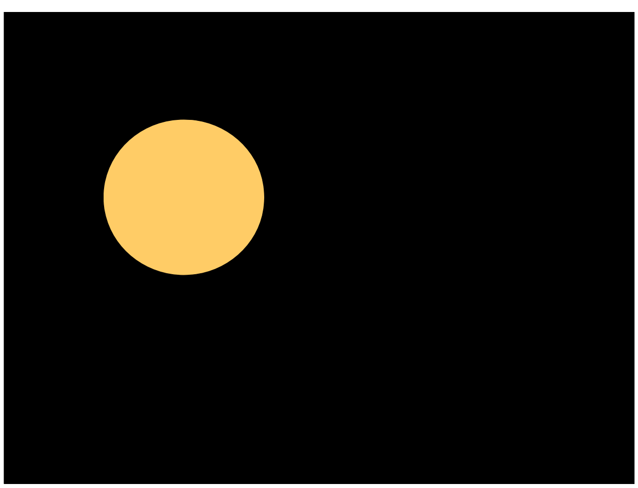
Future of Electrical and Computer Engineering and Biomedical Imaging

Jim Ji

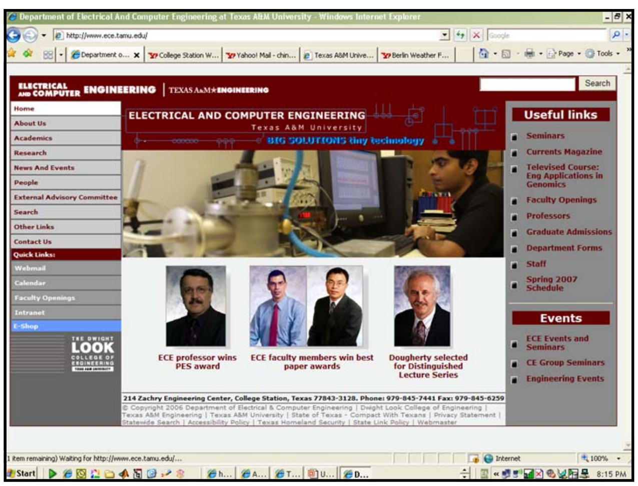
Department of Electrical and Computer Engineering
Texas A&M University
Jimji@tamu.edu

http://www.ece.tamu.edu/~jimji



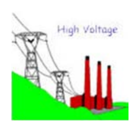
20th Century

- Arguably, transistor (1947 at Bell Lab by John Bardeen, Walter Brattain, and William Shockley) is the most significant engineering invention in the 20th Century.
- Physics, electronics, computers, information



Electric Power & Electronics

- power systems: system modeling, reliability, control, prediction
- power electronics
- Hybrid automobiles

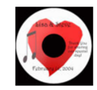


Butler Ehsani Enjeti Huang Kezunovic Russell Singh Toliyat

Analog & Mixed Signal ("Chip")

Communications and Signal Processing

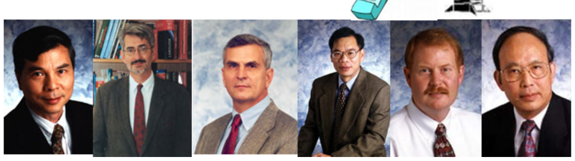
- Cellular communications systems,
- Speech coding and processing
- Data compression for speech and images
- Data security
- Digital signal processing



Miller Kunda Seperdin Georghadis Xiong Narayanan (Not shown: Ji, Chan, Dougherty)

Electromagnetics and Microwaves

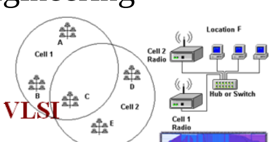
- "High frequency", MHz, GHz
- Wave propagation and scattering
- Antennas and coils
- Microwaves circuits

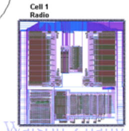


Chang Michalski Nevels Nguyen Wright Chan

Computer Engineering

- **"Computer hardware"**
- **CAD: Design and testing of VLSI**
- **Computer networks**
- **Computer architecture**

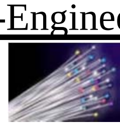




Cantrell Choi Hu Lu Mercer Reddy Shi Watson Zhang

Solid State Electronics, Photonics & Nano-Engineering

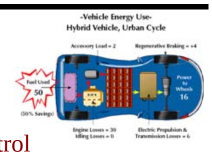
- “Semiconductors”
- “Fiber optics”
- Lithography
- Nanotechnology
- Quantum computing and storage




Madsen Cheng Eknoyan Hemmer Maldonado Strieter Su Wang Weichold

Control

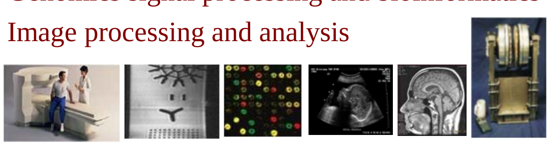
- “Driving”
- Robust and Adaptive control
- Neural Networks and Learning control
- Control System Design for Hybrid Vehicles
- Distributed control algorithms



Bhattacharyya Howze Datta Huang Zountos

Biomedical Imaging

- Magnetic Resonance Imaging: system design, reconstruction algorithms
- Genomics signal processing and bioinformatics
- Image processing and analysis



Wright Chan Datta Dougherty Han Ji Braga Neto Zourntos

21th Century

The 21st century would be the biomedical century just as the 20th century had been the century of physics, electronics, and computers.

-- Elias Zerhouni, NIH Director

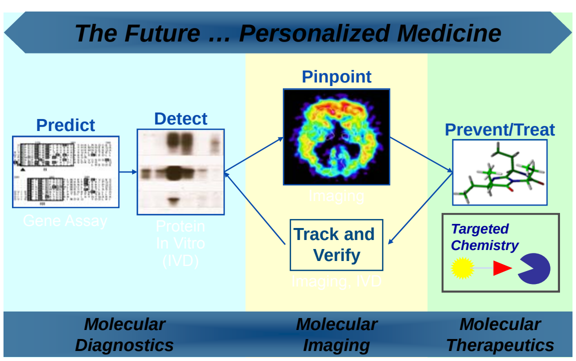
•**Genomics will be the key to medicine, molecular biology, and biomedical technology**

Inner life of the cell

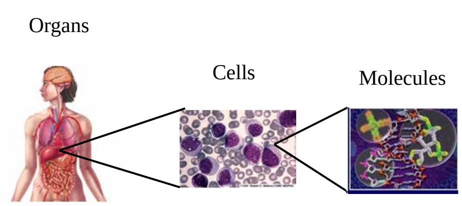
ECE Frontier

- Biomedical imaging => linking molecular biology to system biology (instrumentation)
- genomics signal processing: identify and manipulate the genes that affect system functions (signal processing)

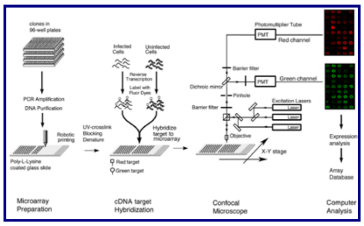
Evolving medical practice – 21st Century Personalized Healthcare



From electrons to genetics

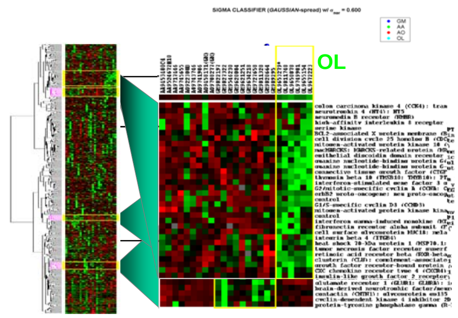


Gene Microarray (DNA Chip)



Packaged DNA chip

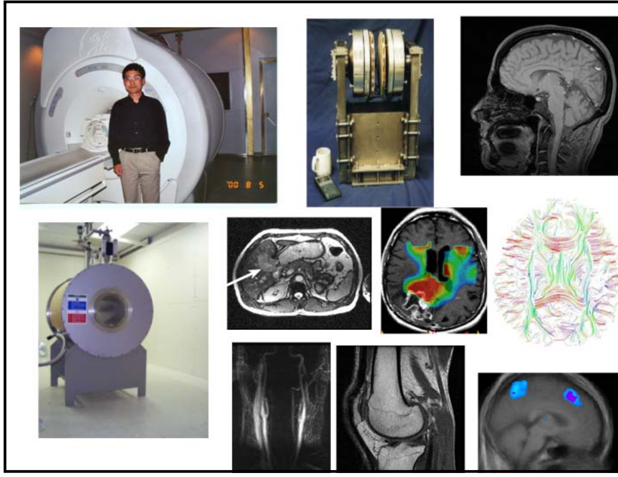
Cancer Clasification



Inference of Genomics Regulatory Networks

Quantized Microarray Data

cdk7	cyc H	cyc E	p21/W	Rb
0	1	0	1	1
0	0	1	0	0
1	1	0	1	1
0	1	0	1	0
1	0	1	0	1
0	1	0	1	0



Nobel Prizes Directly Related to MR

Name	Year	Category	Description
Paul C. Lauterbur	2003	Medicine	"For their discoveries concerning magnetic resonance imaging"
Sir Peter Mansfield	2003	Medicine	Glasgow 2001
Kurt Wüthrich	2002	Chemistry	"For his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"
Richard R. Ernst	1991	Chemistry	"For his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"
Felix Bloch	1952	Physics	"For their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"
Edward Mills Purcell	1952	Physics	
Isidor Isaac Rabi	1944	Physics	"For his resonance method for recording the magnetic properties of atomic nuclei"

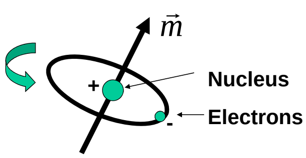
Illinois professor wins Nobel Prize in physiology or medicine

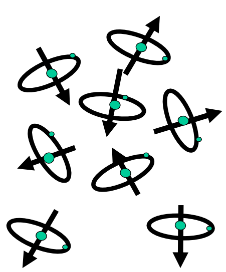
Paul C. Lauterbur, a pioneer in the development of magnetic resonance imaging and a UI faculty member, has been awarded the 2003 Nobel Prize in Physiology or Medicine. He shares the prize with Sir Peter Mansfield of the University of Nottingham in England. Mansfield was a research associate in the department of physics at Illinois from 1962-1964. (10/6/03)

Magnetic Resonance Imaging

- How it works
- MRI in the Aggieland
- Future

Nuclear Spins

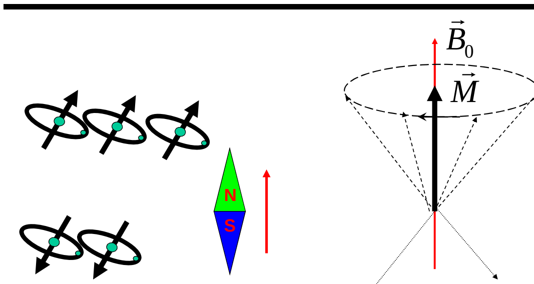




- Spin creates tiny magnetization

$$\vec{M} = \sum \vec{m} = 0$$

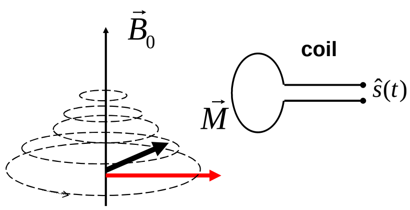
Magnetization



Frquency $\propto$ *B* magnetic field strength

MRI imager has a field 30,000 times of earth field

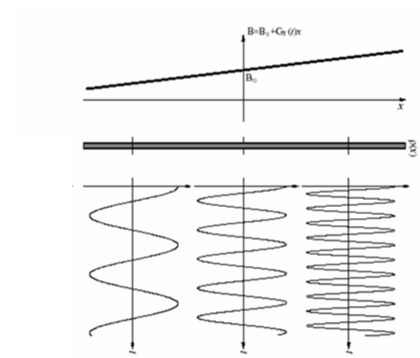
Resonance



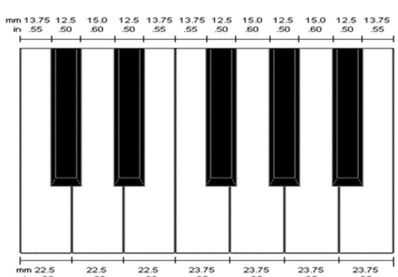
Tapping the system using radio-frequency signals

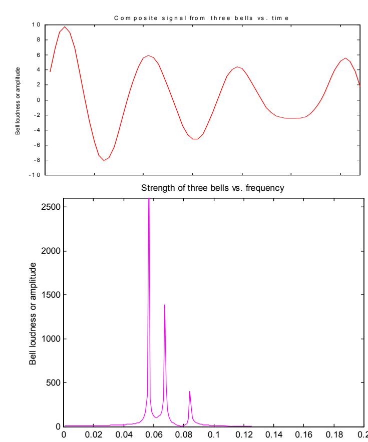
$\vec{B}_1$ frequency: $\omega=\omega_0$

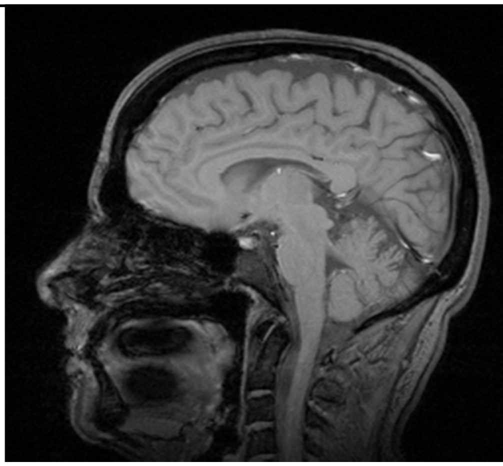
Energy release afterward is picked up by a coil sensor

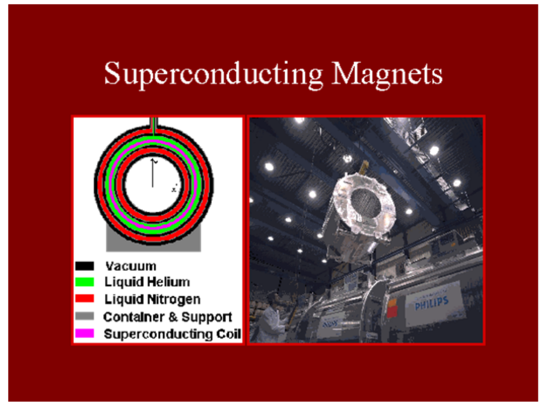


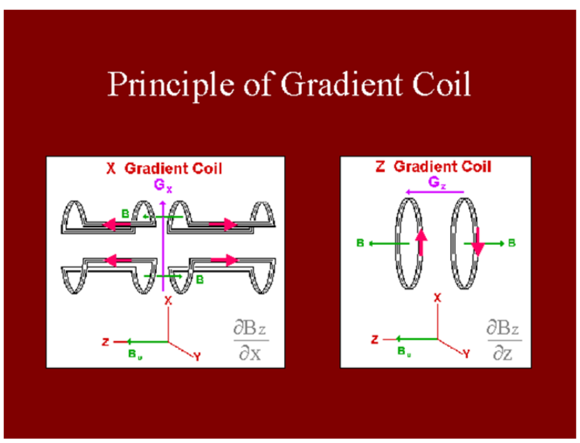
Frequency difference introduced by making nonuniform magnetic field

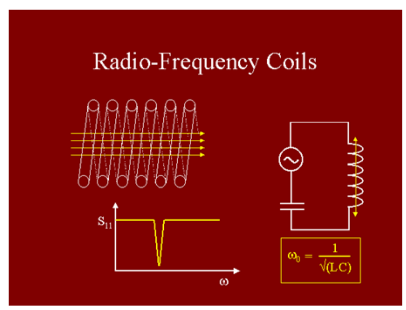


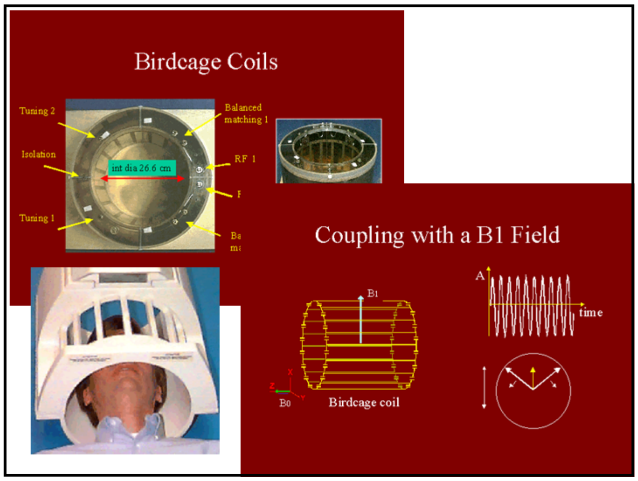




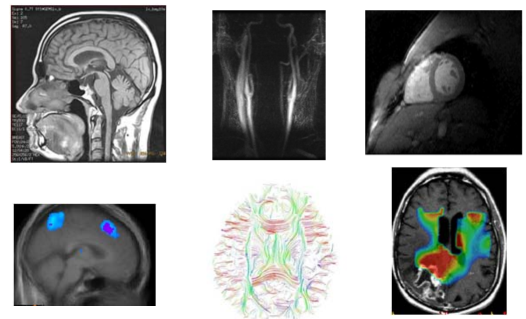

Superconducting Magnets
Vacuum
Liquid Helium
Liquid Nitrogen
Container & Support
Superconducting Coil
PHILIPS


Principle of Gradient Coil
X Gradient Coil
Z Gradient Coil

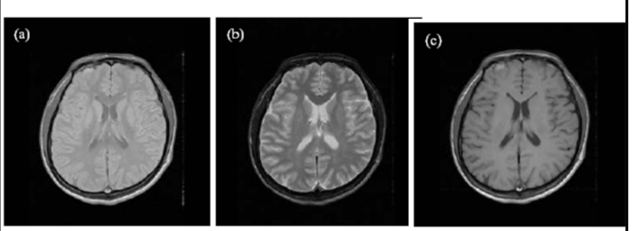

Radio-Frequency Coils



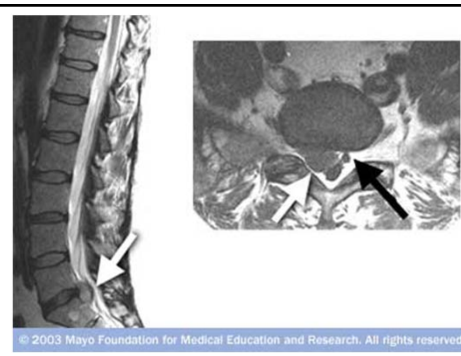
Applications



- Anatomical, angiographic, cardiac, functional, tumor, spectroscopy/spectroscopic imaging…

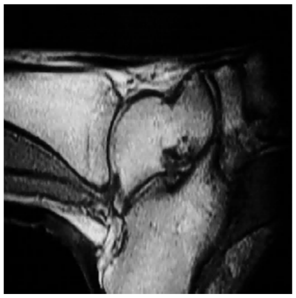


Proton-weighted **T2-weighted** **T1-weighted**

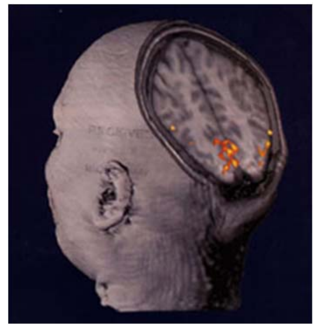


At left, this MRI image shows a side view of a herniated lumbar disk (white arrow). At right, this MRI image shows a cross section of a herniated lumbar disk, looking up the vertebral column in the direction of the person's head. The white arrow points to a herniated disk. By comparison, the black arrow shows a noncompressed nerve root on the opposite side.

Sport Imaging & Kinematic MR

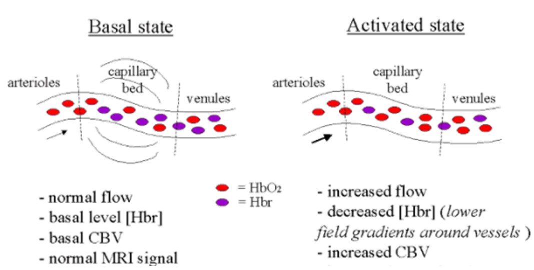


Functional MRI (fMRI)



- Using normal MRI
- Sets of images can then be rendered: baseline and activated
- Images highlighted where activity is

BOLD (Blood Oxygenation Level Detection)



Increased oxygenation level causes more T2 relaxation, which is can be detected by comparing two states

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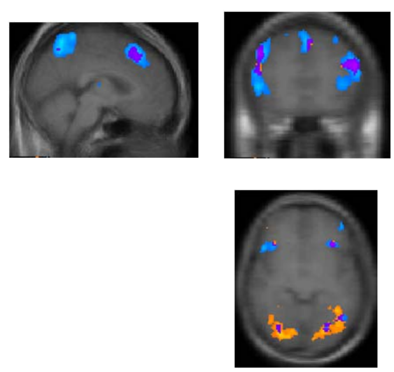
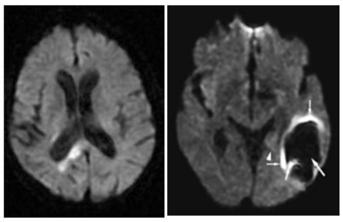
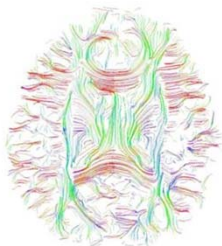
BOLD fMRI



Diffusion-weighted and diffusion-tensor imaging

MR images sensitive to the Brownian motion of the water molecules.





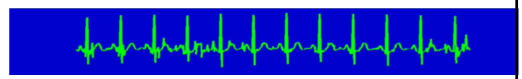
Stroke diagnosis

Brain fibers

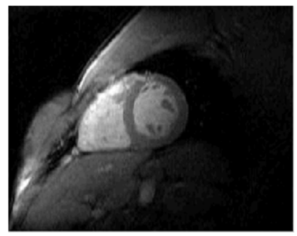
Cardiac Imaging

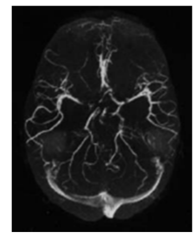
Gated Acquisition + Breath Holding

ECG

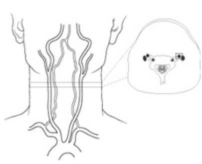


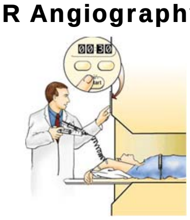
Phase Encodings ….. 0 1 2 3 ….



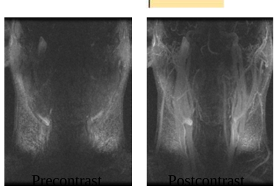


Time-resolved MR Angiography

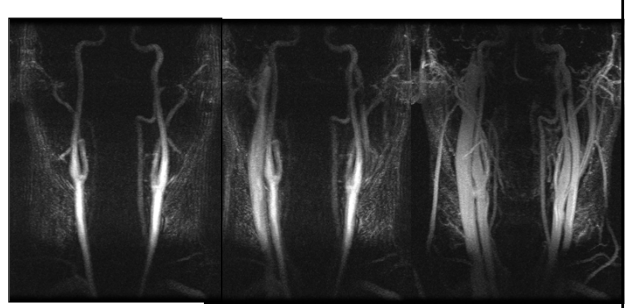




- VTRAC acquisition
- 43ml Omniscan® venous bolus
- TR/TE/α=5.9ms/1.7ms/30°
- FOV=20x15x4.2cm
- Original data 312x192x42



MRA: Maximal Intensity Projection

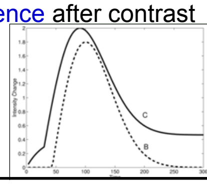


Contrast-Enhanced MRI of Tumors

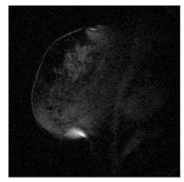
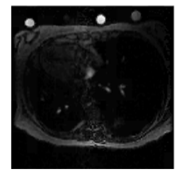
- Cancer -> increased tissue/vasculature growth


Angiogenesis

- Tumors ≤ 1 mm^3 is detectable by MRI but poor differentiation of specificity (30 - 40%)
- Acquiring an image sequence after contrast agent (tracer) injection



Contrast-enhanced tumor imaging
Angiogenesis due to cancer
Benign/malignant tumor specification: Bolus injection followed by time-series imaging

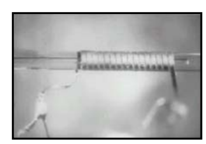
Future?

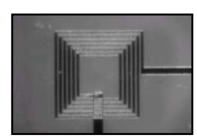
- Smaller: cellular, nanoimaging
- Clearer: high field, sensor design
- Faster: fast strong gradient, parallel imaging
- Smarter: from image to information
- More contrast mechanism and applications: molecular imaging, spectroscopic imaging, …

Mirco-imaging

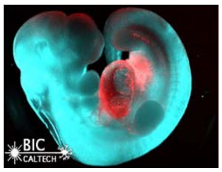
350μm o.d. 250μm i.d. capillary,
50 μm Cu wire. Sample volume 50 nL

147 μm o.d. 50 μm i.d. capillary,
25 μm Cu wire. Sample volume 800 pL

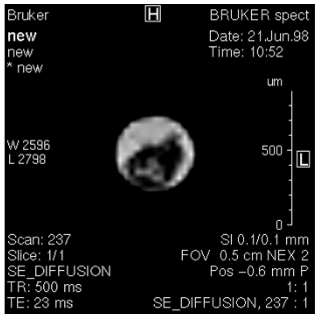

Microcontact printing


Photolithography

Mirco-imaging



Embryo



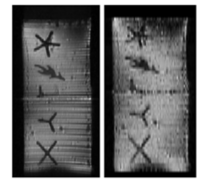
Single Neuron

Parallel MR Imaging

- ***The world's first MRI system with 64 receiver channels (Prof. Wright)***
- Improving imaging speed (factor of 64), resolution, or SNR.
- Future work:
  - Improve penetration
  - Applications: spectroscopy, 3D imaging, dynamic imaging,…

Receivers

Coils



Acquired Image

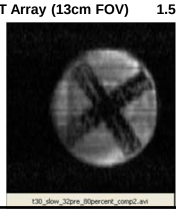
Parallel MRI with Massive Arrays and Receivers

A 64-channel system is developed at Texas A&M University

4.7T Array (13cm FOV)

1.5 T Array (30cm FOV)

Receivers



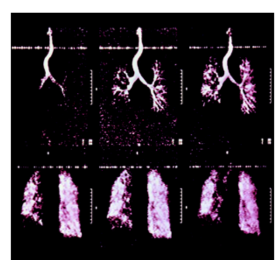
125 frames/second, 256 x 64 images

S. M. Wright, M.P. McDougall, and D. G. Brown, Proc. Second Joint EMBS/BMES Conference, pp. 23-26, 2002
M. P. McDougall and S. M. Wright, IEEE-EMBS 2004

MRI enhanced with polarized noble gases (Lungs)

Fast dynamic He3 MR imaging (130 ms/ image) of an inspiration (300 mL He3) in a patient with idiopathic pulmonary fibrosis (IPF) on the right and a well-functioning lung graft on the left [11]. Note delayed He3 entry into the native fibrotic lung (1st image) and premature emptying from this lung (last image).

Photo and Caption: Balthasar Eberle, Klaus Markstaller, Wolfgang G. Schreibner, Hans-Ulrich Kauczor. "Hyperpolarised gases in magnetic resonance: a new tool for functional imaging of the lung." Swiss Medical Weekly, 131 (2001): 503-509.



Molecular Imaging: **1) in-vivo study; 2) molecular level functional information; 3) Usually through contrast agent specific to certain genes or structures. 3) Primarily PET, also US, MRI, Optical imag., or x-ray CT.**

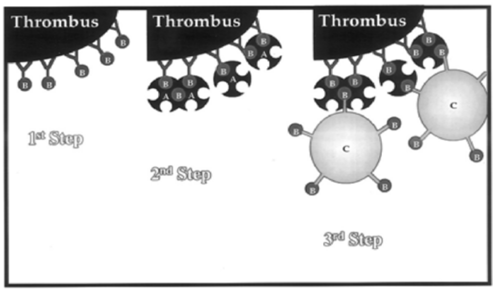


Figure 11. Illustration depicting the use of avidin-biotin interaction to target specific molecular epitopes through a three-step approach. Step 1: Biotintylated ligands (B) specific for molecular epitopes of interest, such as fibrin, are administered and bind to the target. Step 2: Avidin (A) is given, which conjugates and cross-links to the biotintylated ligand. Step 3: Biotintylated perfluorocarbon emulsion nanoparticles are administered, which attach to the bound antibody-avidin complexes through unoccupied receptor sites.(Reprinted with permission from Lanza GM, et al. Circulation 1997; 95:3334–3340.)

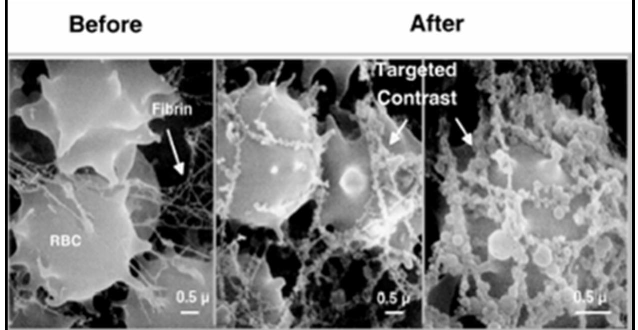


Figure 12. [illegible]

An US example

MR Spectroscopic Imaging

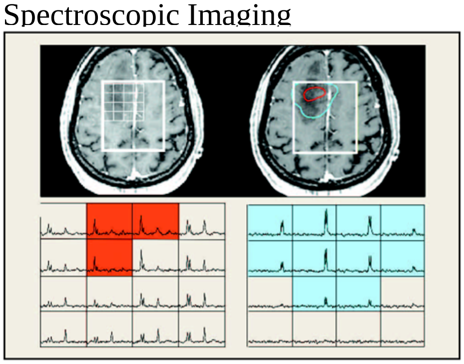


Fig. 3. Lactate-edited MRSI data from a patient with a nonenhancing grade-III glioma. The spectra on the left show Cho, Cr, NAA, and Lip, while the spectra on the right are from the same voxels but show only Lac peaks.

S. Nelson, IEEE Engineering MEDICINE AND BIOLOGY MAGAZINE, P 30, sept/oct 2004

Steven Wright

Jim Ji

Mary McDougall

Interactive Lab Video

Magnetic Resonance Systems Lab
Electrical and Computer Engineering
Texas A&M University

A career in radiologic technology offers a promising future, job stability and good salaries. As technology advances and the population ages, …. The country needs a growing number of qualified professionals to provide medical imaging and radiation therapy.
-- Excerpt from monster.com

Mary P McDougall **Haiyan Wang**

"Everything that can be invented has been invented"
--Charles H. Duell, Commissioner, U.S. Office of patents, 1899,

"640K ought to be enough for anybody"
--Bill Gates, 1981

- Are we going to find a cure for cancers, AIDS, and alike?
- Are we going to live happily and healthy ever after?

Acknowledgment

Zhi-Pei Liang **Paul C Lauterber**

Steve Wright **Mary McDougall** **Ulisses Braga Neto**
Takis Zourntos

My students