Welcome to 20.109

Laboratory Fundamentals of Biological Engineering

Orientation Lecture
Spring 2009
Introducing 20.109

• Why you’re here
  – course mission
  – principles of investigation

• What you’ll do
  – three experimental modules
  – assessments/communication
  – course logistics
Course Mission for 20.109

- To teach cutting edge research skill and technology through authentic investigation

- To inspire rigorous data analysis and its thoughtful communication

- To prepare students to be the future of Biological Engineering
Olivia’s experiment: an 8th-grader poses a question

- Effect of R&B vs. classical (CL) music on heart-rate

- Hypothesis 1: R&B will ↑ heart-rate, CL will ↓

- Other hypotheses: opposite effect
  - no change (null)
  - H2 assume tempo is key parameter

experiences ➔ definitions / biases
Olivia’s experiment: controls and interpretation of data

• Experimental design:  
  – Measure heart-rate before and after exposure
  – How many groups? (1) pre → R&B → CL
    (2) A/B/C/L/... matched (sex, age ...)

3rd group - external control: “rock” 2 min. w/ headphones

• What if heart-rate is unchanged in all 3 cases? 
  null (reject others)

• What if heart-rate increases is in 3 cases? 
  stress exp. conditions
Olivia’s experiment: quantification

• Which data suggest a real difference? How can we know?

- 20% chance by random
- 5% chance

• Ways to process the raw data:

\[ \text{heart rate (bpm)} \]

\[
\begin{array}{c|c|c}
\text{Control} & \text{R&B} & \text{Control} & \text{R&B} \\
\hline
50 & 75 & 100 & 125 \\
75 & 100 & 75 & 100 \\
100 & 125 & 100 & 125 \\
\end{array}
\]
Olivia’s experiment: community

- What if her classmate got very different results?

Heart-rate (bpm)

- **Control**
- **R&B**

- **Olivia's**

- **Control**
- **R&B**

- Lack of reproducibility → differences, is I reliable?
  - Repeat, revised
  - Sample size

- More homo. pop.
- Better equipment
Olivia’s experiment: what does all this have to do with 20.109?

• Posing a good question:
  – Consider interest and impact
  – Recognize your assumptions
  – Seek out prior knowledge

• Interpretation of data:
  – Develop good controls
  – Understand each collection step
  – Perform quantitative analysis
  – Peer review
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Engineering Principles + Modern Biology

Manipulate and Make

Measure → Model

Nagai et al.

Myriad length scales, systems, and applications
Module 1  Protein Engineering (A. Jasanoff)
Module 2  Expression Engineering (L. Samson)
Module 3  Cell-Biomaterial Engineering (A. Stachowiak)
Protein Engineering: calcium sensor redesign

Experimental Goals

*Design: Modify DNA + protein*

- Mutagenize wild-type plasmid
- Express and purify protein
- Assess effect on protein

Lab+Analytical Skills

- Bacterial cell culture
- DNA manipulation and analysis
- Protein characterization
- MATLAB modeling
- Discuss primary research article
Expression Engineering: siRNA knockdown

Experimental Goals

*Design: siRNA, comparison*

- Transfect cells with DNA + siRNA
- Measure gene knockdown
- Assess genome-wide changes

Lab+Analytical Skills

- Mammalian cell culture
- Reporter plasmids
- Large data sets, statistics
- Intended and unintended effects
- Present primary research article
Cell-Biomaterial Engineering: making cartilage

**Experimental Goals**

*Design: Culture conditions*

- Study how environment affects cell health, and expression + production of tissue-specific proteins

**Lab+Analytical Skills**

- 3D cell culture
- Fluorescence microscopy
- Measure specific mRNAs
- Identify protein from mixture
- Present a novel research idea
Scientific writing must tell a story

• Archimedes, Newton, Kekulé
  – Stories help us remember

• You discover the narrative that the data tell

• Then convince an audience of your findings
  – Step-by-step explanations
  – Repetition of central ideas
  – Clear visuals

*Your data should be true even if your story is wrong*

~ Darcy Kelley, Columbia (from The Canon, N. Angier)
Communication and Grading

50% Written Work
Module 1: research article
Module 2: condensed report, submission letter
Module 3: data summary

30% Oral Presentations
Module 2: published article
Module 3: original proposal

20% Daily(ish) work
9% Homework
5% Quizzes
4% Lab Notebooks
2% Participation
Writing & Oral Communication Faculty

• Neal Lerner
  – Lectures/discussions
  – Written feedback (→ opportunity to revise)

• Atissa Banuazizi
  – Lectures/discussions
  – One-on-one review of videotaped talk
After 20.109, you should be able to…

- Organize a lab notebook
- Implement laboratory protocols
- Design novel experiments with appropriate controls
- Interpret qualitative data
- Analyze quantitative data
- Recognize utility of models
- Examine the scientific literature
- Communicate in multiple modes
- Present salient points of your own and others’ ideas
Course Logistics

Lecture  Tuesdays and Thursdays 11-12, 4-237
Lab    Tuesdays and Thursdays 1-5, 56-322
       Wednesdays and Fridays 1-5, 56-322

There are no “make-up” labs

Collaboration with integrity is encouraged: assignments can be worked on together but must be submitted individually. You will perform experiments in pairs.