Biology at the Interface: Teaching Biology to Engineers

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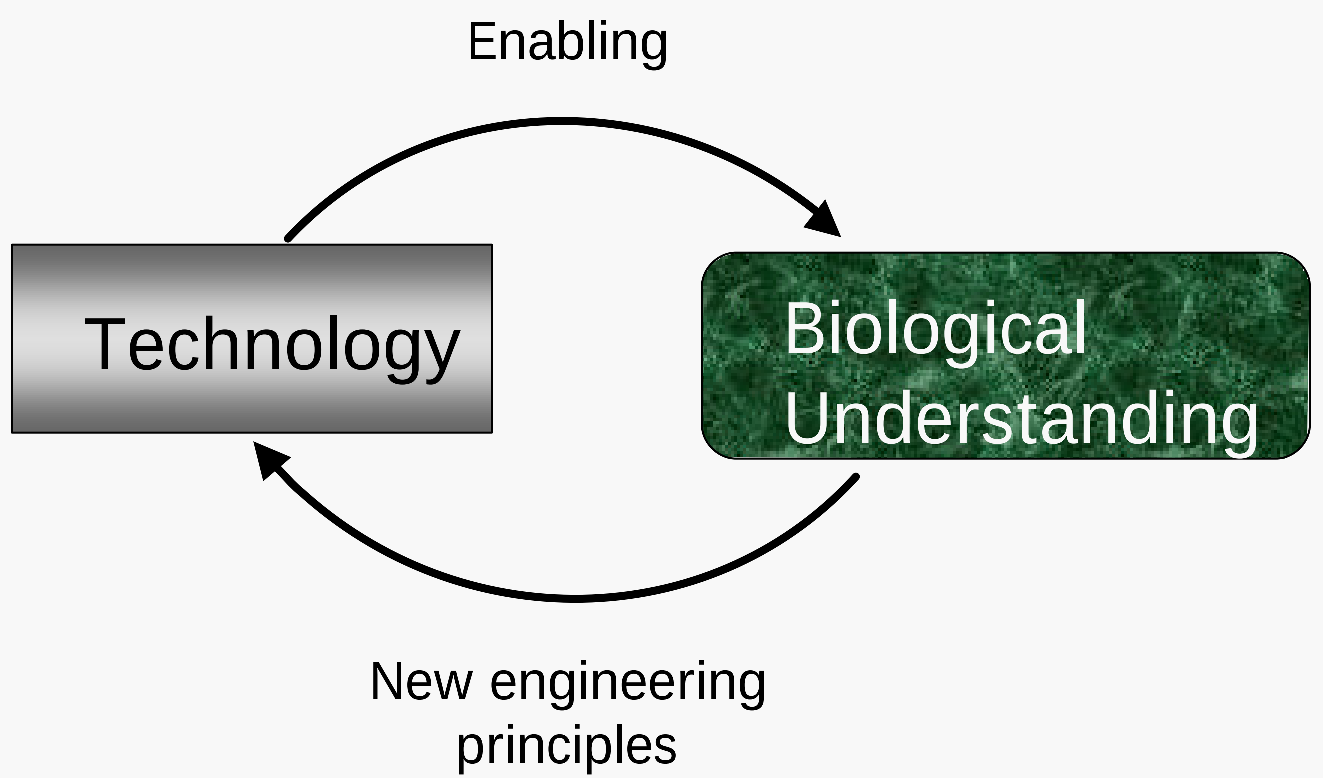
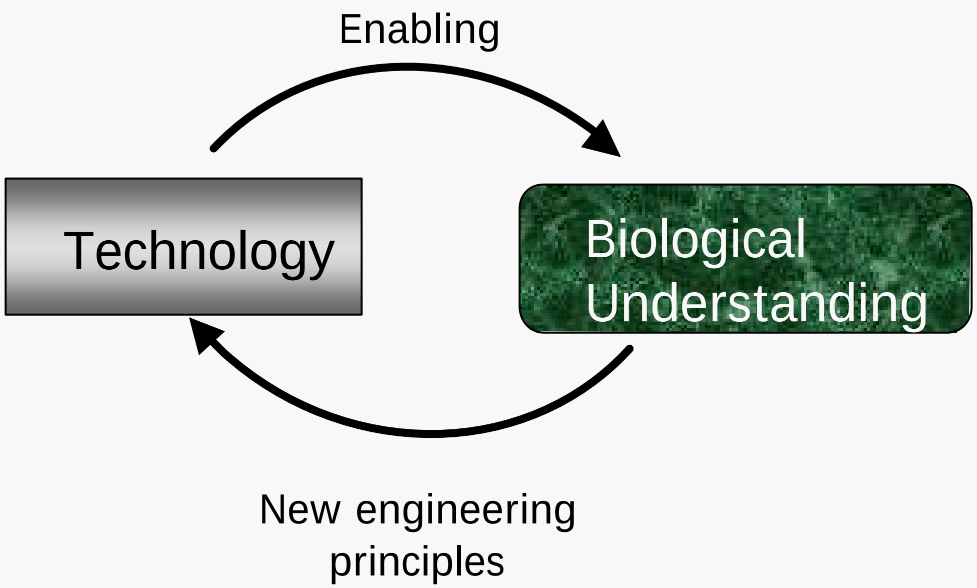
Partnership Between Biology and Technology



Positive feedback loop
Fuel advances in both biology and technology

How Will We Support and Sustain The Partnership?



People: bright people with good ideas, engaged and excited

The New Research Workforce

- Firmly based in a core discipline
- “Translators”: able to understand and communicate about other disciplines

Need:

- **Attract students from chemistry, computer science, math, physics, engineering to the technology/biology boundary**
- **Provide tools for success**

Lidstrom HHMI Professor Project

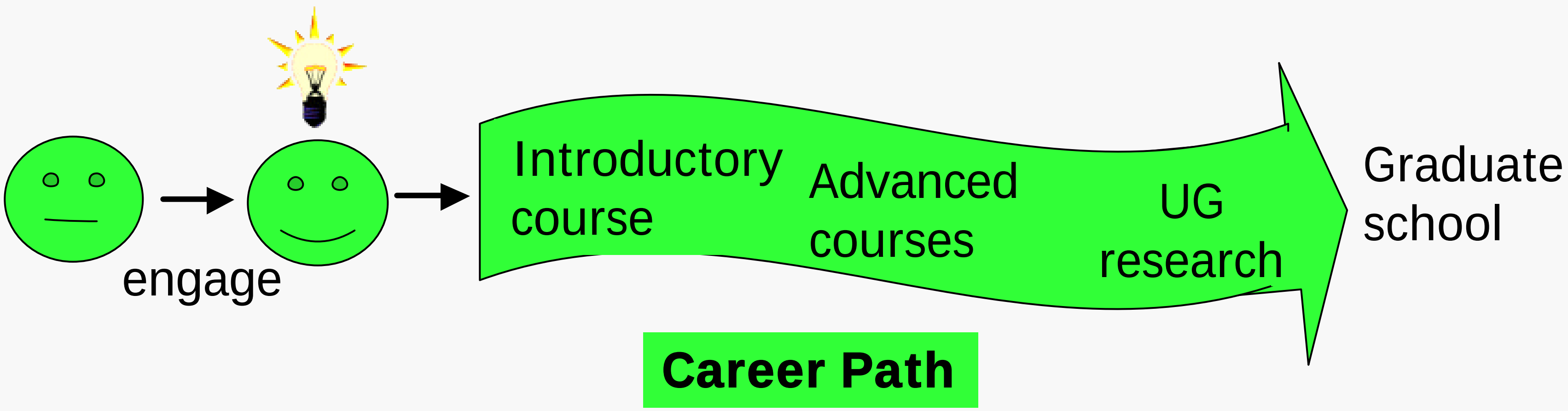
Learning at the Life Science/Engineering Boundary

http://biologyforengineers.org/

- Initiated Fall 2001
- Based on initial funding from NSF Action Agenda program

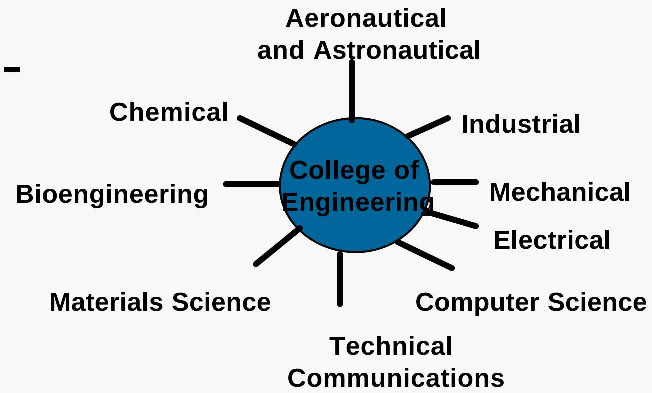
Goal

- Attract, engage, and motivate outstanding engineering and computer science students to a career at the technology/biology boundary

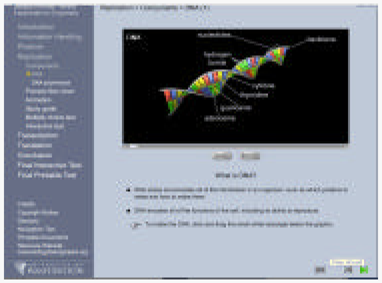


Program elements

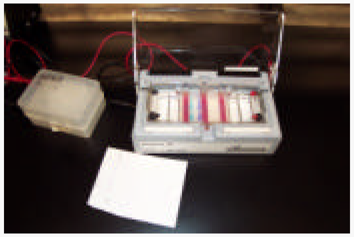
- 1) Development of life sciences-oriented pathways within the 9 engineering majors at the UW (other than Bioeng).



- 2) Development of curricular enhancements for introductory courses



- 3) Creation of a program for undergraduate research projects focused at the life sciences/engineering boundary.



Introductory courses

- ChemE 355 Biological Frameworks for Engineers

introductory course for students with no biology background

Biology presented as a series of engineering problems

↓

how nature has solved them

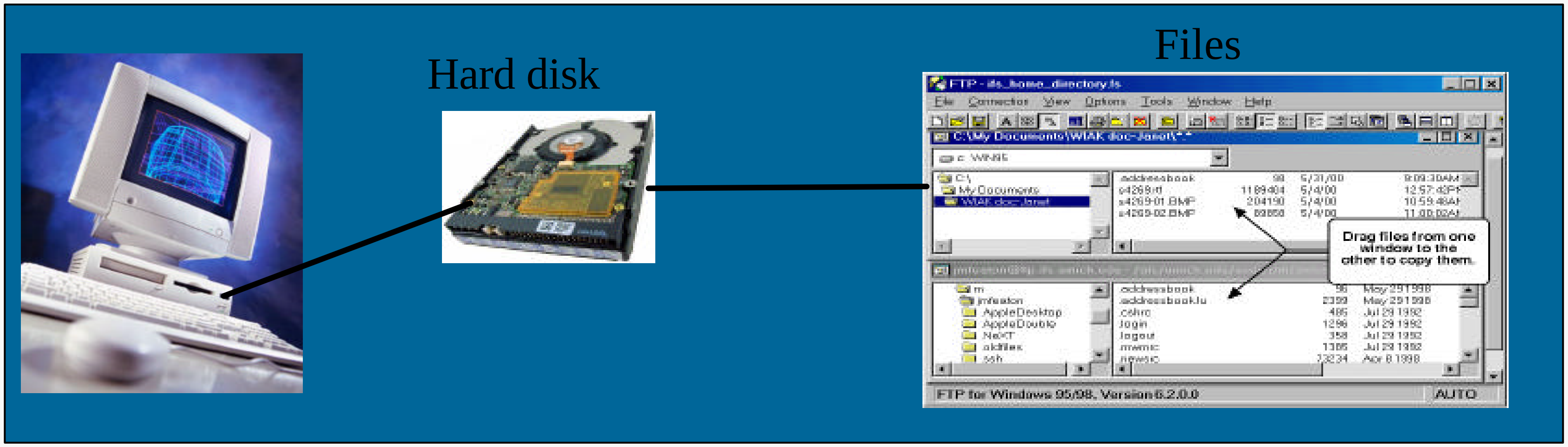
Taught from an engineering perspective

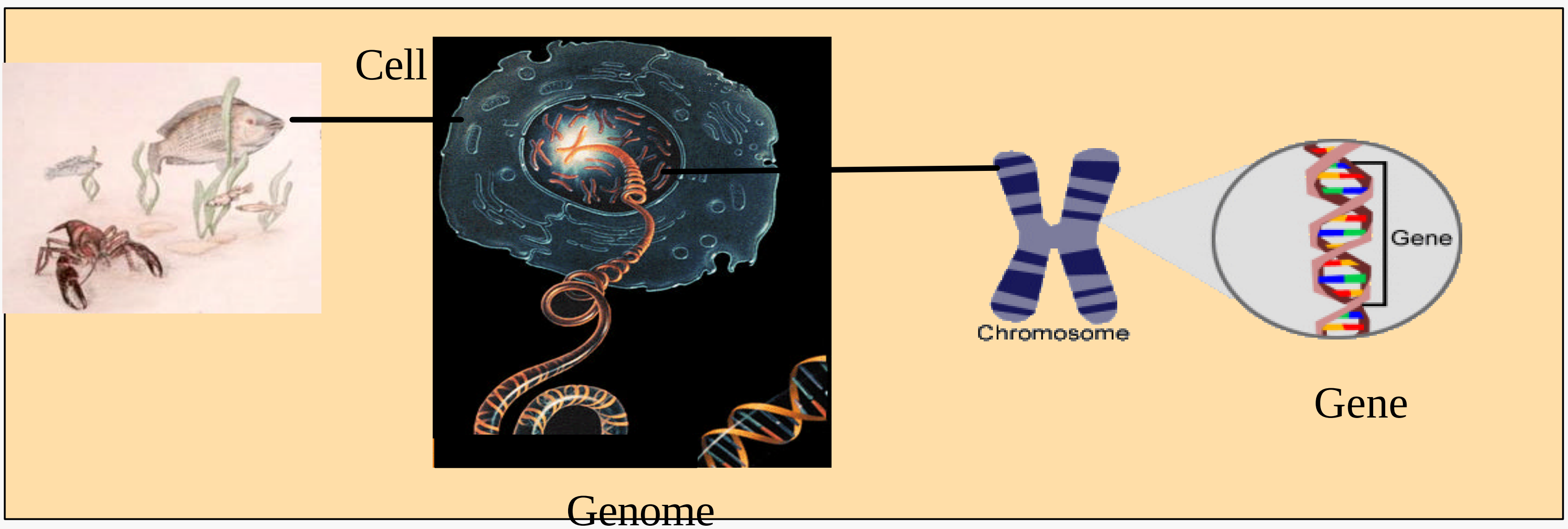
Nature as the engineer

Evolution as the design tool

Engineering analogies

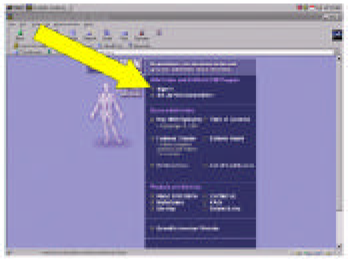
Information transfer in organisms is like information transfer in a computer





Student-Centered Learning

•Guided web "scavenger hunt" to obtain content outside of class



- In class
  - Team exercises to grapple with information, concepts, processes, ethics
  - Computational exercises to illustrate the quantitative nature of biology
  - Laboratory exercises to obtain hands-on experience

Team Exercises

- Based on information from the homework due that day (prospective homework)

Break up into small teams (4-5); discuss for 15 min; each group reports out

Example: analyze inheritance of an X-linked genetic disease (hemophilia) and discuss ethical issues involved in genetic screening for hemophilia

Computational Exercises

- Teranode-based software
- Simulations (TeraSim):
  - metabolic feedback loops
  - Heart/lung/vascular system feedback loops
- Laboratories (TeraLab):
  - Flow-chart based protocols
  - Links to relevant web sites

Laboratory examples

•Students PCR out variable region of own mitochondrial DNA
•Analyze sequence phylogenetically

Very engaging!

Expanded ChemE355 offerings

One size does not fit all

Three groups of engineers

1. "process-oriented" ChemE355 (01, 02, 03, 04)

   ChemEs, Mat Sci Engr, Civil Env Engr
2. "circuits- and information oriented" EE400 (04, 05)

   Elec Engr, Comp Sci Engr
3. "systems-oriented" ME400 (05)

   Mech Engr, Aero & Astro Engr, Indus Engr

Curricular materials available at www.biologyforengineers.com

Develop a new learning tool

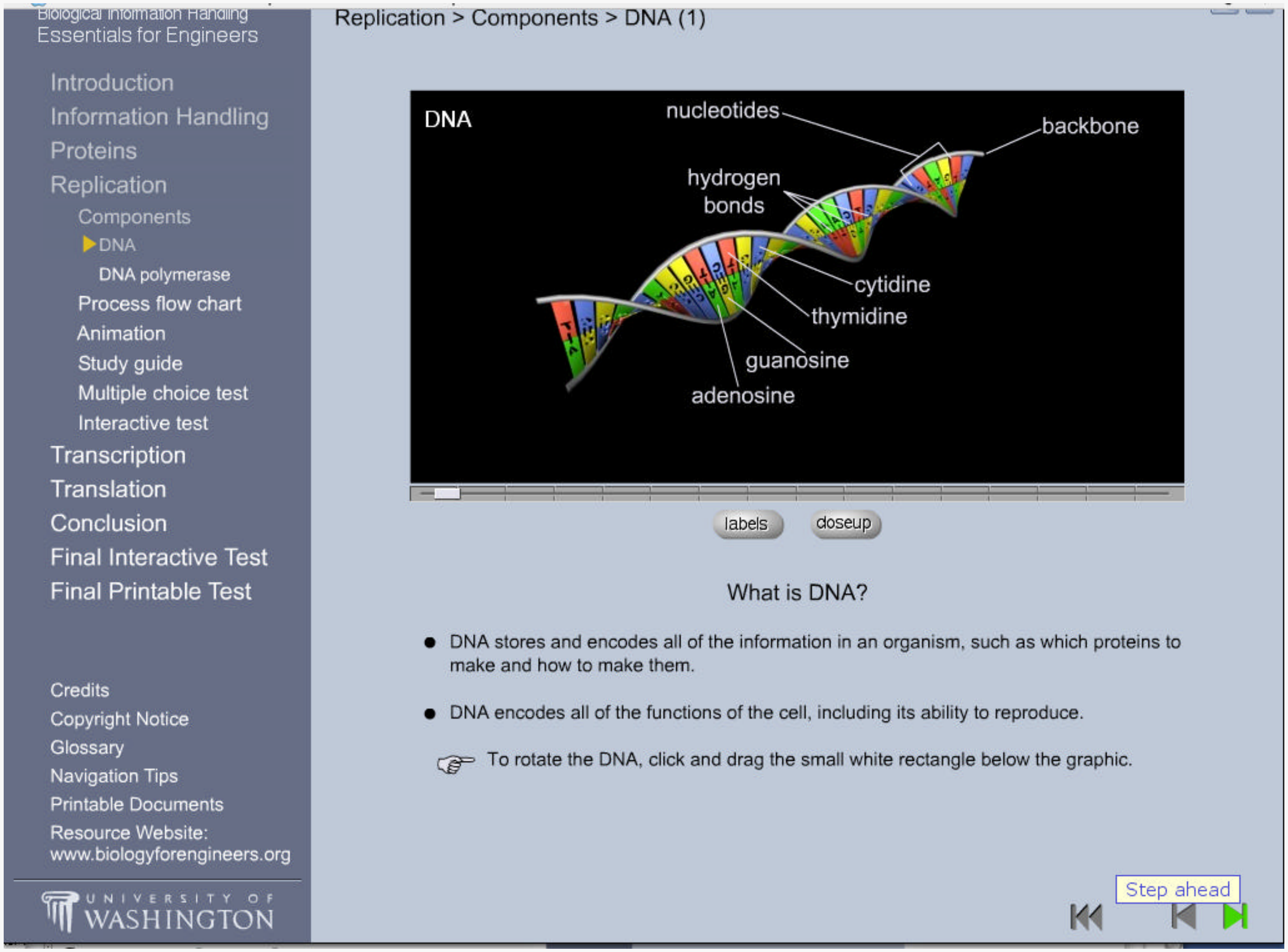
Problem:

–Students come into the classroom with widely varying expertise

–Commercial products not oriented to quantitative approach

Solution:

– Develop an interactive CD to teach life science basics to engineers and computer scientists
  - Information transfer parts and processes



–Based on learning style analysis, usability studies

–Interactive features

- •3D, manipulable structures
- •Interactive quizzes

Available by request (CD)
Or by download:
www.biologyforengineers.com

Challenge

- **Teaching one discipline to students in a different discipline**

Basic issues, regardless of the two disciplines

My focus: teaching biology to engineers

Basic Issues

Raise interest, then engage

- Understand student’s motivation
- Address misconceptions specific to that discipline
- Address jargon

Understand Motivation

- What would a student wish to learn in this discipline?
- The answer is probably not the same as for a student in the discipline

e.g.

Engineering students wish to understand HOW BIOLOGY WORKS

Biology students wish to understand WHAT BIOLOGY IS

Curricular response: focus organization around mechanisms rather than on details
(Nature as the engineer, evolution as the design tool)

Address Misconceptions

- All students bring learned misconceptions to a new subject. This is especially true of biology, because they are living organisms, in a world of biology.
- It is essential to address those fundamental misconceptions directly, to replace them with the correct concepts

e.g. Engineering students view biology as "magic", somehow escaping the laws of thermodynamics.

Curricular response: highlight the thermodynamic basis of life

e.g. Engineering students view biology as "soft", not explainable by equations

Use computational simulations based on "hard" equations to describe processes, circuits, feedback loops, etc.

Address Jargon

- Terms completely unfamiliar
  - Keep to a minimum
- Terms with different meanings in the two disciplines
  - Like misconceptions, these must be addressed directly, or the new term will never replace the familiar one

e.g.: “expression”

Technical Communication students: writing

Engineering, math students: mathematical equation

Biology: transcription and translation

e.g.: “vector”

Engineering, math students: mathematical term

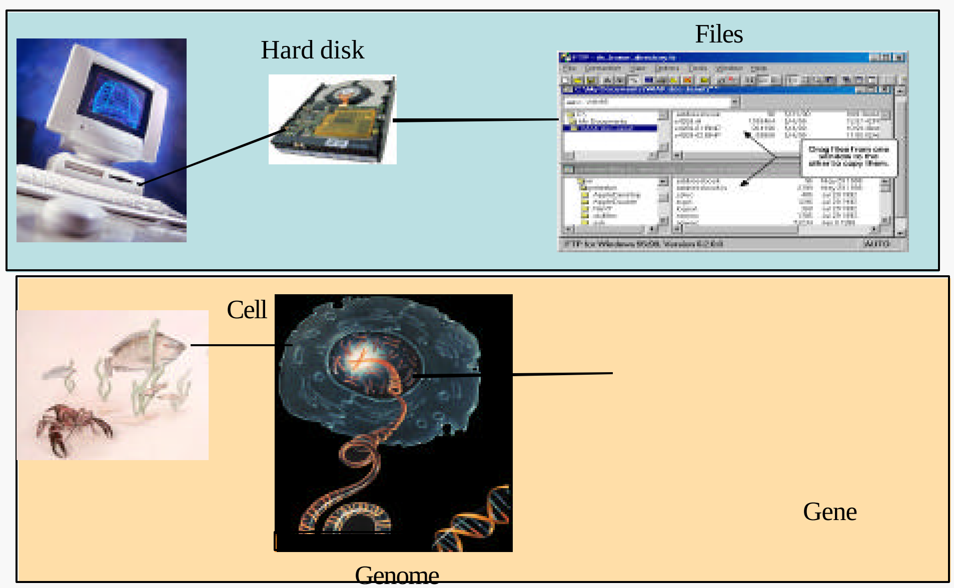
Biology: disease transfer mechanism or plasmid

Address Jargon (cont.)

Curricular response: never use these terms unless necessary; ALWAYS define them when used

Use engineering examples whenever possible

--Central Dogma = information processing in a computer
--Metabolism = chemical factory (unit operations)
--Regulation = process control; electrical circuits



Faculty Issues

- How understand motivation and identify misconceptions
  - Experience in the discipline
  - Open dialog with students, in-class exercises
  - Discussions with colleagues

Faculty Issues (cont.)

- How address jargon
  - Give up teaching “everything”
  - Be constantly aware of jargon
  - Make a vocabulary list for each class session and ask, “is this necessary?” for each item
  - Develop rapport with students, encourage them to speak up

Pedagogy

- Interest and engage students

  use multiple pedagogical styles

  - Lectures
  - Laboratory
  - Computer exercises
  - In-class problem exercises
  - Interactive multimedia tools
  - Songs

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Greg Crowther, Lecturer

http://faculty.washington.edu/crowther/Misc/Songs/

Student assessment: strong support for multiple pedagogical styles in learning a new discipline

Assessment

- Pre- and post-surveys of attitudes towards biology and research
- All questions on homeworks/exams coded to learning objectives
- Surveys for specific tools (CD, TeraNode software)
- Standard bubble evaluation at end of course + comments
- Focus groups, telephone follow-ups (outside evaluator)

Team meets each quarter to discuss results and modify course appropriately

Introduce Students to Research

- Last day of class, session on undergraduate research
  - Describe opportunities, process
  - Offer to provide recommendation
  - Bring in engineering grad students who work at the biology/technology boundary, who did research as undergraduates
- Met with high enthusiasm

Results

- Learning objectives met for >90% of students
- Substantial increase in depth of knowledge in biology, ability to apply and evaluate knowledge
- Strong change in attitudes towards biology
  - Commitment to the area
  - Engagement in research
- Significant increase in the % who go on to do undergraduate research

Surprises

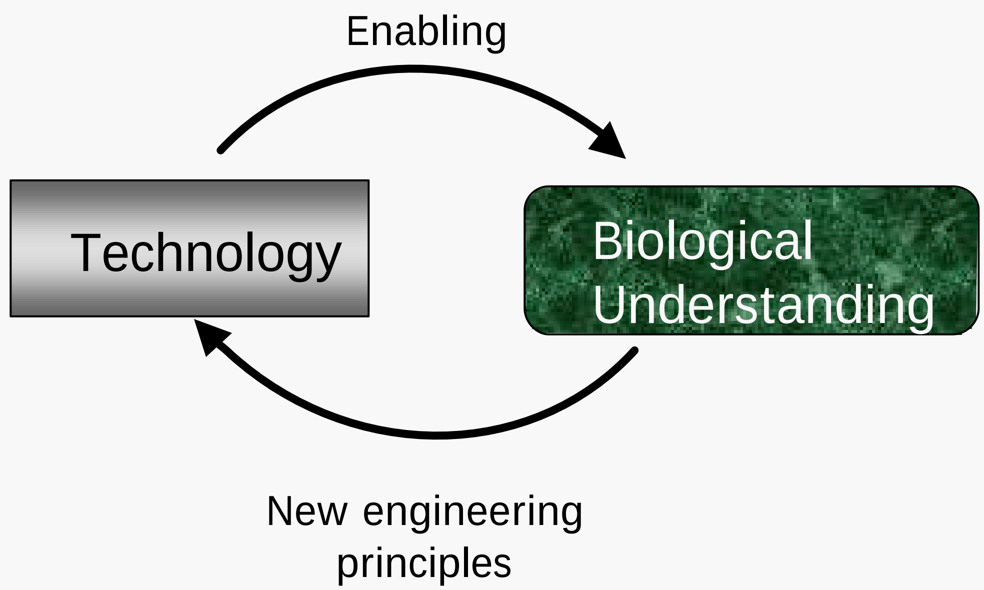
Who are the students

- –Female (60-70%)
- –Diverse (20% underrepresented minorities)
- –Upper half of their class

Risk-takers, broad thinkers

Projected Outcomes

- Cohort of outstanding engineering students with interest in and expertise at the engineering/life science boundary
- Exportable model for bio-oriented pathways within traditional engineering majors
- Curricular tools for exporting to other programs



What About Teaching Engineering to Biologists?

- Motivation: biologists want to USE it, not understand HOW IT WORKS
- Misconceptions: need to understand and address
- Jargon: need to avoid, relate to biology, use biological examples

Acknowledgements

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Poison Dartfrog Media (CD Flash Designers)

Teranode (Simulation Software)