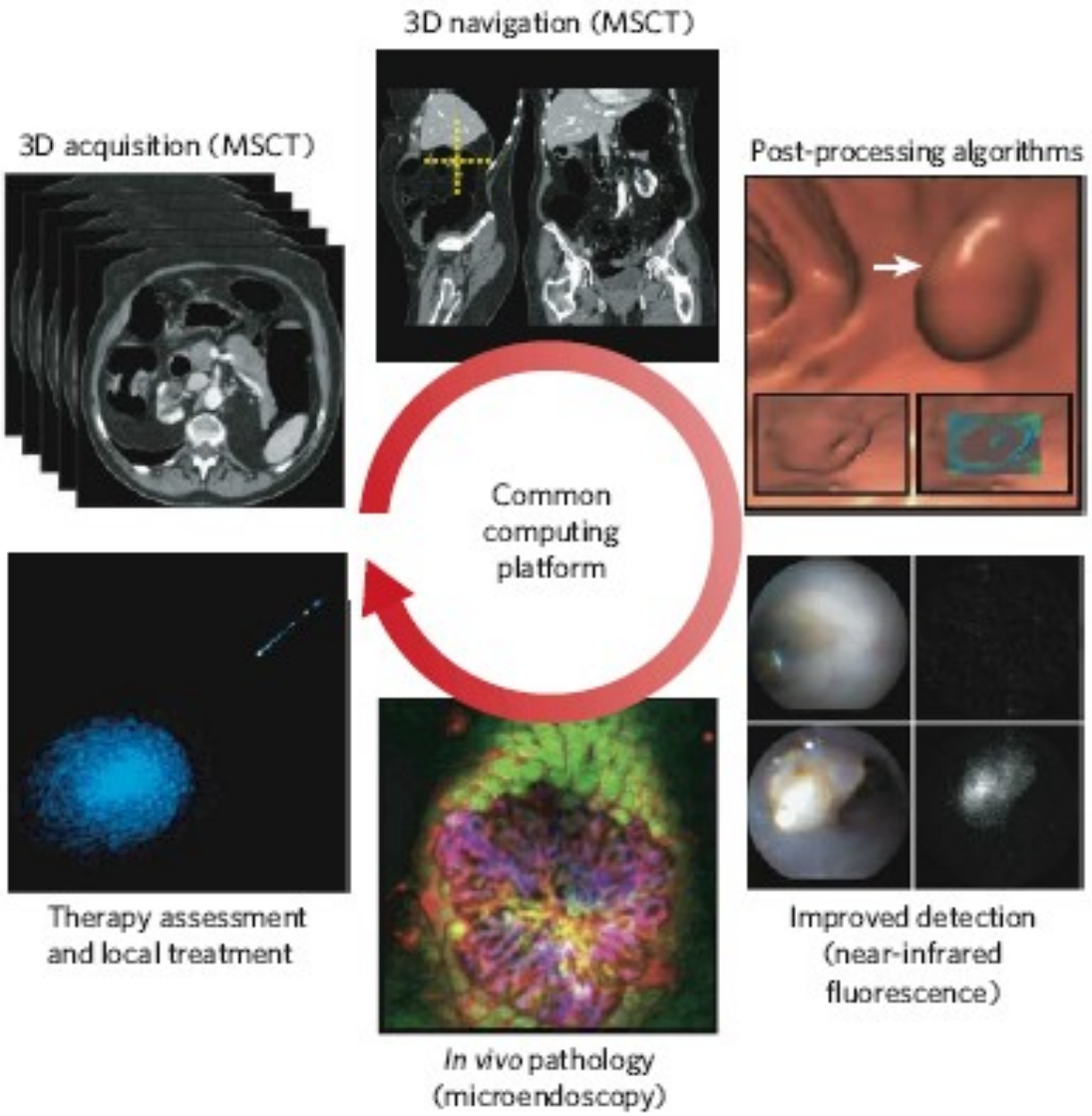


Target	Number/cell
Gene (DNA)	2
Message	50-1,000
Protein	100 - 1,000,000
Function	massive

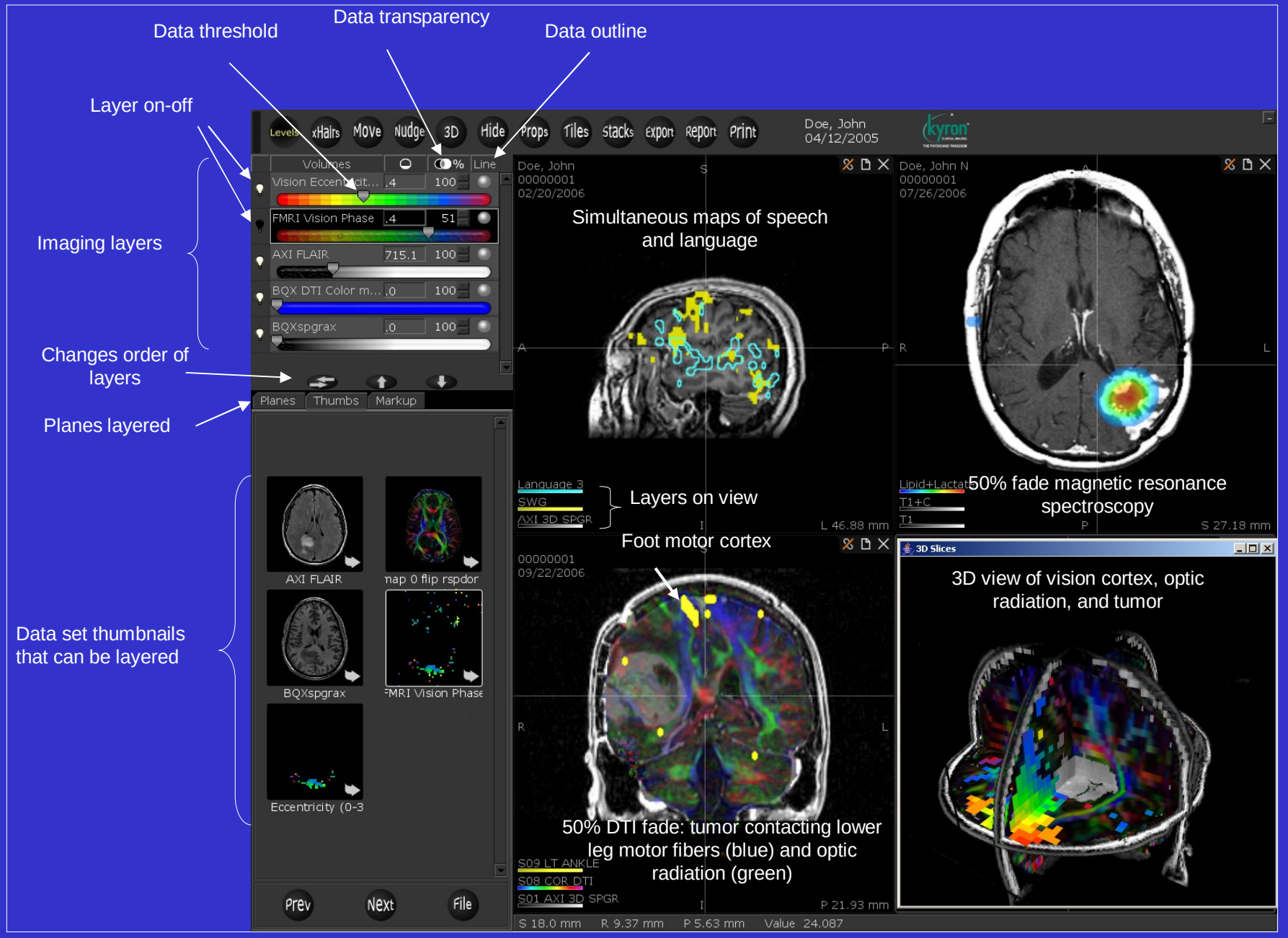


Adapted from Weissleder, R. et al. Radiology 2001;219:316-333

Integrating Image Information

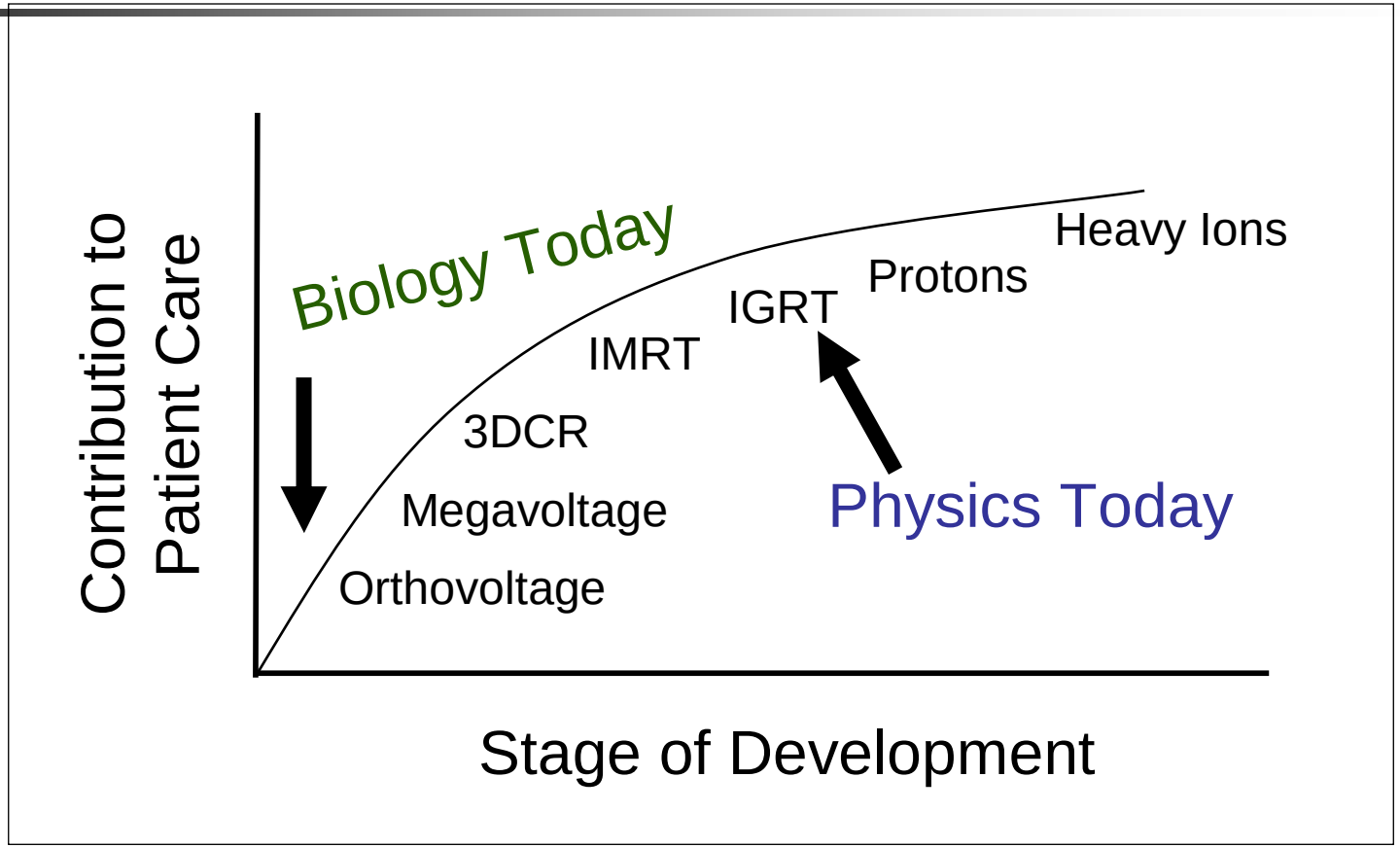


R. Weissleder, MJ Pittet, Nature 2008



Evolution of Radiation Therapy

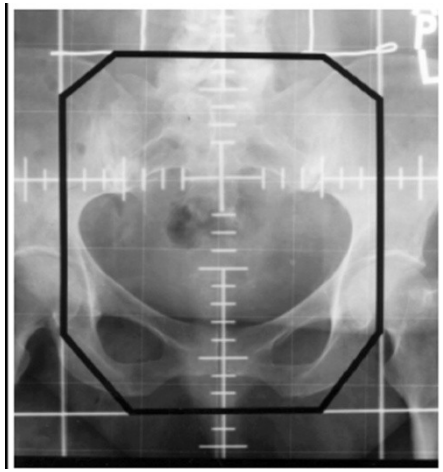
Physics-Biology Stage of Development

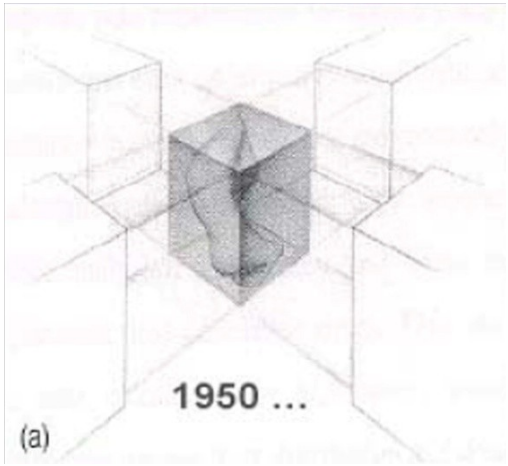


Evolution of Radiation Therapy

2DRT (Conventional RT): 1950's – late 1980's

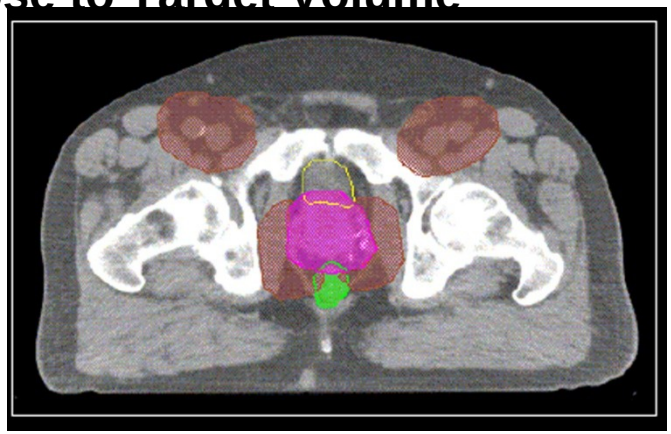
- **Blocked fields**
- **2D planning**
- **Relatively large vol. of normal tissue irradiated**

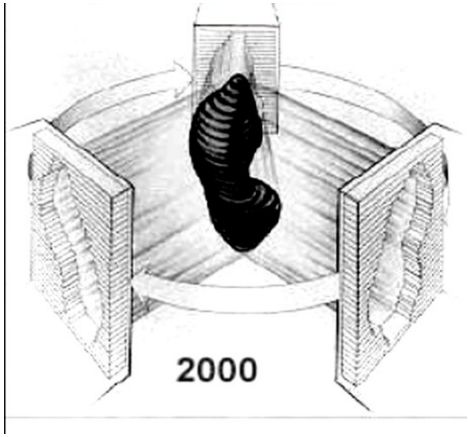




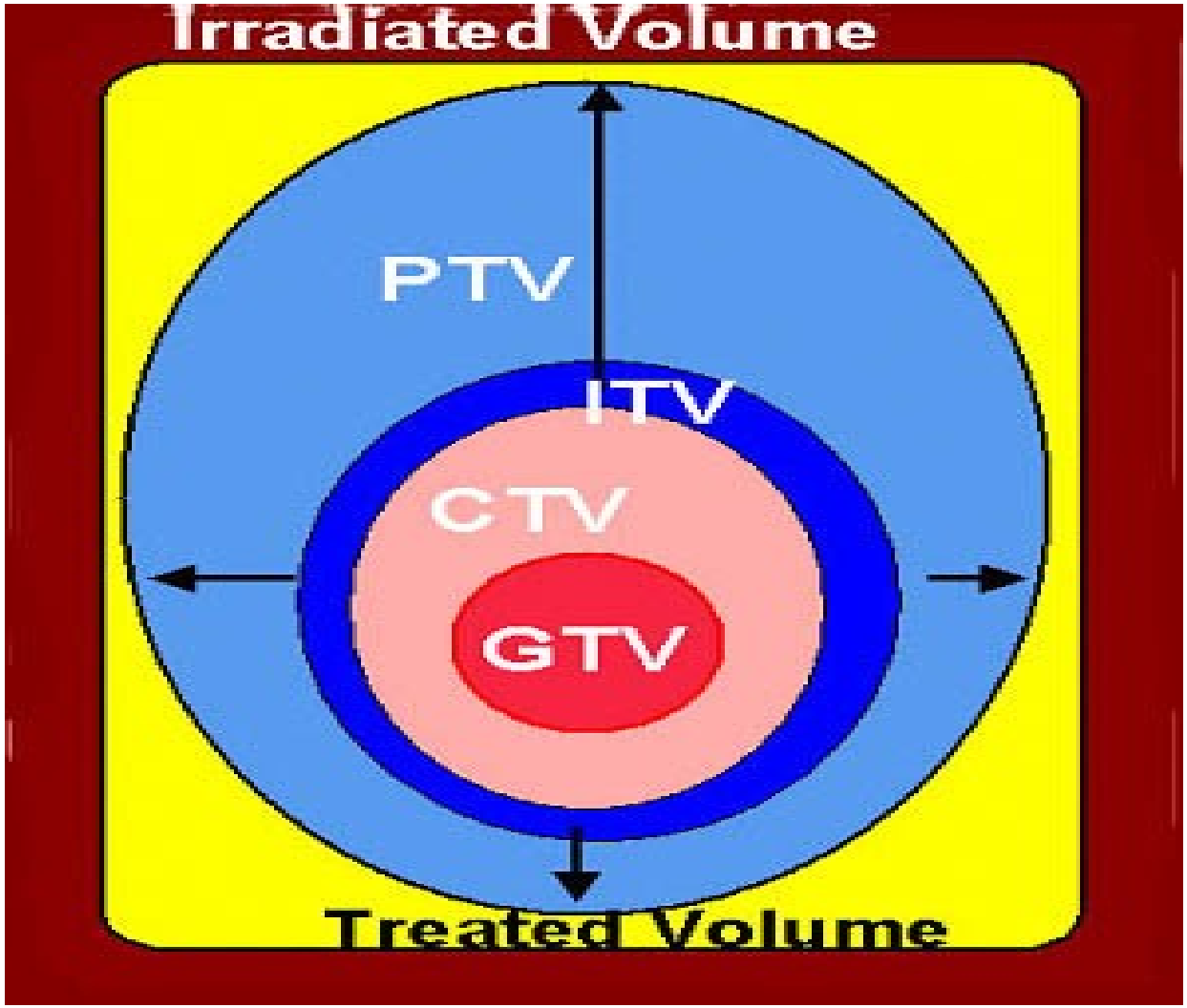
3DCRT (Conformal RT): late 1980's – 2000

- **Imaged-based Volumes**
- **3D planning to conform dose to Target Volume**
- **Spare normal tissue**
- **Intensity-Modulated Radiation Therapy (IMRT)**
- **Biologically-Adaptive Radiation Therapy (dose painting)**

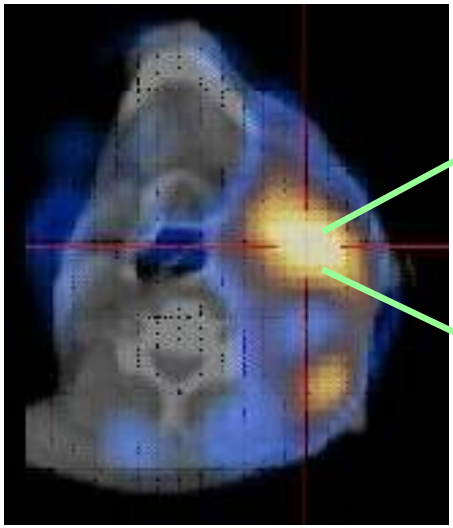


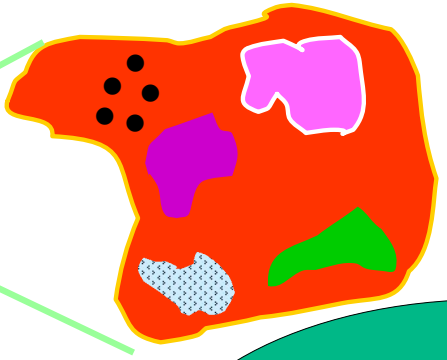


Accurate Specification of Volumes



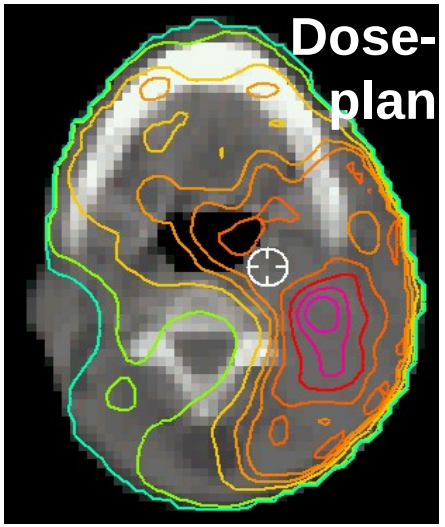
Biological Adaptive RT (dose painting)





- Metabolism Marker :
  - ^{18}FDG (Glucose metabolism)
  - ^{11}C-methionine / -choline (Prostate-Ca.)
- Hypoxia Marker:
  - PET: ^{18}F-MISO, ^{18}FAZA
- Apoptosis Marker
  - ^{99}Tc-Annexin V

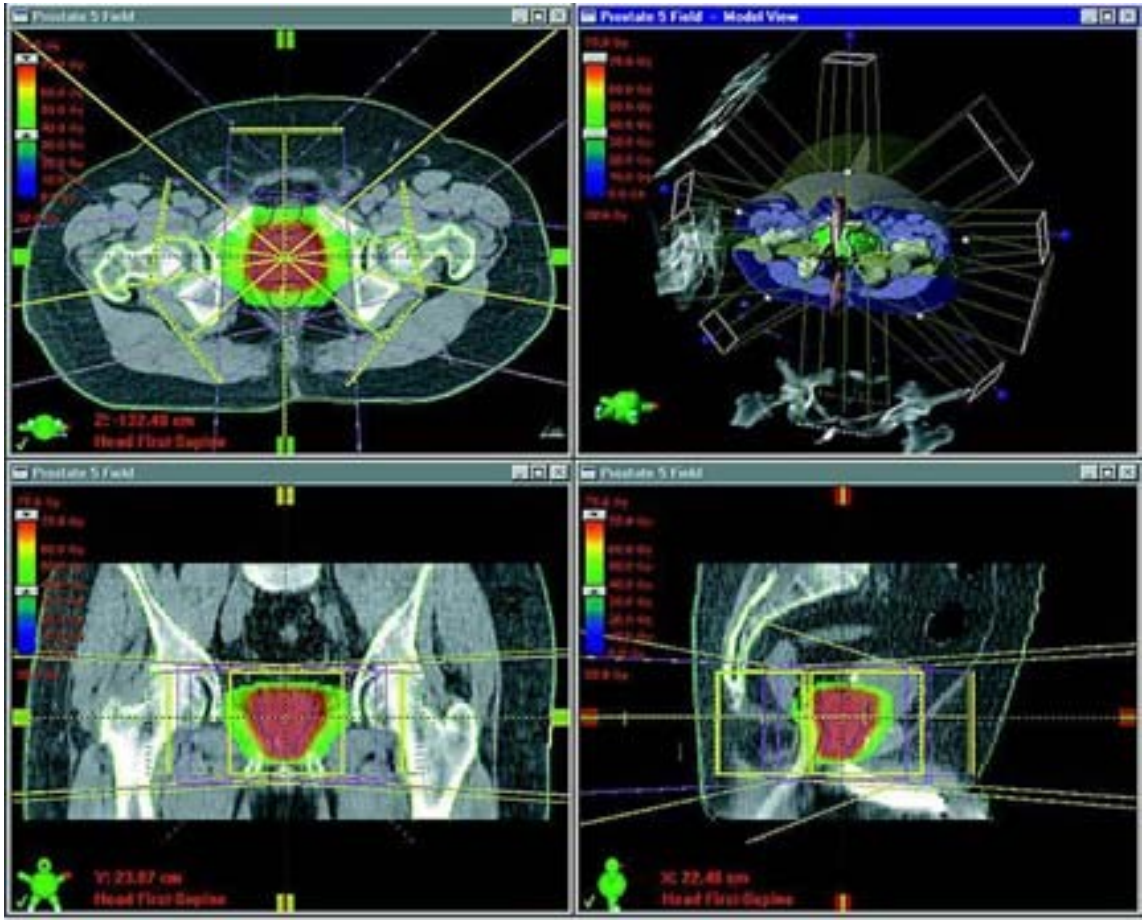
- Identification of tumor areas with varying sensitivity
- Adaption of the dose distribution
- Dose Escalation



Summary

- Molecular Imaging replaces population based treatment methods by personalized genotype/phenotype adapted concept
- Molecular Imaging enables
  - more reliable target volume definition
  - specification of tumor heterogeneity
  - Treatment response assessment of tumor and normal tissue
- Molecular Imaging has the potential to provide
  - earlier diagnosis
  - more effective and less toxic treatment
  - better treatment outcome

Opportunities in Medical Physics
IMRT

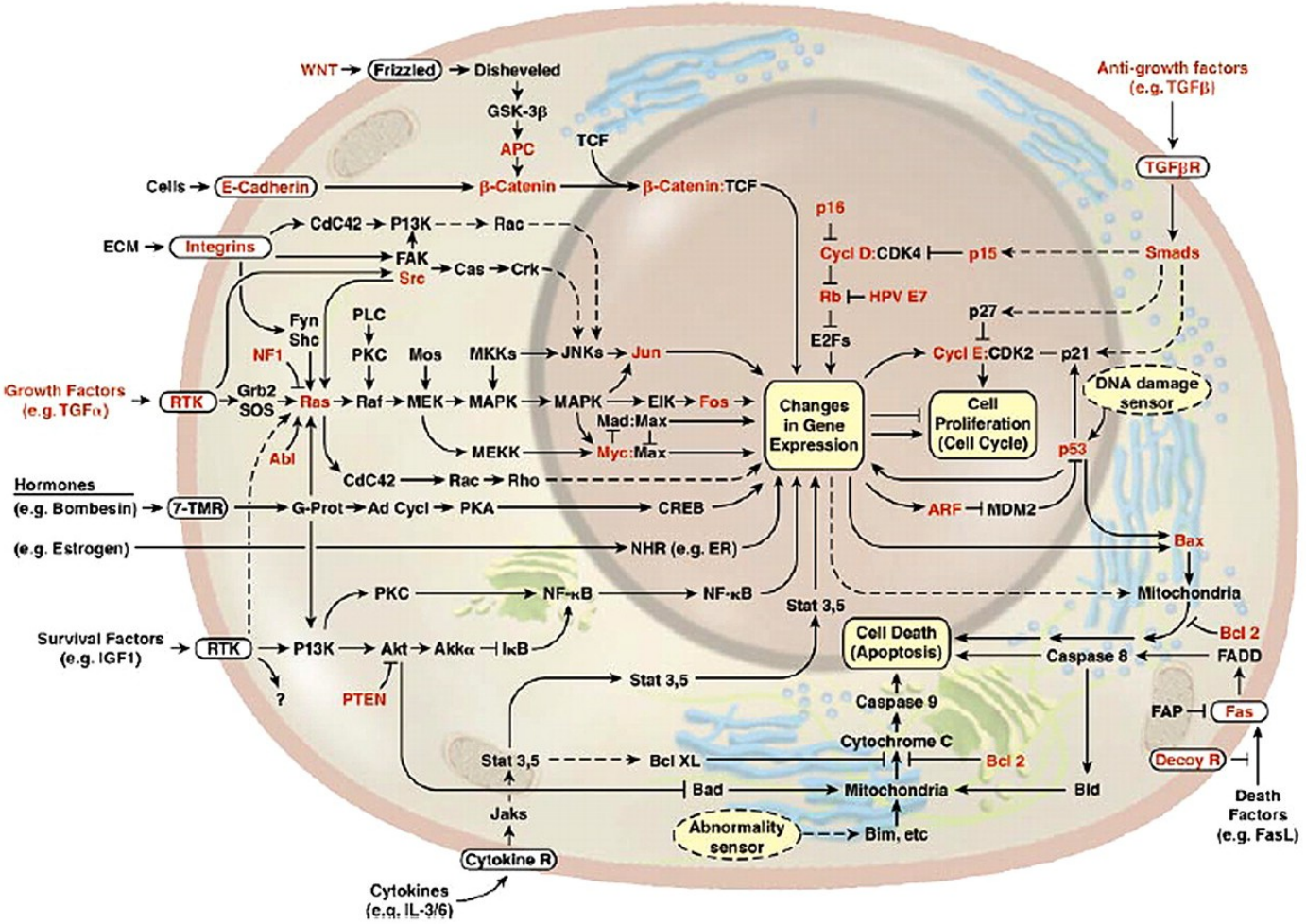


Opportunities in Medical Physics IMRT

- Is dose uniformity the correct criterion?
- How should tumor margins be defined
- Hypofractionation –safe and effective?
- What to do about motion?
- Is biological sensitivity a better criterion?

Opportunities in Medical Physics
Molecular Imaging

The emergent integrated circuit of the cell



Hoffman J M, Gambhir S S Radiology 2007;244:39-47

Radiology

Opportunities in Medical Physics – Molecular Imaging

- What are promising receptor-specific agents?
- Will nanostructures have a role in MI?
- How will we solve the penetration issue?
- What will functional imaging contribute?
- Will we be able to screen patients?
- Will we be able to design treatments for individual patients?

Demands on the Medical Physicist

- Expanding breadth and depth of knowledge
- Enhanced responsibilities for quality assurance
- Greater involvement in individualized patient care
- Commitment to translational research (Entrepreneurship)
- Increased demand for accountability
  - Professional
  - Patient
  - Public