

Quantitative and Functional Imaging

BME 4420/7450

Fall 2022

Biomedical imaging

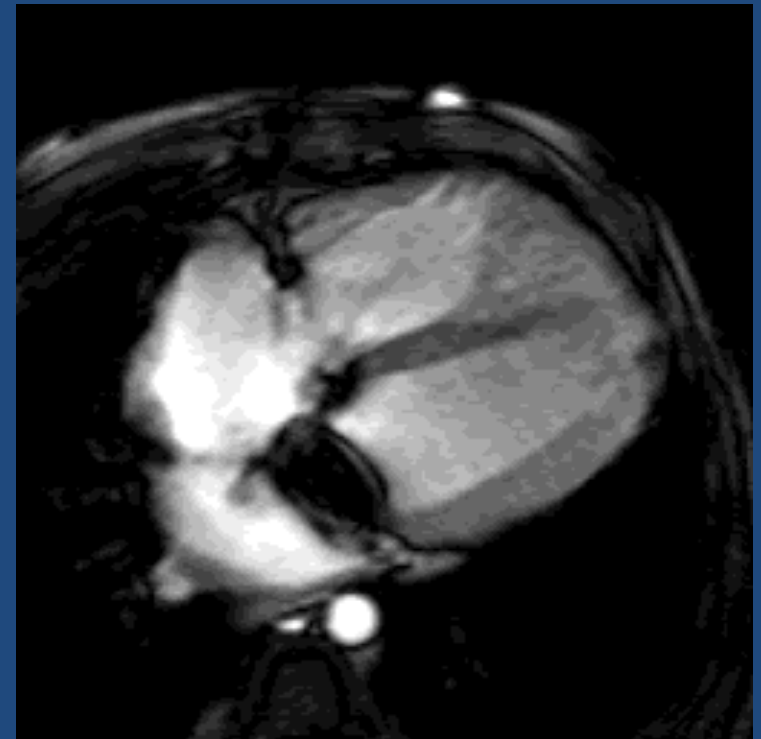
- Qualitative for most of its history
- Much more information available
- Apply knowledge of
 - Basic science
 - Math
 - Engineeringto gain more information



Image from 1896 (Kevles, 1997)

Information in biomedical images

- Spatial information
 - Geometric properties
 - Spatial resolution (organ/tissue specificity)
- Time dependence
 - Position vs. time (velocity)
 - Image series to capture changes over time
- Physical properties
 - Interactions between tissues and external sources of energy



Quantitative Imaging

- How are biomedical imaging methods used to measure tissue structure and function in the body?
 - How do structure and function affect images?
 - What biophysical properties can be mapped with imaging?
- Imaging modalities
 - Ultrasonography (US)
 - X-ray computed tomography (CT)
 - Magnetic resonance imaging (MRI)
 - Positron emission tomography (PET)

Physical properties revealed by imaging

- Image intensity can reflect
 - Atomic/Molecular composition
 - Chemical properties
 - Mechanical properties
 - Electromagnetic properties
- These physical properties in turn vary with tissue composition and function
- Reflect physiology and pathology

Non-invasive measures of the internal state of the body



Non-invasive measures of the internal state of the body

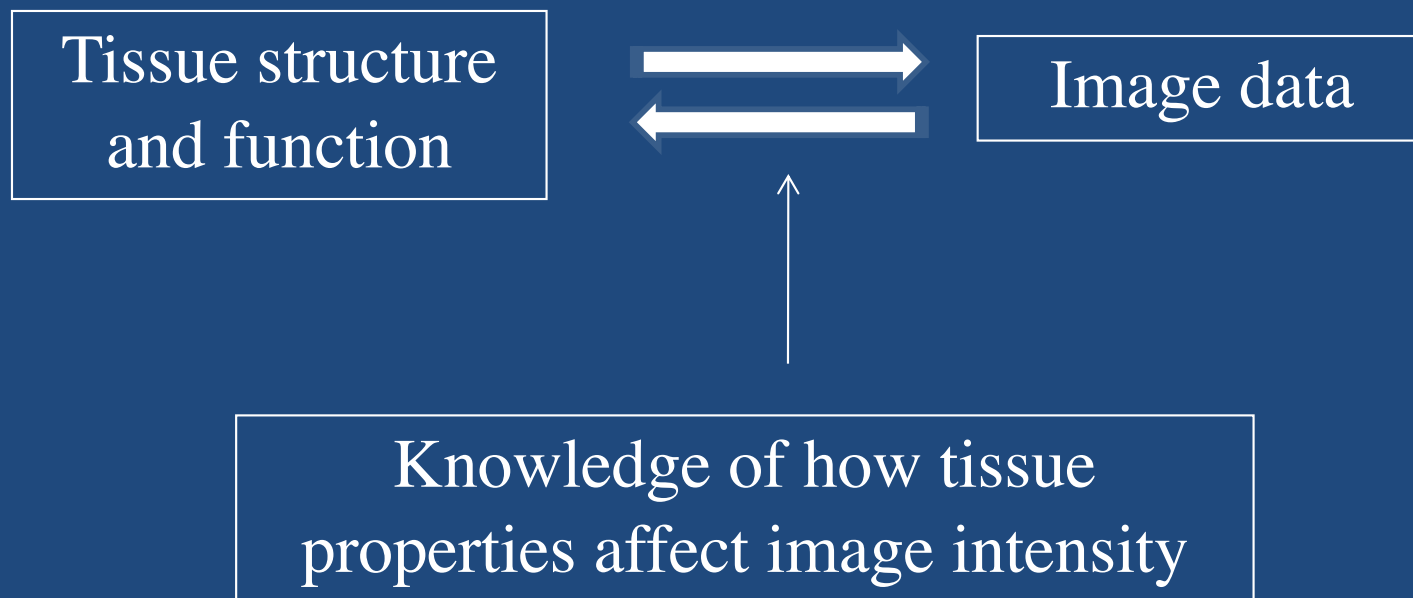
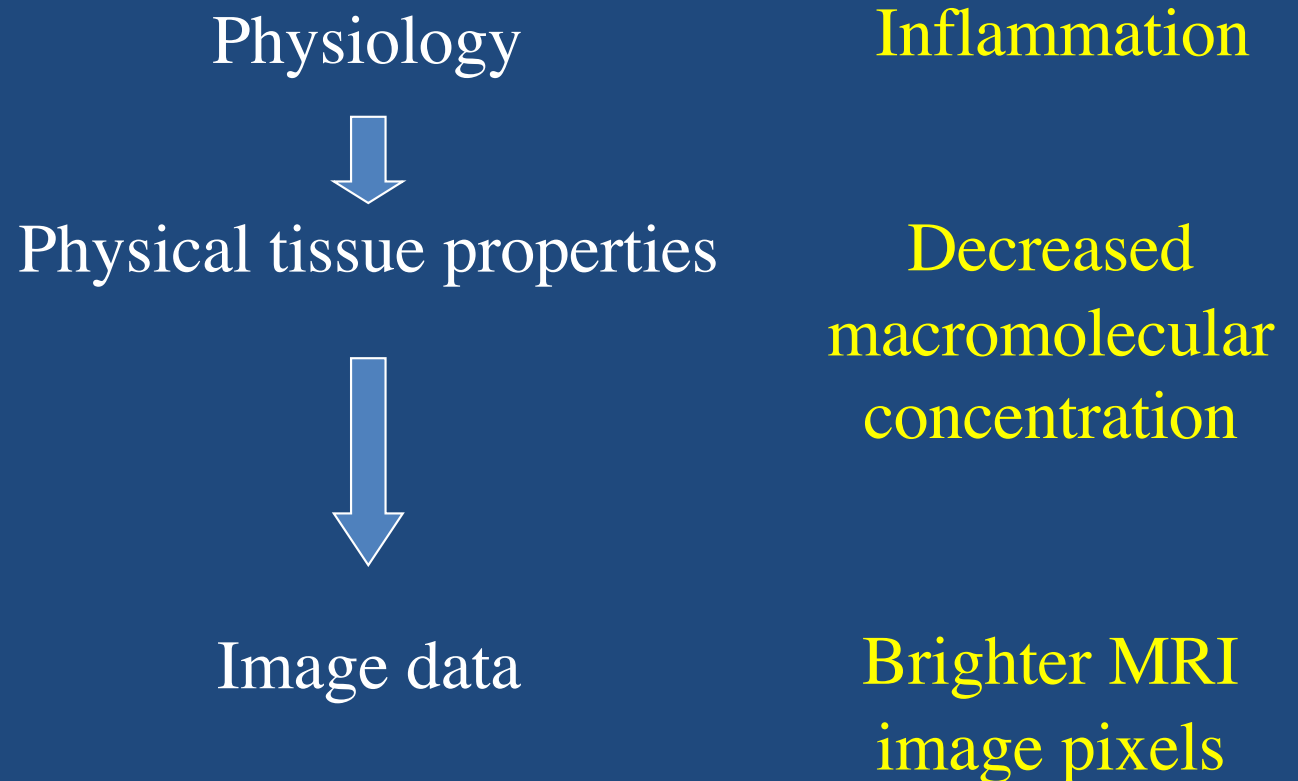
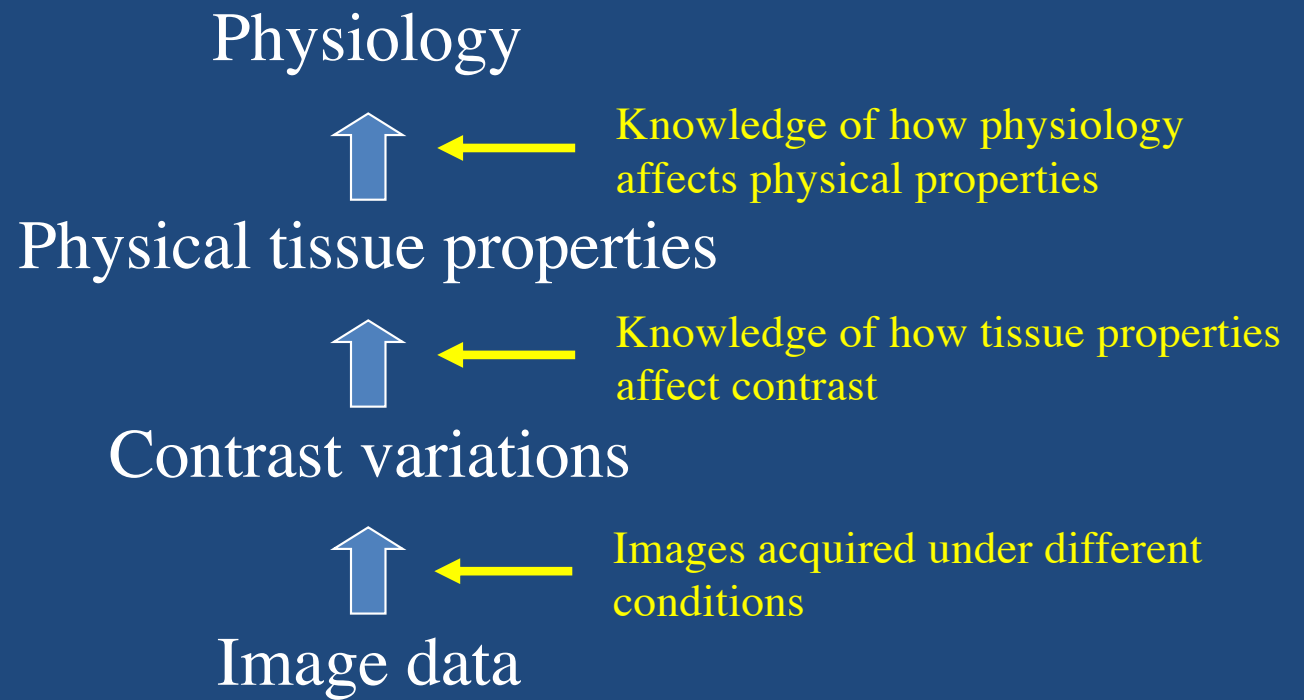
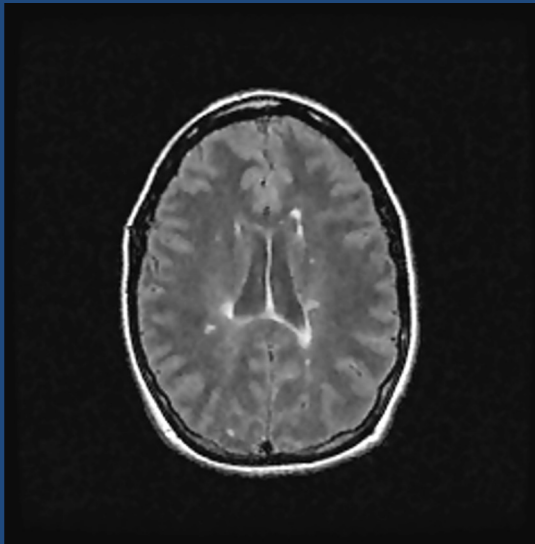


Image contrast is sensitive to physiology





Improved understanding of disease



Dependence of physiological
variable on disease state, treatment,
development, etc.



Physiology



← Knowledge of how physiology
affects physical properties

Physical tissue properties



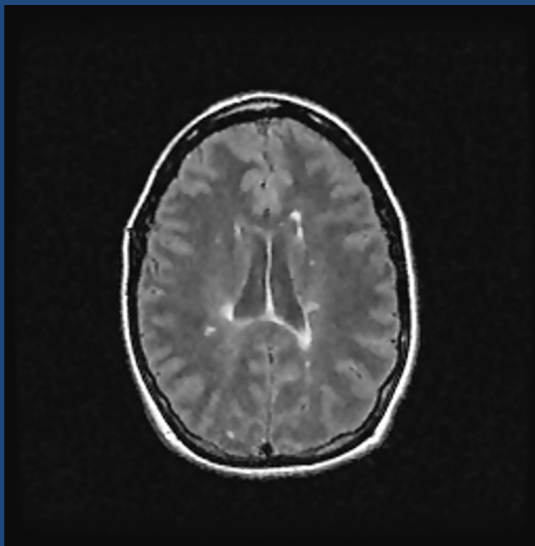
← Knowledge of how tissue properties
affect contrast

Contrast variations



← Images acquired under different
conditions

Image data



Imaging provides a non-invasive probe of the internal state of the body

- Images carry information on the state of tissues
- Quantitative image analysis characterizes that state
 - Similar to a blood test (chemistry and cells)
 - Provides different information (if we know how to derive it)
- Benefits for
 - Human studies
 - Only feasible measurement method in many cases
 - Animal studies
 - Longitudinal (survival) studies

Relation of imaging to other measurements

- Spatial localization can improve sensitivity, specificity
- But imaging methods have limited
 - Time resolution
 - Sources of contrast
- Imaging can provide information complimentary to other biomedical data

Aspects of quantitative image analysis

- Measure image properties
 - Area (or volume), signal differences
- Fit signal changes to mathematical models
 - Determine values of parameters in the model
 - Test models
- Improve image quality
 - Signal-to-noise ratio, contrast-to-noise, resolution
 - Suppress artifacts
 - Improves diagnosis

Applications of quantitative imaging

- Patient-based
 - Diagnosis
 - Treatment planning
 - “Precision” medicine
- Disease-based
 - Causes/consequences of pathology
- Basic science
 - Normal physiology
 - Cognitive science
- Pharmaceutical R&D
 - Drug development
 - Clinical trials

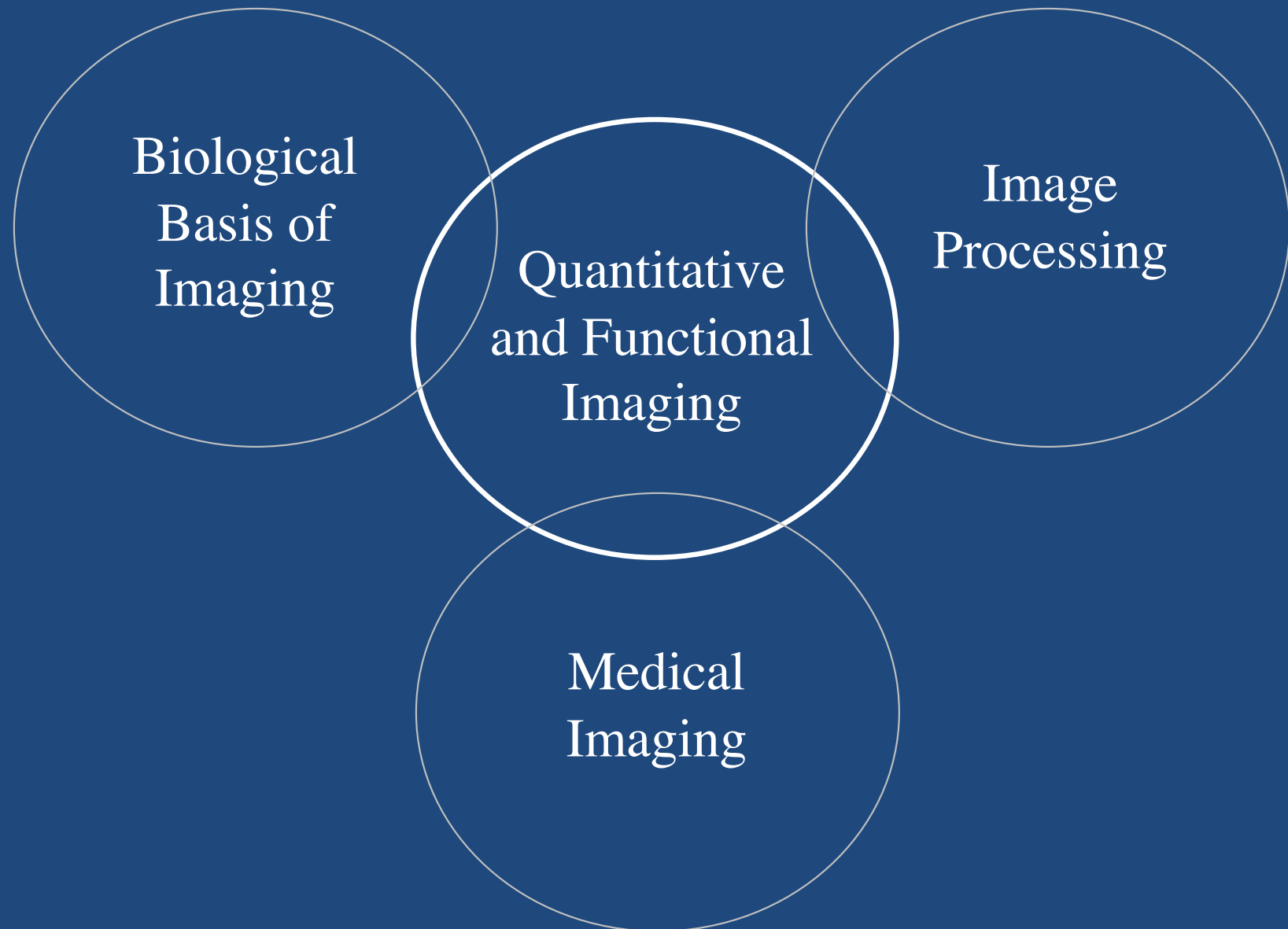


D. Ballon, NIBIB Picture Gallery

What is an image?

- Graphical representation of the 2(+) dimensional distribution of data
- Many different possible formats for storing this information
- Often, an image file includes image data and information about the data (*metadata*)
- First in-class exercise:
 - What metadata do you think would be useful?
 - This will vary with the application, so be specific.

How is this course related to others?

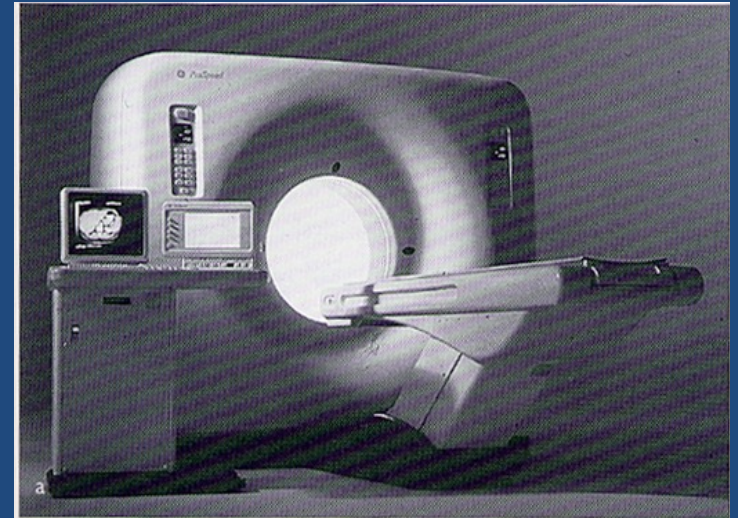


QFI Main Topics

- Image properties
- Image modeling
- Anatomy and tissue structure
- Motion and flow
- Metabolism
- Molecular imaging
- Biomarkers

Imaging methods

- Computed tomography
- Ultrasonography
- Positron emission tomography
- Magnetic resonance

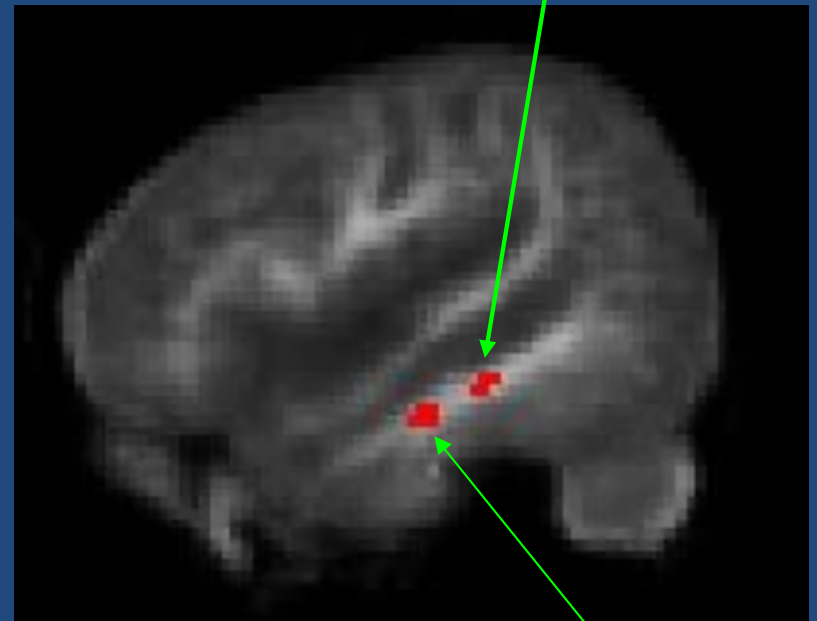


Wolbarst (1999)

Image modeling

- Links image data to tissue properties
- Model fitting
 - Linear
 - Non-linear
- Correlation with non-imaging data aids interpretation

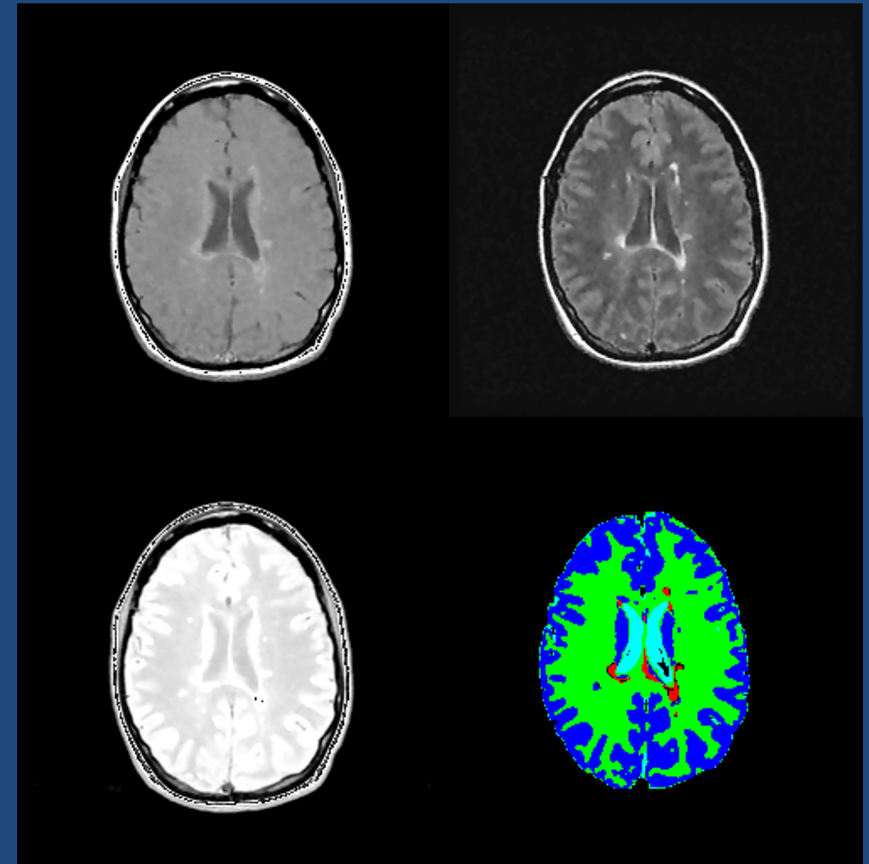
PR RT	EC RT	Wrat-M
-.615**	-.598**	.482**
* p < .05; ** p < .01		



PJPrePC	Wrat-M
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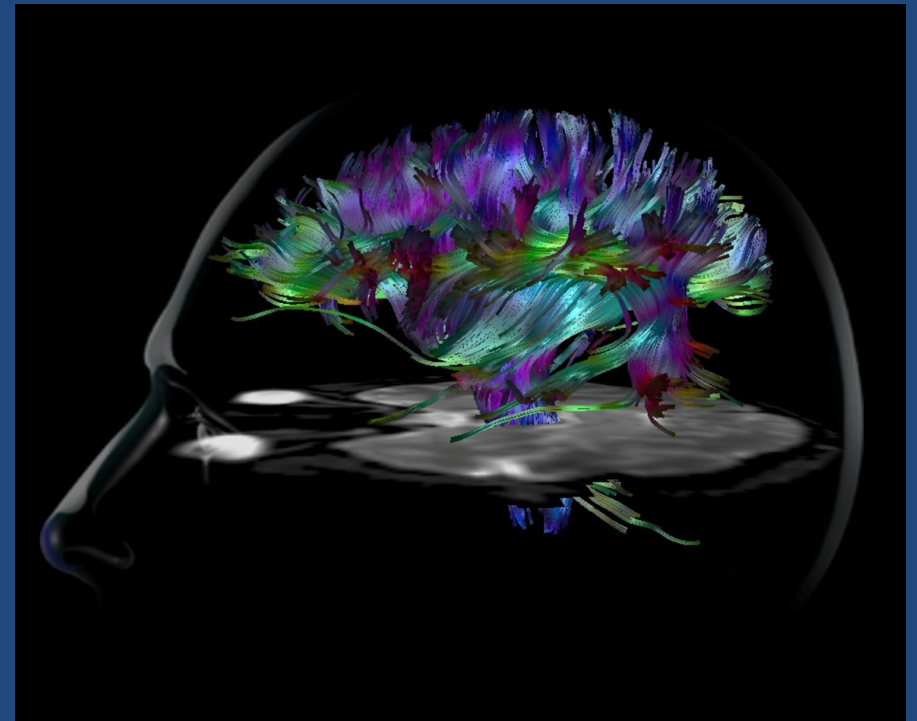
Tissue structure

- Volumetrics
 - Cardiac ejection fraction
- Tissue classification
 - Multiple sclerosis lesion load



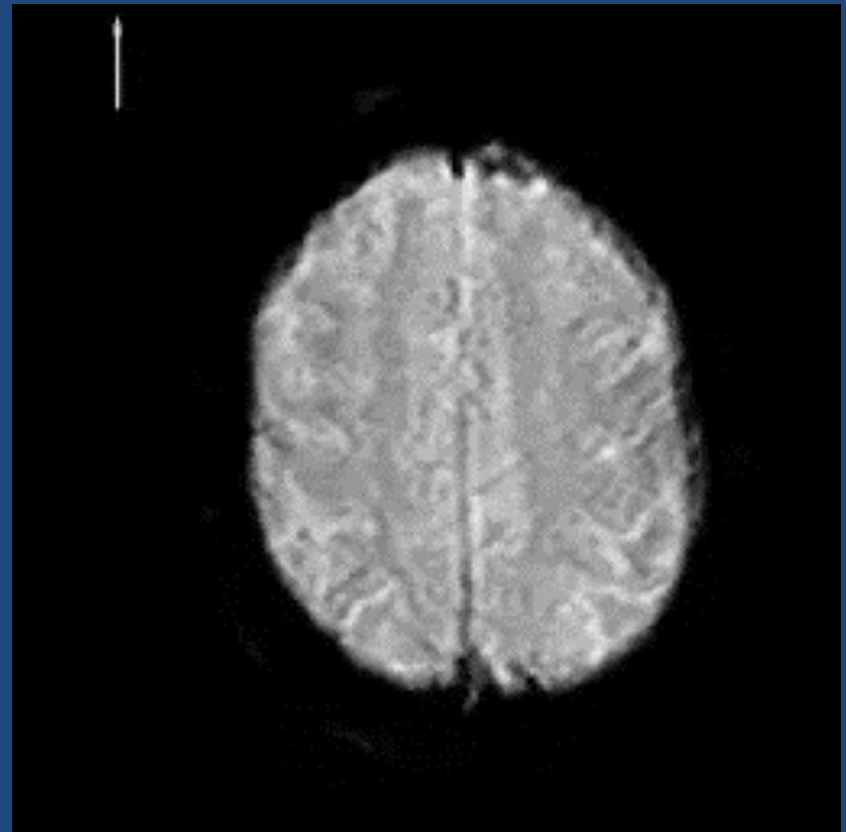
Tissue microstructure

- Detect changes on cellular level
 - Cell populations
 - Myelination
 - Cell orientation
- Neuronal fiber tracking
 - Brain connectivity



Tissue perfusion

- Perfusion is capillary level blood flow
- Exchange
 - Blood \rightleftharpoons tissue
- Reflects metabolism
- Stroke detection



Microscopic flow

Tissue perfusion

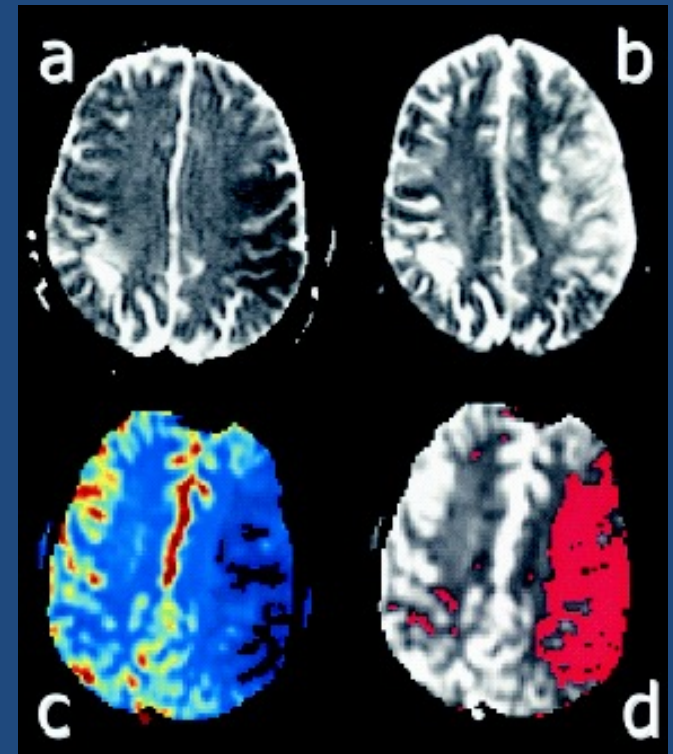
- Hypoperfusion in stroke

Predict tissue fate

- Death
- At-risk
- Uninjured

ADC map
(at 2 hours)

T₂-w at 7 days



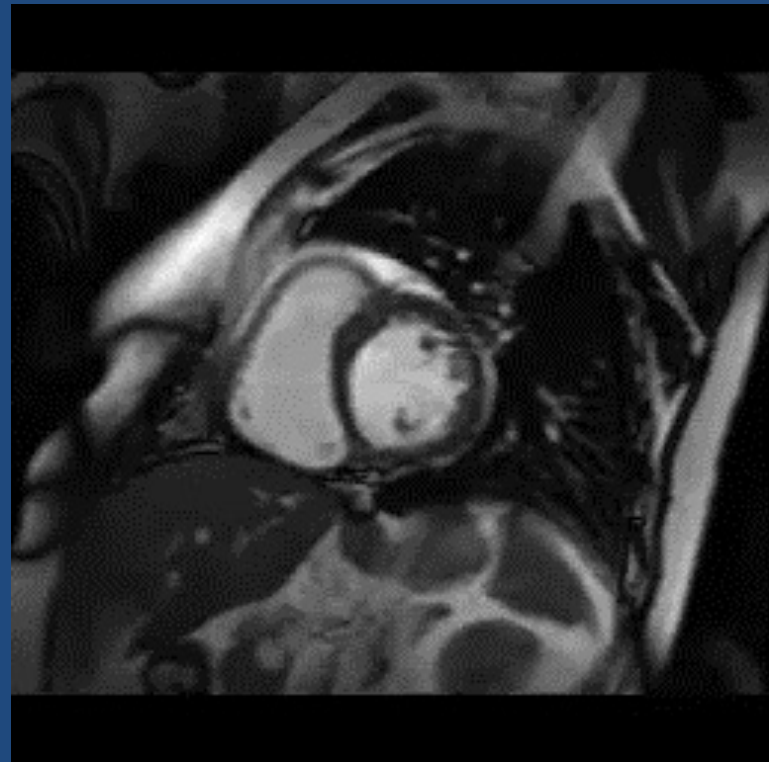
Perfusion map
(at 2 hours)

Thresholded
perfusion

Fiehler et al, Stroke, 2002

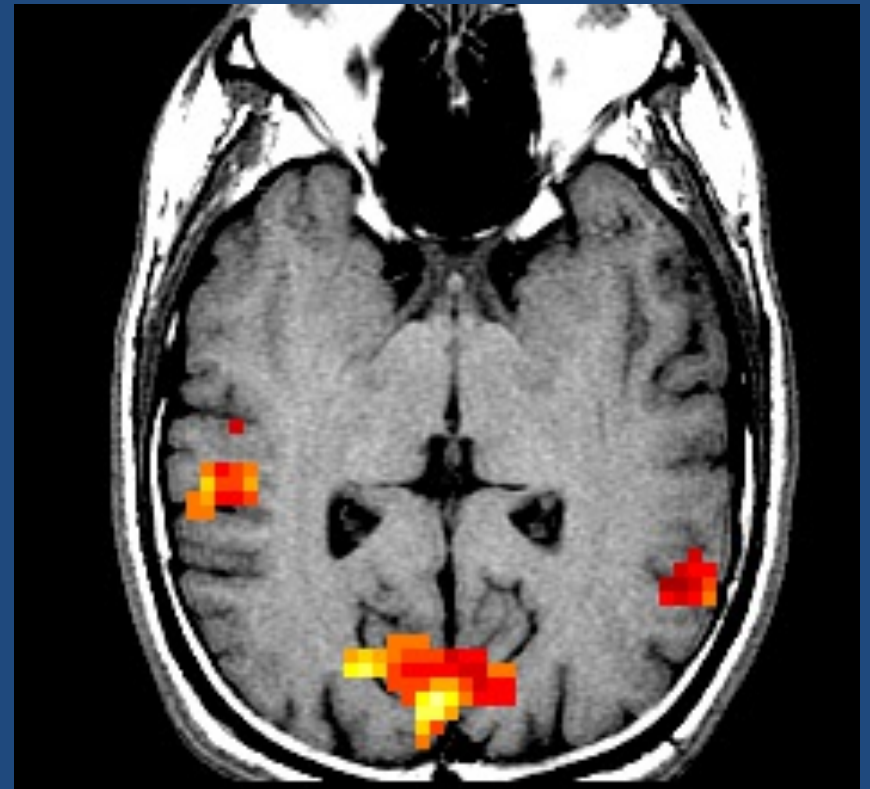
Cardiac function

- Evaluate
 - Blood volume
 - Blood motion
 - Cardiac wall contraction
- Identify site and extent of injuries



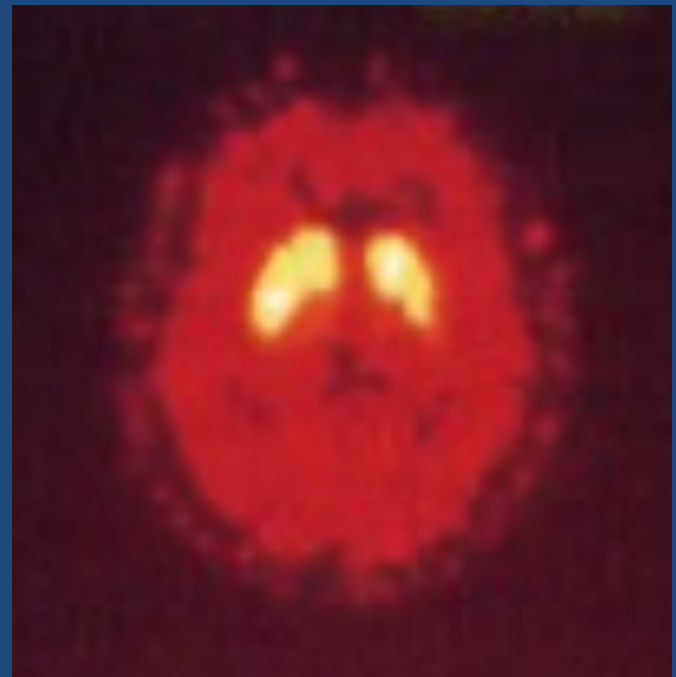
Metabolic imaging

- Mapping blood oxygenation
 - Functional MRI
- Mapping glucose usage
 - Radionuclide PET imaging



Molecular imaging

- Receptor mapping
 - Neurotransmitter receptors
- Targeted contrast agents
 - Cancer screening
 - Cancer therapy



Goals of the course

- Understand how biomedical imaging is being used in medicine and biomedical research
- Have practical skills in image analysis
- Have sufficient knowledge to
 - Work in an imaging lab
 - Use imaging in your research
 - Develop your own new ideas

QFI course assignments

- Analysis projects (65%)
- Problem sets/in-class exercises (10%)
- Final exam (25%)

Suggested Reading

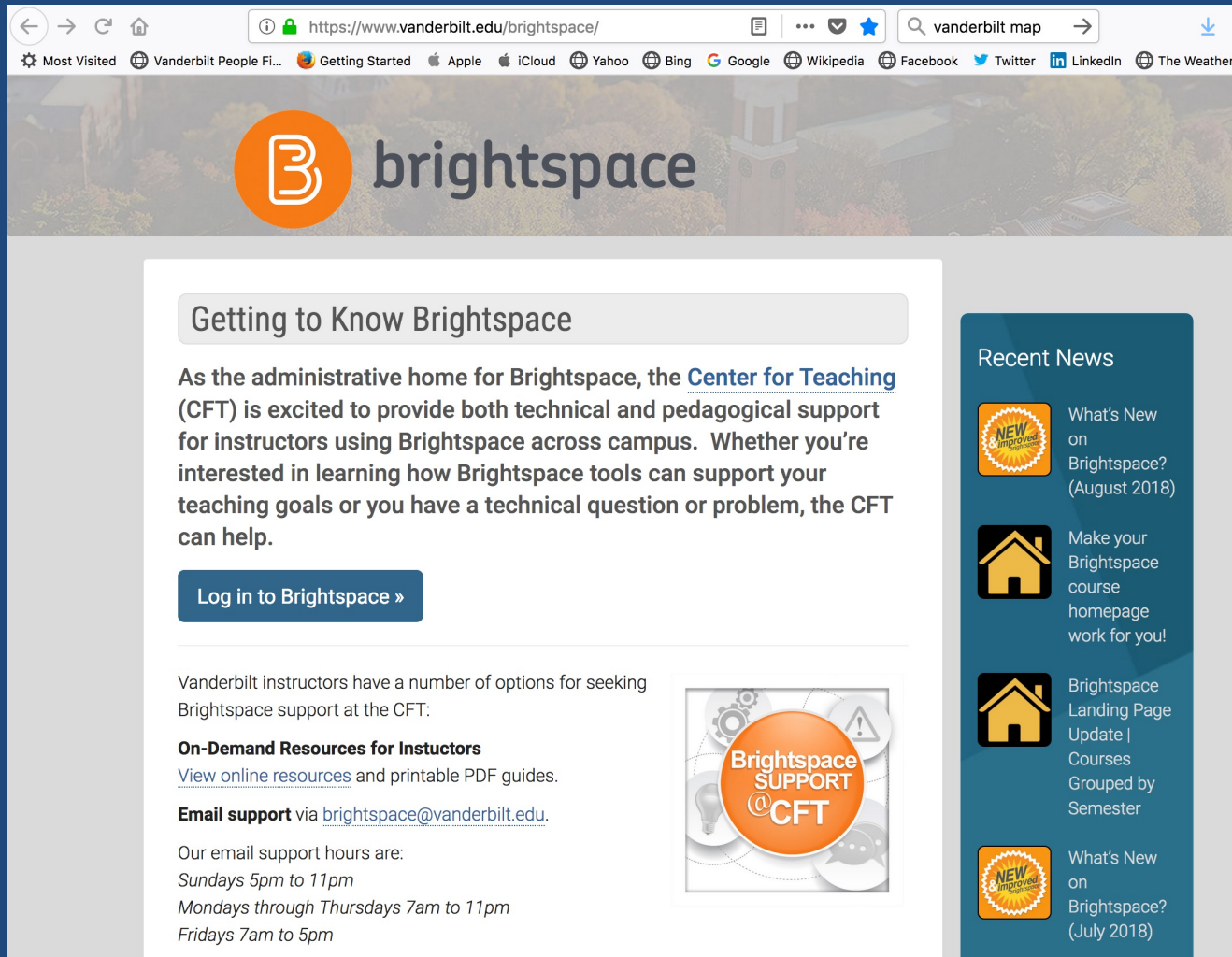
- Lecture notes posted on Brightspace
- No single textbook covers what we need
 - *Fundamentals of Medical Imaging* by Suetens (Cambridge, 2017)
 - *Functional Magnetic Resonance Imaging* by Huettel, Song, and McCarthy (Sinauer Associates, 2004)
 - *Emission Tomography: The Fundamentals of PET and SPECT* by Wernick and Aarsvold (Elsevier, 2004)
- Individual book chapters and articles

Contact information

- Offices
 - Institute of Imaging Science (VUIIS)
Medical Center North AAA3108
(vuiis.vanderbilt.edu/contact.html) 322-8353
- Office hours on Zoom
 - Wednesday: 1:00-2:00pm or by arrangement

Course material is on Brightspace

<https://brightspace.vanderbilt.edu>



The screenshot shows a web browser window with the address bar displaying <https://www.vanderbilt.edu/brightspace/>. The browser's toolbar includes various icons for navigation and search. The website header features the Brightspace logo, which consists of an orange circle with a white 'B' and the word 'brightspace' in a dark grey sans-serif font. Below the header, the main content area is divided into two columns. The left column has a light grey background and contains a section titled 'Getting to Know Brightspace' in a rounded rectangle. This section includes a paragraph about the Center for Teaching (CFT) and a blue button labeled 'Log in to Brightspace »'. Below this, there is text about support options for instructors, including links to online resources and email support, followed by email support hours. The right column has a teal background and is titled 'Recent News'. It contains four news items, each with an icon (a 'NEW' badge or a house icon) and a brief description of the update.

<https://www.vanderbilt.edu/brightspace/>

brightspace

Getting to Know Brightspace

As the administrative home for Brightspace, the [Center for Teaching \(CFT\)](#) is excited to provide both technical and pedagogical support for instructors using Brightspace across campus. Whether you're interested in learning how Brightspace tools can support your teaching goals or you have a technical question or problem, the CFT can help.

[Log in to Brightspace »](#)

Vanderbilt instructors have a number of options for seeking Brightspace support at the CFT:



On-Demand Resources for Instructors
[View online resources](#) and printable PDF guides.

Email support via brightspace@vanderbilt.edu.

Our email support hours are:
Sundays 5pm to 11pm
Mondays through Thursdays 7am to 11pm
Fridays 7am to 5pm

Brightspace SUPPORT @CFT

Recent News

-  What's New on Brightspace? (August 2018)
-  Make your Brightspace course homepage work for you!
-  Brightspace Landing Page Update | Courses Grouped by Semester
-  What's New on Brightspace? (July 2018)

Course material is on Brightspace

<https://brightspace.vanderbilt.edu>

The screenshot displays the Brightspace interface for Vanderbilt University. At the top, the browser address bar shows the URL <https://brightspace.vanderbilt.edu/d2l/home>. Below the browser, the Vanderbilt University logo is on the left, and navigation icons (grid, mail, chat, notifications) and the user name "Adam Anderson" are on the right. A secondary navigation bar includes links for "Calendar", "ePortfolio", "YES", "Ask a Librarian", "My Media", and "Help".

The main content area is divided into two columns. The left column, titled "My Courses", features a filter bar with "All", "Conversions", "2018 Summer", "2018 Spring", and "2018 Fall". It displays four course cards:

- BME ABET**: Image of a snowy mountain range.
- BME 7450-01 Adv Quant and Funct Imagin (2018F)**: Image of a mountain landscape at sunset.
- BME 8999-26 Non-Candidate Research (2018F)**: Image of a bridge with the word "Inactive" overlaid.
- BME 8999-26 Non-Candidate Research (2018U)**: Image of a blue and red abstract pattern with the word "Inactive" overlaid.

The right column contains two announcement boxes:

- Instructor Announcements**: A message for instructors to make their course "active" and a link to "on-demand resources".
- Student Announcements**: A message for students to verify their enrollment and a link to the "Brightspace support site".

Course material is on Brightspace

<https://brightspace.vanderbilt.edu>

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<https://brightspace.vanderbilt.edu>

BME 7450-01 Adv Quant and Funct Imagin (2... Adam Anderson

Content Activities & Assessments ▾ Classlist Class Progress Course Admin Media Gallery More ▾

Search Topics 🔍

Syllabus

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Lecture 02: Imaging Methods, part 1

Print Settings

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lecture02_imagingMethods1 ▾ ✓

PDF document

Add a sub-module...

References

- B.H. Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (Addison-Wesley, 1997).
- A.B. Wolbarst, *Looking Within: How X-Ray, CT, MRI, Ultrasound, and other Medical Images Are Created, and How They Help Physicians Save Lives* (Univ. California Press, 1999).