

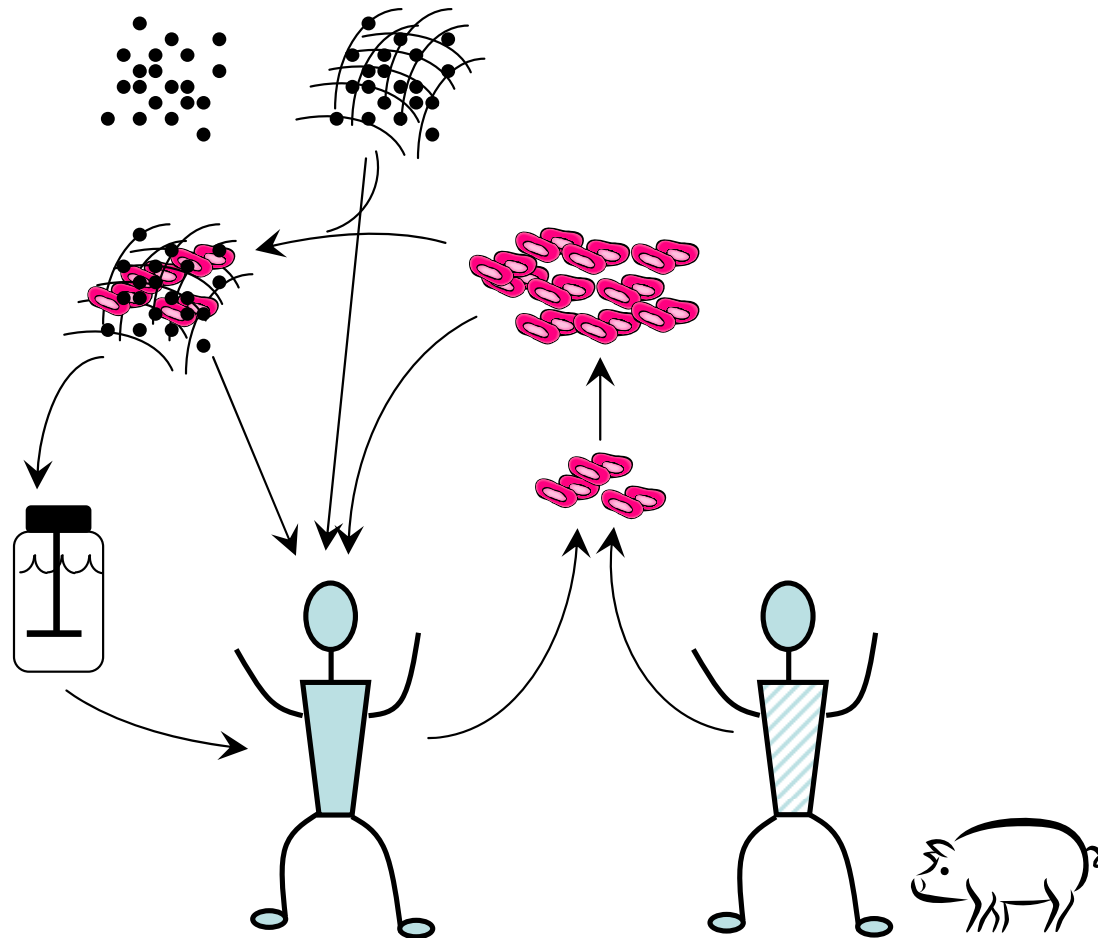
Tissue Engineering Education: What does it mean to learn “Tissue Engineering”?

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The Many Faces of Tissue Engineering

- What constitutes fundamental knowledge of tissue engineering?



What are the components of Tissue Engineering?

- A tissue engineering therapy:
 - may or may not involve delivery of cells
 - if it does involve cell delivery, they may or may not be stem/progenitor cells
 - may or may not include a biomaterial
 - may or may not include delivery of other factors
 - may or may not require culture in a bioreactor

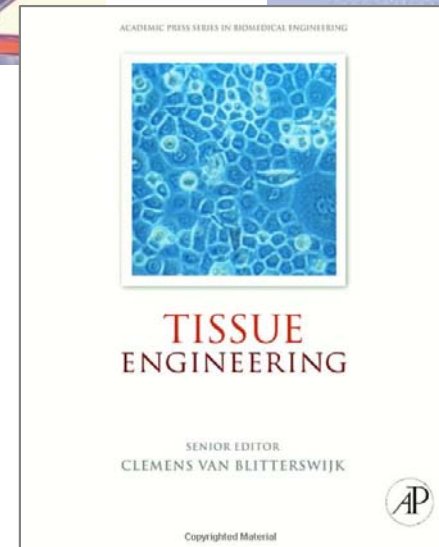
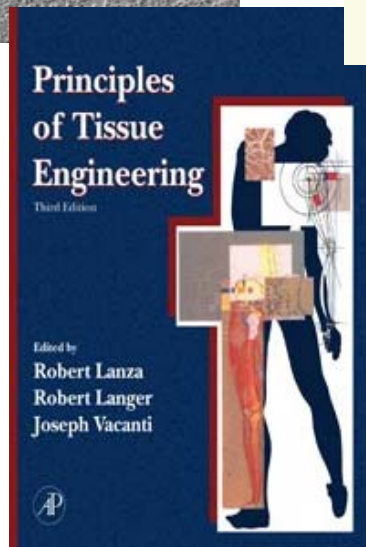
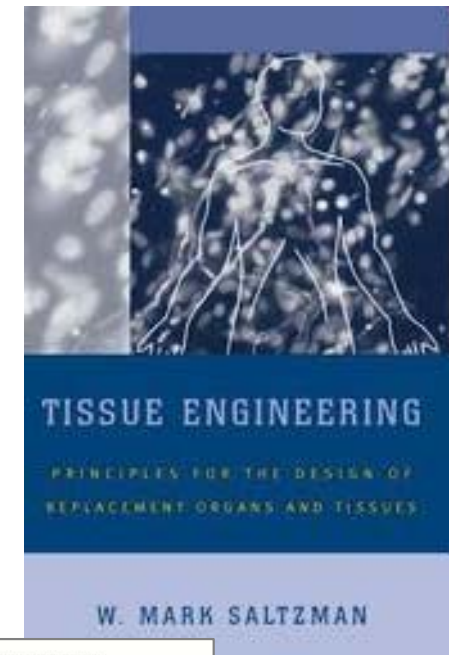
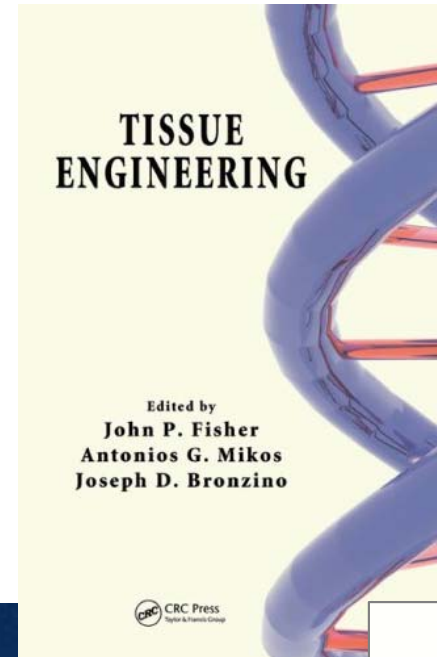
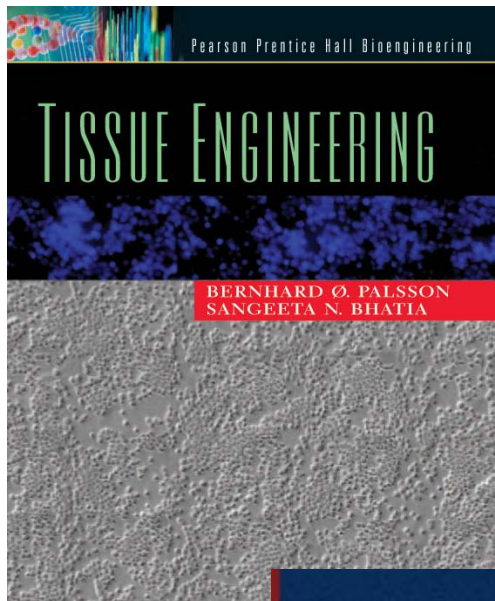
When teaching TE, what do we choose to define as the most important aspects of TE?

What is “fundamental” TE knowledge?



Seeking Guidance from TE Textbooks...

- 2003: First official textbook dedicated to Tissue Engineering



Much in Common...

	Book			
	1	2	3	4
Adult Stem Cells	X	X	X	X
Embryonic SCs	X	X	X	X
Tissue Morphogenesis	X	X	X	X
Mature Cell Function	X	X	X	X
Cell Sourcing/Culture	X		X	X
Cell Delivery			X	
Cell Signaling	X	X	X	X
Cell/Tissue Mechanics		X		X
ECM	X	X	X	X

	Book			
	1	2	3	4
Biomaterial Properties	X		X	X
Tailoring/Designing Scaffolds	X		X	
Cell-Material Interactions	X	X	X	X
Drug Delivery	X	X		X
Gene Delivery			X	X
Analytical Techniques			X	
Bioreactor Design	X		X	X
Case Studies	X	X	X	X
Regulatory Issues			X	X
Ethics	X		X	X

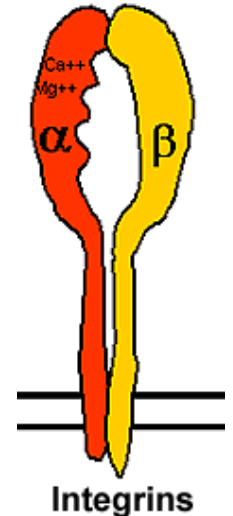
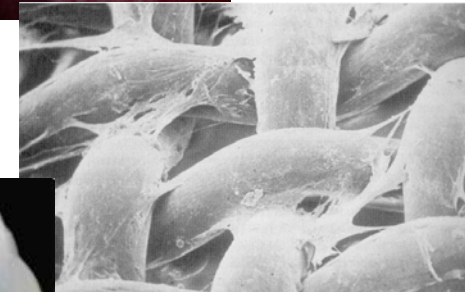
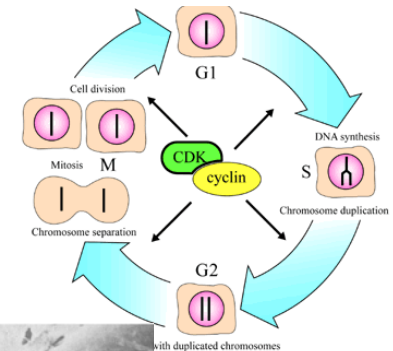
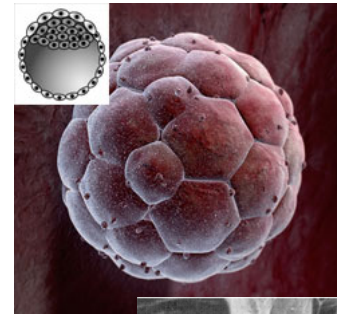
... but also quite different



Defining the TE Knowledge Base

- According to textbook commonalities, a fundamental knowledge base for TE consists of:

- stem cells
- tissue morphogenesis
- mature cell/tissue function
- cell signaling
- ECM
- cell-material interactions
- case studies



- Are there things missing from this list?
- Let's also look at the emphases of the different books...

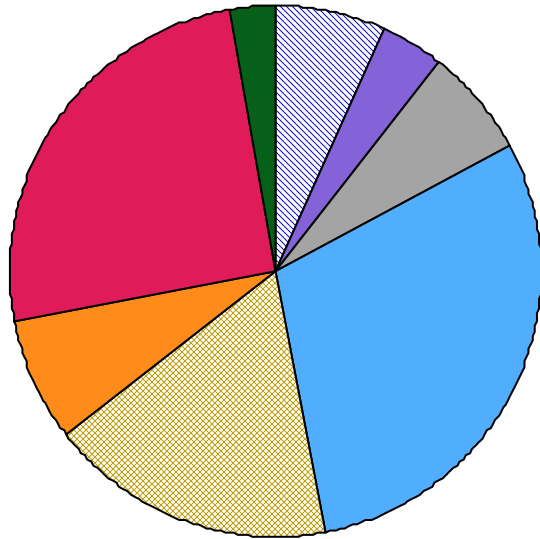


Varied Emphases on Content Areas

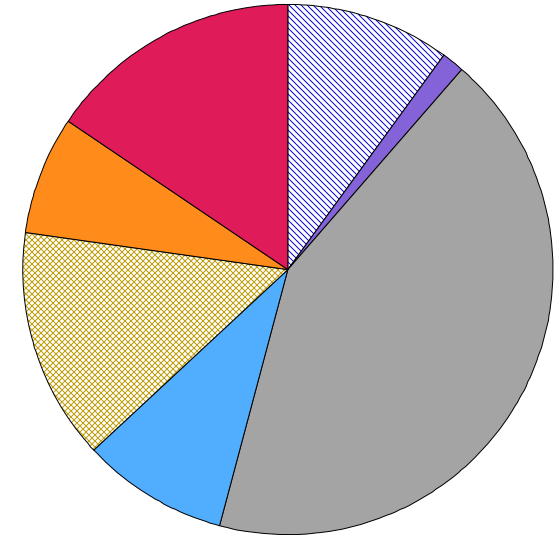
Topic	% of Book Devoted to Topic			
	Book 1	Book 2	Book 3	Book 4
Development/ Morphogenesis	6.7%	9.8%	6.8%	4.2%
Stem Cells	3.7%	1.4%	17.8%	3.6%
Cell Function	6.7%	41.6%	4.2%	24.8%
Scaffolds	29.6%	8.8%	9.1%	11.3%
Cell/Tissue Logistics	17.4%	13.9%	2.4%	20.6%
Other factors (i.e., molecule delivery)	7.2%	6.9%	9.4%	21.19%
Case Studies	25.1%	15.3%	41.6%	6.9%
Ethics, Regulation	2.8%	0%	2.1%	4.5%

A Pretty Big Standard Deviation...

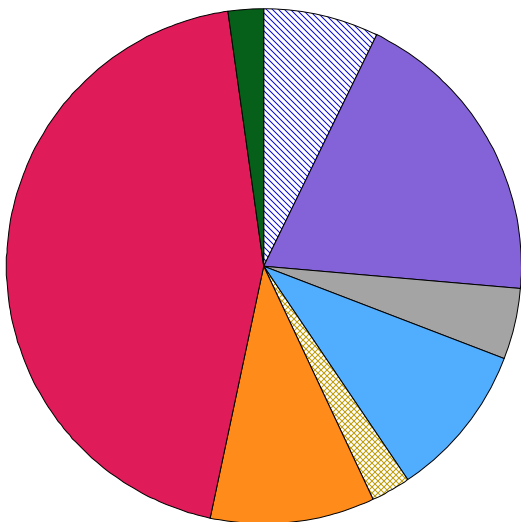
Book 1



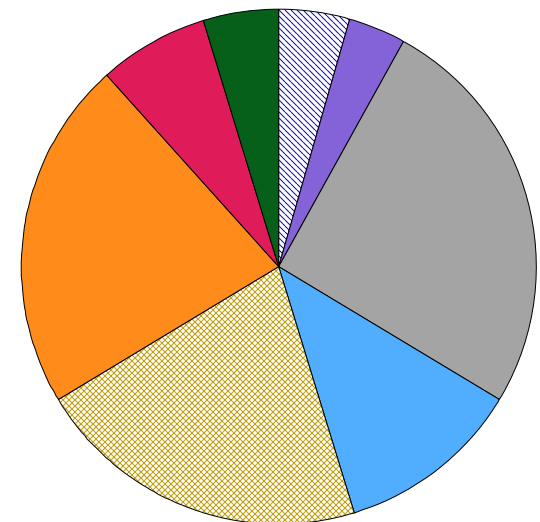
Book 2



Book 3



Book 4



Reviewing our Textbook Analysis

- Some common ground on which topics are covered
- Large variation in emphasis on these topics - No two books share the same major emphases
 - Is this a problem?
 - Does this indicate a need to define what constitutes ‘fundamental knowledge’ in TE?
- Is that high standard deviation in content OK? Are we confident that a student in one TE class comes away with similar background as a student in another TE class?



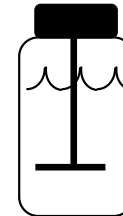
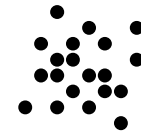
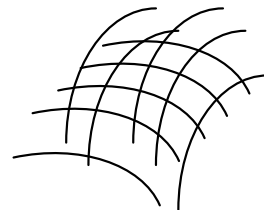
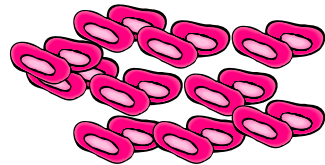
Other Comments on Content...

- Wide variation in quantitative content
 - Challenging given the varied academic backgrounds of BME/BioE students
- Wide variation in coverage of analysis methods
- Little coverage of commercialization, regulation, and ethical issues (usually <15 pages/book)
 - With increase in TE commercialization and increase in use of components with particular ethical concerns, should this be receiving more attention?



Experience in Integration of TE Components

- Lessons learned from teaching TE:
 - Students understand the individual components of TE (cells, materials, tissue development, etc.) but often lose sight of the ‘big picture’ or have trouble integrating these components



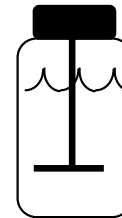
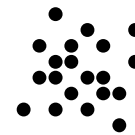
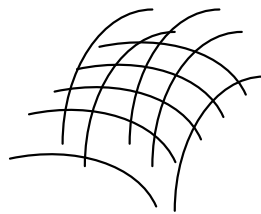
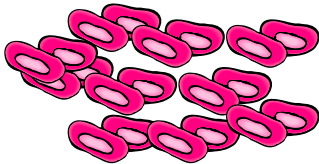
To address this problem:

1. *It's never too early for case studies!*
2. *Design your own engineered tissue!*



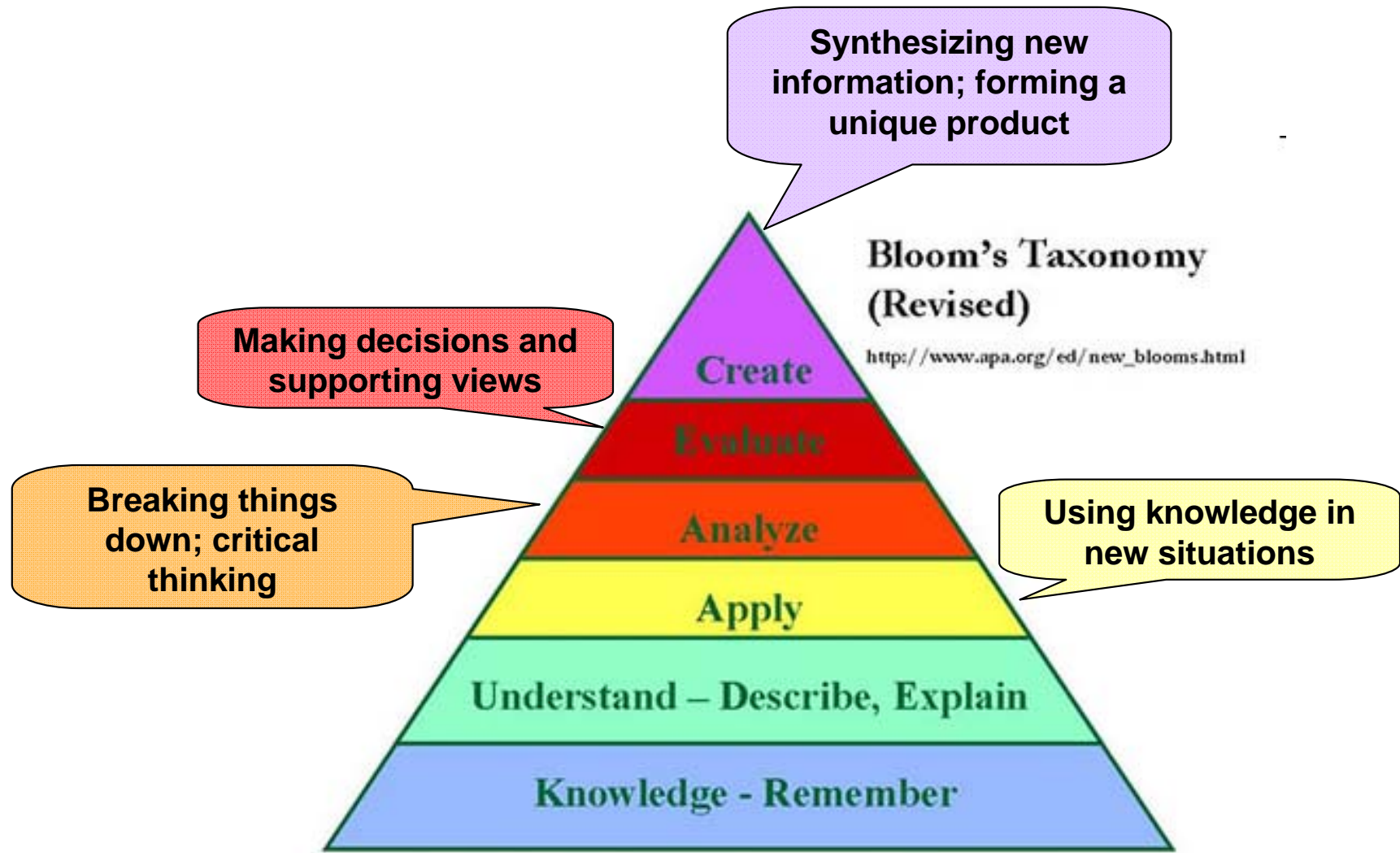
1. Introduction of Case Studies

- Case studies often found at end of textbook
- But, students need a context into which they can put the TE component knowledge they are gradually acquiring
 - **By student request**: Case studies introduced as each TE component is covered



2. Integration of TE Knowledge

- A need to go beyond prescribed case studies



Based on an APA adaptation of Anderson, L.W. & Krathwohl, D.R. (Eds.) (2001)

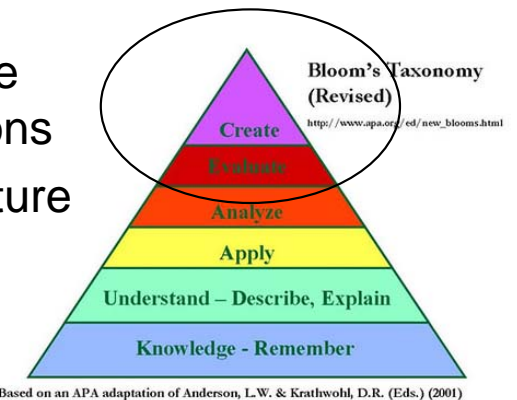
Higher-Order Learning: Synthesize/Create/Design

- Final Assignment: Design your own engineered tissue
 - Create an original ‘product’ by combining your TE knowledge
 - Defend and support your choices in designing your product
 - Evaluate the merits and potential drawbacks of your approach
- Every year, get notes, emails, evaluations about how this was the students’ favorite assignment

Summary of the TE Creation Assignment

- Freedom in selecting what type of tissue they want to engineer
 - **Approach:** provide rationale for what type of TE approach used
 - **Cells:** if applicable, describe source, rationale for that source, obstacles/limitations of source, and delivery mode
 - **Biomaterial:** if applicable, describe type, rationale, obstacles/limitations, processing/delivery logistics
 - **Molecule/gene delivery:** if applicable, describe what will be delivered, rationale, delivery mechanism, obstacles/limitations
 - **Bioreactor:** if applicable, describe what type, rationale, culture parameters

min.
2/4



- Assessment: describe how 'success' will be measured, including specific cell/tissue analysis techniques
- Discuss the overall pros and cons in using the engineered tissue that you have designed
- Discuss ethical considerations or implications for this work



Questions to Consider

- What are the prerequisites for an Introduction to TE course?
 - Will these limit a TE course to only BME/BioE students? Is that ok?
- No two books share the same major emphases
 - Is this a problem?
 - Does it simply reflect personal differences in priorities, or does it indicate a need to define what constitutes ‘fundamental knowledge’ in TE?
 - Is this material just too much to cover in one course?
 - Should the emphasis vary with level of course? (graduate vs. undergraduate)
- What else should we be emphasizing?
 - High variability in coverage of quantitative TE, analysis methods, and ethics/regulation

