Tissue Engineering Education

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Tissue Engineering Paradox

Highly Interdisciplinary Field

Facilitates Innovative Advances

Increases Complexity of Curriculum

Challenge: To identify fundamental concepts in tissue engineering and to adapt course material as the field evolves

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Indicators of Advances

- FDA approved tissue engineered products
- Technical publications
  - Peer-review journals
  - Conference proceedings
  - Edited Volumes
  - Textbooks
- Professional societies and conferences
  - Oral and poster presentations
  - Special interest groups
- Public/governmental policies and publications
  - Public reports
  - Legislative actions
- Technical short courses

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Assessment of the Field's Strategic Directions to Optimize Research and Development

Polled a worldwide sample of 24 leaders in tissue engineering.
A goal was set:

"The field of tissue engineering will exhibit broad clinical success by the year 2021"

- Each leader contributed +/- 10 critical steps needed to achieve this goal.
- Used a modified Hoshin strategic process
- Outlined 145 critical "steps" in 14 general categories

"Strategic Directions in Tissue Engineering"
PC Johnson, AG Mikos, JP Fisher, JA Jansen
Tissue Engineering, December 2007

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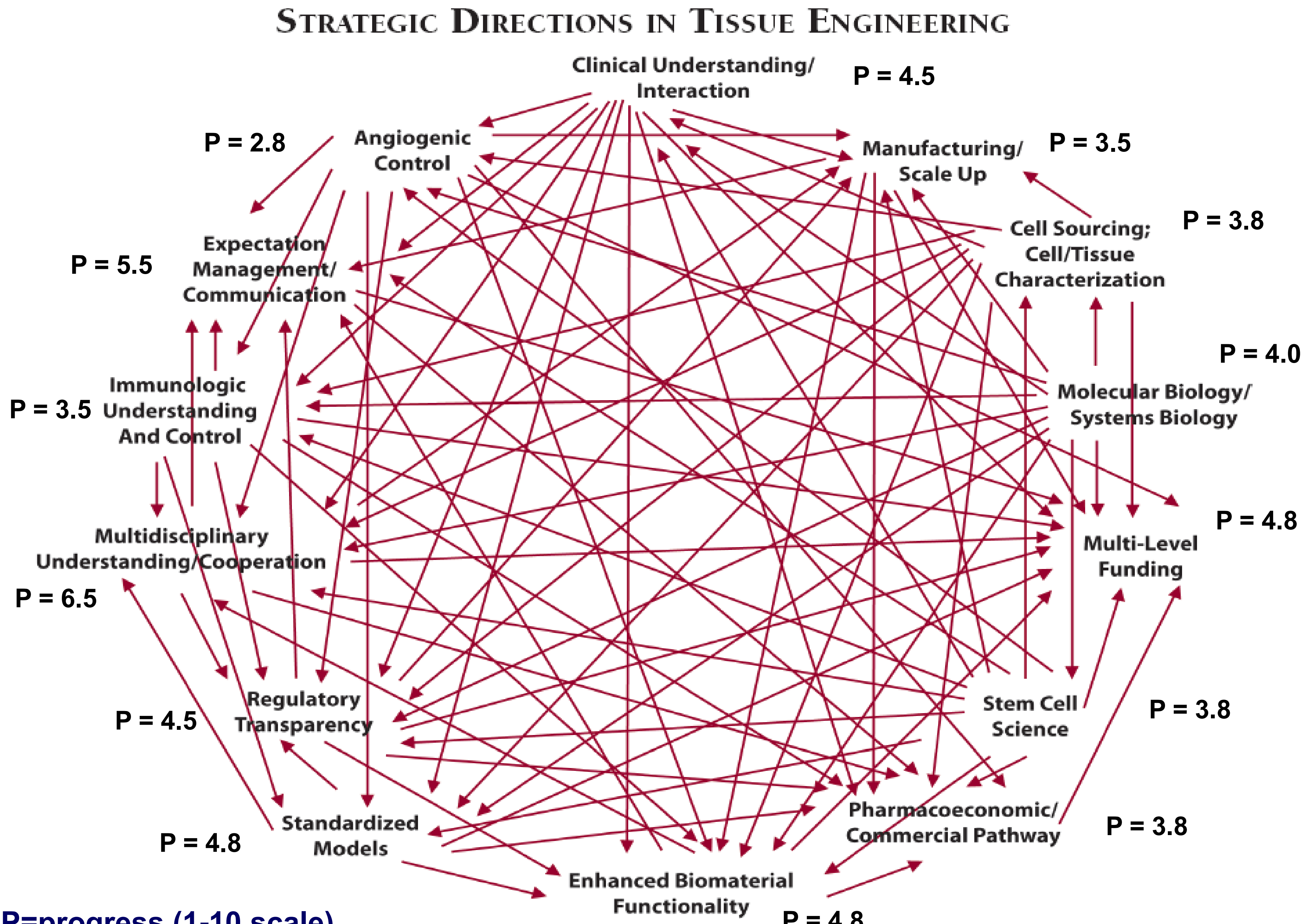

P=progress (1-10 scale)

Four Goals for Tissue Engineering

1. Understanding and controlling the cellular response
2. Formulating biomaterial scaffolds and the tissue matrix environment
3. Developing enabling tools
4. Promoting scale-up, translation and commercialization

Source: Advancing Tissue Science and Engineering: A Multi-Agency Strategic Plan, U.S. Government Multi-Agency Tissue Engineering Science (MATES) Interagency Working Group, 2007

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Controlling the Cellular Response

- Understanding and mimicking organogenesis
  - Signaling (spatial, temporal, mechanical, etc.)
  - Differentiation (pathways, transdifferentiation, etc.)
- Cellular regulation
  - Interactions with other cells
  - Interactions with the extracellular environment
  - Self-regulation
- Cell culture and expansion
  - Conditions for cell culture
  - Duration of culture

Involves cellular and molecular biology, developmental biology, extracellular matrix biology, mechanobiology, and stem cell biology

Source: MATES Interagency Working Group, 2007

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Scaffolds and the Environment

- Scaffold composition
  - Naturally-derived
  - Synthetically-derived
- Scaffold properties
  - Mechanical properties
  - Porosity (size, interconnectivity, etc.)
  - Controlled biodegradability/bioresorbability
  - Surface chemistry
  - Cytocompatibility/biocompatibility
  - Handling characteristics
  - Geometry and architecture

Involves materials science, extracellular matrix biology, cellular and molecular biology, and chemistry

Source: MATES Interagency Working Group, 2007

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Enabling Tools

- Biomarkers (cellular and molecular identification, tracking, etc.)
- Cell imaging, sorting and identification assays
- High-throughput technologies (genomics, proteomics, etc.)
- Multi-parametric cell sorting technologies
- High-resolution imaging technologies
  - Non-invasive
  - Real-time
- Fabrication technologies (rapid prototyping, microstamping, etc.)
- Computational modeling and bioinformatics
- Bioreactors and cell culture systems
- Tissue preservation and storage technologies

Involves materials science, biochemistry, physics, optics, computer science, cellular and molecular biology, mathematics, and statistics

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Source: MATES Interagency Working Group, 2007

Scale-up and Commercialization

- Cost-effective, large-scale culture technologies
- Testing criteria and equipment for quality assurance
- Storage, shipping and packaging techniques
- Standards for pre-clinical models (*in vitro* and *in vivo*)
  - Biocompatibility
  - Toxicity
  - Immunogenicity
  - Inflammatory response
- Intellectual property issues (publications, patents, etc.)
- Regulatory considerations
- Societal and ethical considerations

Involves materials science, cellular and molecular biology, industrial engineering, chemical engineering, robotics, toxicology, pathology, law, and ethics

Source: MATES Interagency Working Group, 2007

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Summary

The interdisciplinary and dynamic nature of tissue engineering contributes to the complexity of the field.

Understanding of current and future challenges to the tissue engineering field may facilitate the development and adaptation of curricula for effective tissue engineering education.

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