Active Listening in Mentoring Student-Led Projects in Mathematical Biology

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Research Experience for Undergraduates (REU)

- 8 week program
- 3.5 weeks lecture and problems in mathematical biology
  - epidemiology and ecology.
  - nonlinear systems of difference and differential equations, discrete and continuous time Markov chains, partial differential equations, and agent based modeling.
- Students form groups and choose topics
- 1 week presentation project proposals
- 3.5 weeks work on project
- Technical report

Pre-assigned vs student-led

Pre-assigned

- Pre-chosen tasks place teachers or teacher-researchers in a dominant role where the teacher has an opportunity to learn and know everything there is to know about the problem
- Assigning a task to students gives students constraints that guide their development and their modeling activity. Students make fewer decisions.

Student-led

- Student frequently knows more about the topic than the mentor (Camacho et. al, 2003)
- Mentor is a specialized consultant, not a leader (Camacho et. al, 2003)
- Students take the lead as subject experts and decision makers (Castillo-Garsow & Castillo-Chavez, 2015)
- Improvements to motivation, self-efficacy (Castillo-Garsow & Castillo-Chavez, 2015)

REU Values

- Student selected topics, student led projects
- Many projects are in epidemiology & ecology.
- Past projects have included such topics as, eating disorders, gangs, party politics, prison education, immigration, the menstrual cycle, classroom education
- Student project choice is often very personal
  - Prisons, gang recruitment, immigration
  - Student suffered from the disease their group chose to study

Sources of Data

- Four groups: Vector borne disease (Vector), STD, Menstrual cycle (Biochem), Tumor growth (Cancer)
  - 17 undergraduates, 18 mentors
- Presentation Week
  - Students choose a topic, develop a research question and model with faculty feedback
  - Six days of presentations video & audio recorded
  - Open and closed coded
  - Transcripts and codes compared to final Technical Report
  - Re-coded based on results from initial coding
- There were 25 presentations, 12 hours, 17 minutes of video, 1,381,557 characters of transcript, 2631 mentor comments, and four technical reports

Identified Themes

- Biochem
  - Mentoring Challenge: Following the students' lead
- Cancer
  - Mentor Challenge: Filling in the gaps
  - Mentor Challenge: Letting students explain at their own pace
- STD challenge
  - Mentoring Challenge: Dynamics over research question
  - Mentoring Challenge: Tracking the problem constraints

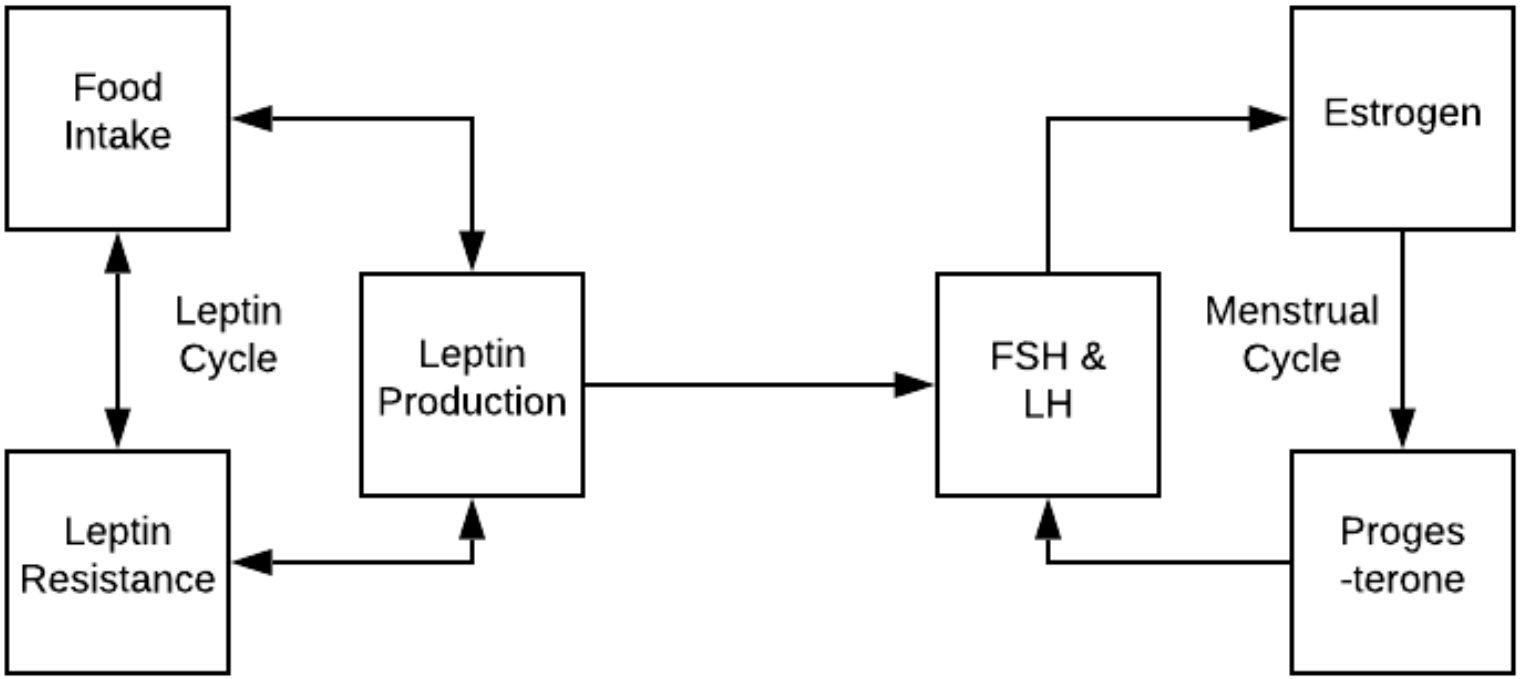
Following the student's lead

BIOCHEM

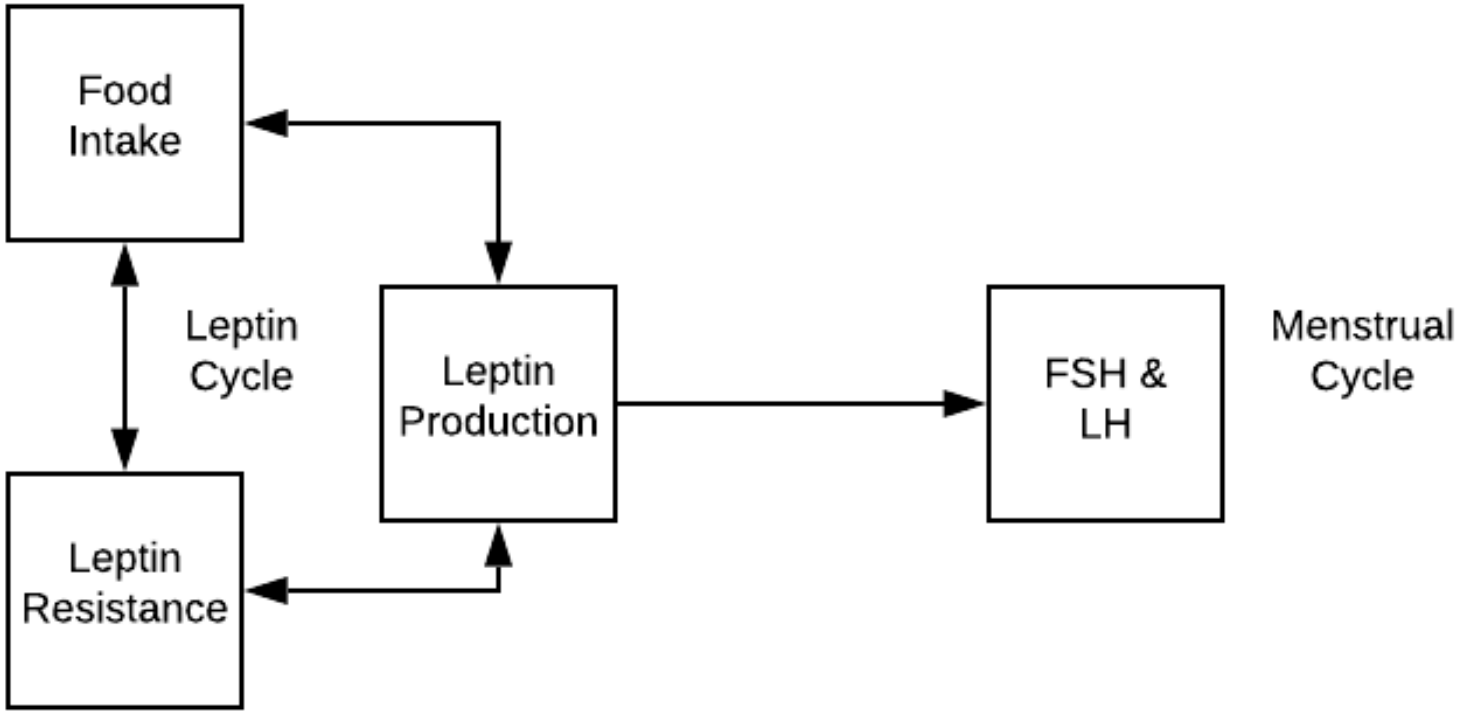
Mentoring Challenge: Following the students' lead

- Consistent research question:
  - "Tracking eating disorders through hormonal irregularities in the menstrual cycle" (day 1)
  - "what is leptin's effect on the induction of the menstrual cycle?" (day 6)
- But leptin did not appear in the final paper!
  - "This is your model, only focus on this one, no leptin yet... then, if there is time, you go adding the leptin."
  - "probability of that is zero" (day 6)

The system

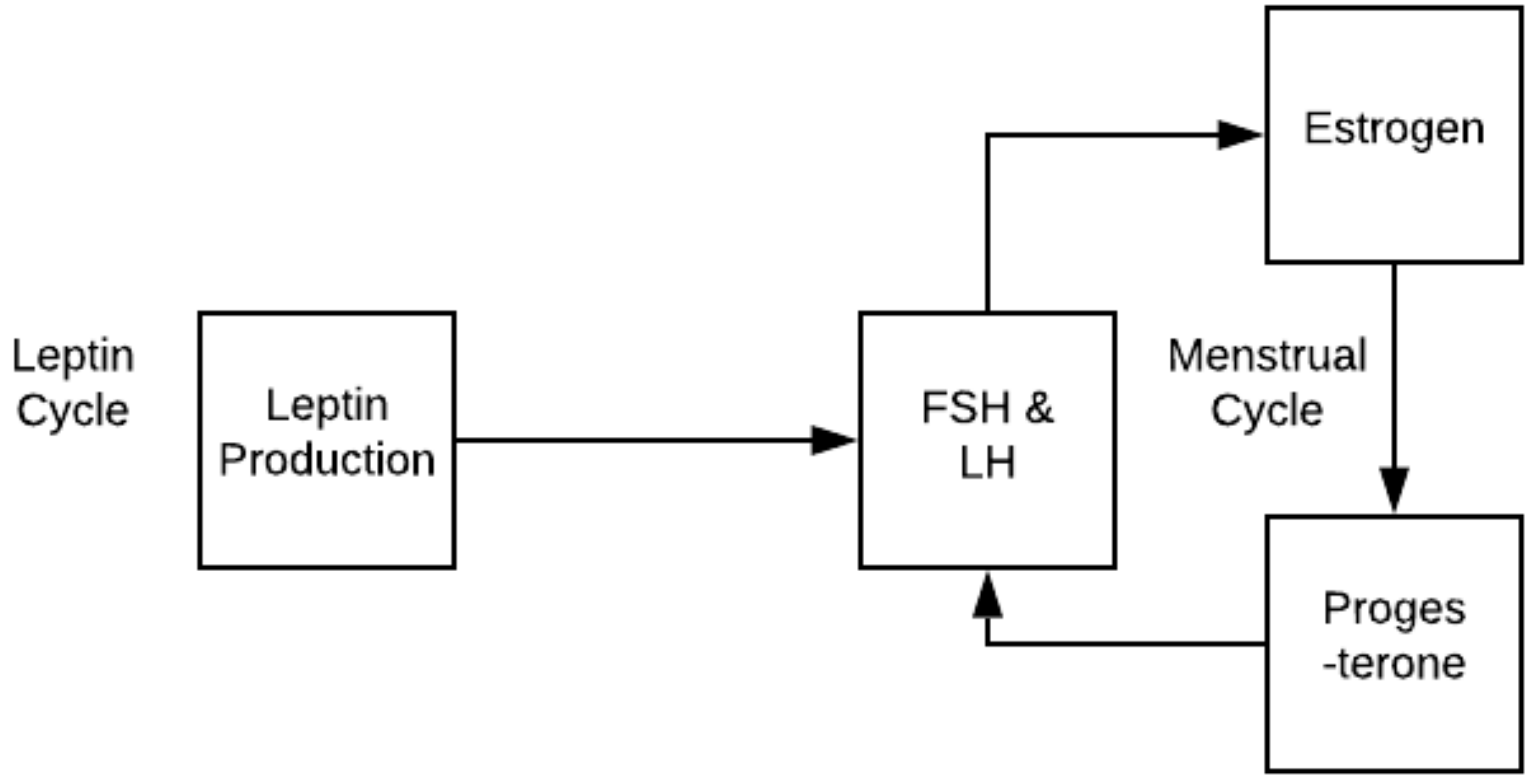

Food Intake
Leptin Cycle
Leptin Production
Leptin Resistance
FSH & LH
Estrogen
Menstrual Cycle
Proges -terone

Students' interest



"Tracking eating disorders through hormonal irregularities in the menstrual cycle" (day 1)

What Mentors heard



“We're studying the effect of leptin on the induction of the menstrual cycle.” (day 4)

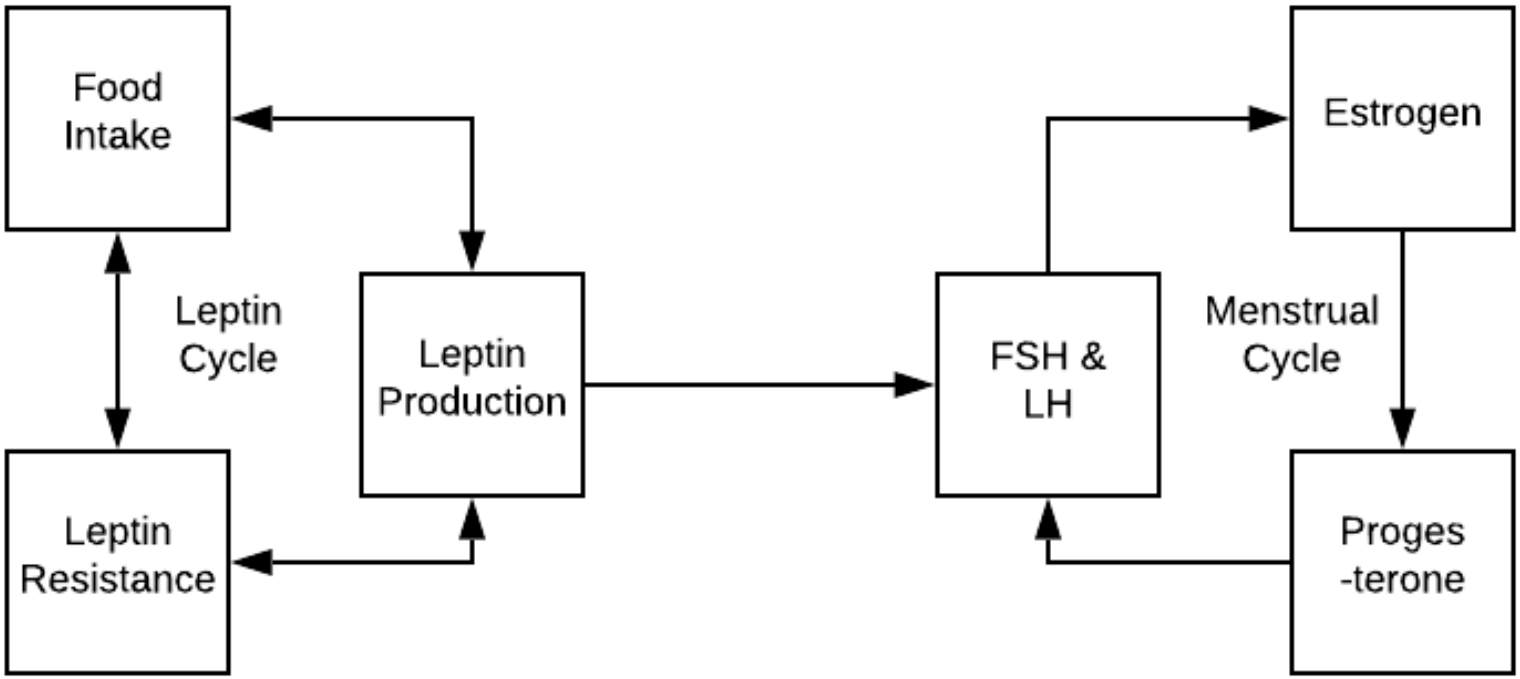
Instructors push students away from stated goals

- Students: "a mathematical model that can assist tracking eating disorders through hormonal irregularities in the menstrual cycle"
- Mentors:
  - Day 1: “if you’re looking at the effect of eating disorder on a menstrual cycle, specifically if you're looking at something like the effect of leptin resistance on menstrual cycle, then what you need is you need a working menstrual cycle so that when you add leptin resistance to it, you can observe it work”
  - Day 2: “You cut from two because that only can impact to the forward. You do not have anything feedback.”
  - Day 2: “the top half of the model doesn't have any interesting dynamics. It has very, very simple dynamics. The only thing where there's some complexity to it is the feedback of the bottom half”
  - Day 2: “we understand that you want to look at the effect of leptin on FSH. It seems you would need to look at the effect of the other hormones on FSH also”
  - Day 2: “"In this model here you're only looking at what creates FSH, not what regulates it, not what causes it to diminish, not what metabolizes it, not what causes it to decay.””
  - Day 6: “this is your model, only focus on this one, no leptin yet. Until, unless-- when you complete the analysis everything [equilibrium analysis], and estimates apparently whatever you're doing, then, if there is time, you go adding the leptin”

Mentor concerns

- Leptin is only feed forward into the menstrual cycle. Lack of feedback means that the cycles do not affect each other in mathematically interesting ways. Only studying one cycle is necessary
- Many things influence initial hormones FSH & LH besides leptin. Mentors were concerned about studying the effect of leptin without studying the influence behaviors of more significant factors as well

Other places to cut



Filling in the gaps

CANCER

Student Challenge: Finding a research question

Research question	Presentation Day
“How does the intensity of anti-angiogenesis treatment affect the survival rate of adenocarcinoma cells in old people and relatively healthy patients?”	Day 1
“We're studying the spread of a malignant tumor, more specifically, adenocarcinoma in the lungs.”	Day 2
“What is the dynamics of the spread of cancer if we use the spatial-- sorry, cell competition?”	Day 2
“How does the growth factor mechanism affect the spatial dynamics of cell strife?”	Day 3
“The initial stages of cancer, especially how it is started.”	Day 4
“The spatial dynamics of the growth rate of the cells here and the cancerous cells of the lung... adenocarcinoma... with this idea of a cell competition”	Day 4
“We're looking about how a synergistic effect between ... mechanical sensing and the competition for nutrients"	Day 4
“We don't have a clear, concise, research question here because we're reading the literature.”	Day 4
“How does cell nutrition contribute to massive cancerous cells?”	Day 4
“We want to see what happens for example to the function of [lung] cells when adenocarcinoma begins”	Day 4
“Due to the defensive secretion of cytokines of tumor cells against the immune system was there resulting environment around tumor cells around tumor masses to survive”	Day 5
“We want to study the spread of cancer and as a spatial model”	Day 6

How did this happen?

- *Student*: “a new theory that has been grouped in ***Drosophila melanogaster***”
- *Student*: “Then the cells that surround that abnormal cell will **sense their fitness level**, and they sense that the fitness level is lower than the surrounding cells. They will emit some signals to **induce apoptosis to that abnormal cell**.”
- *Student*: “The theory actually is **called cell competition** because cells are competing for nutrients and space”
- *Mentor*: Suppose the literature they talk about some **MYC levels** suppose levels are higher some MYC levels are lower, MYC levels. **The higher the MYC levels kill the cells in the lowered one**. They are the winners in the competition model [nearby]

How did this happen?

- There is a theory studied in *Drosophila* that during normal cell competition, some cells ”super-compete” by sensing MYC levels and releasing toxins in response that kill cells with lower MYC levels. (Baker, 2020; Donaldson & Duronio, 2004; Johnston, 2014)
- Students described this process as “fitness sensing” and “cell competition”
  - But there are many ways to define “fitness” and “competition”
  - Students could not explain the details
  - Narrative of “fitter cells out compete less fit cells” is not interesting, potentially circular
- Only one mentor comment that would have helped slipped through the cracks

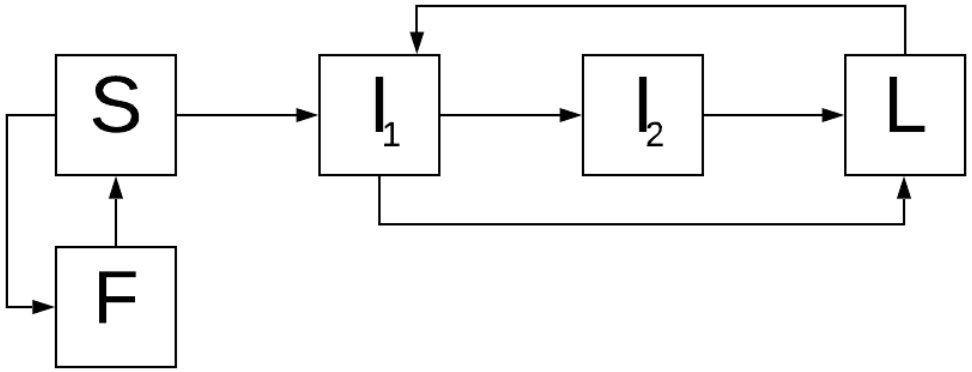
Dynamics over research question

STD

The core research question

- Imagine an STD, where once you have it, you have it for life.
- There is no cure, only a treatment that reduces the symptoms and infectiousness
- The disease has two stages
  - I1: Symptoms resemble many other diseases (ex: flu)
  - I2: Symptoms are characteristic of this disease
- There is no test, we can only judge by symptoms
- If we only treat people in I2, we will only treat people with this disease, but the disease will spread in I1.
- If we treat people early (I1) then we might reduce the spread of the disease, but we will waste a lot of money accidentally treating people with flu.
- What is the best way to spend money to reduce the spread of the disease?

Mentor Feedback

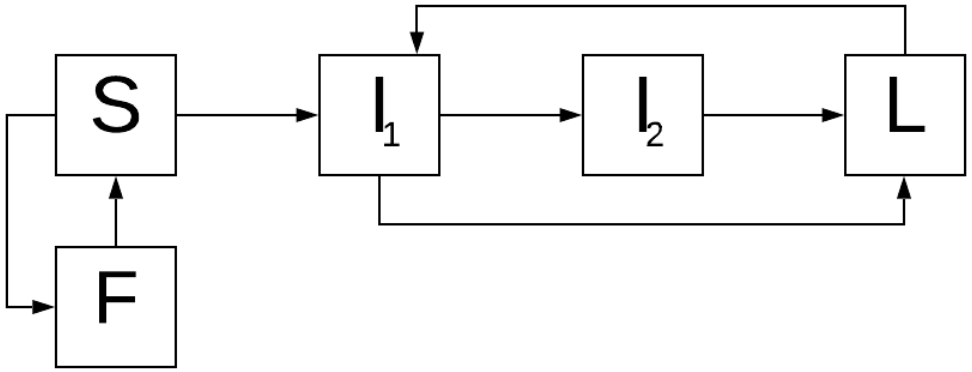


- "Okay. Just forgot that part, that part never play any role there"
- "If you only consider dynamics, F compartment does nothing to”
- "Yes that is true. So you don't need it—"

Tracking the problem constraints

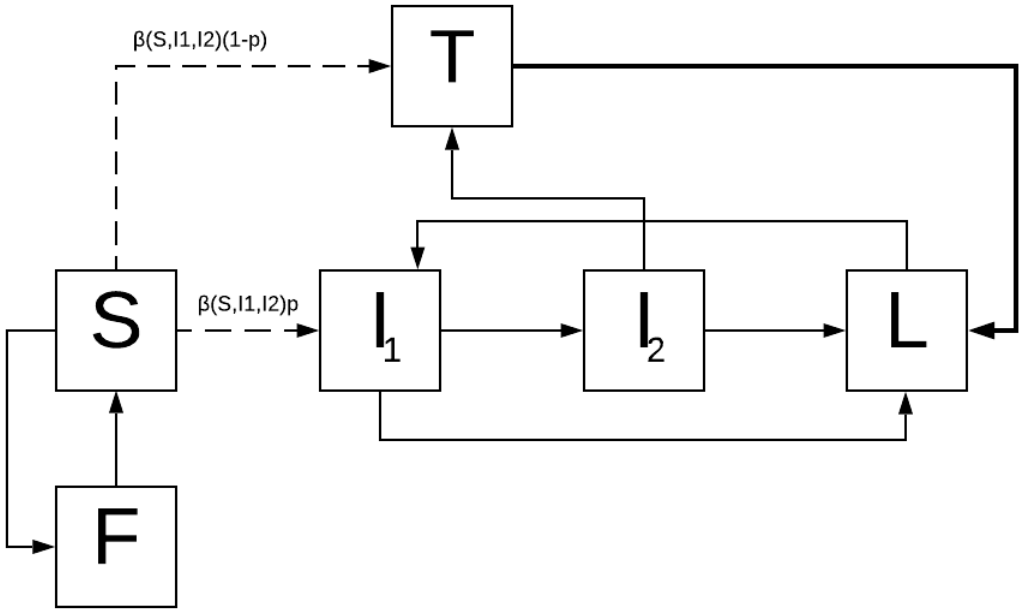
STD

Mentor Feedback



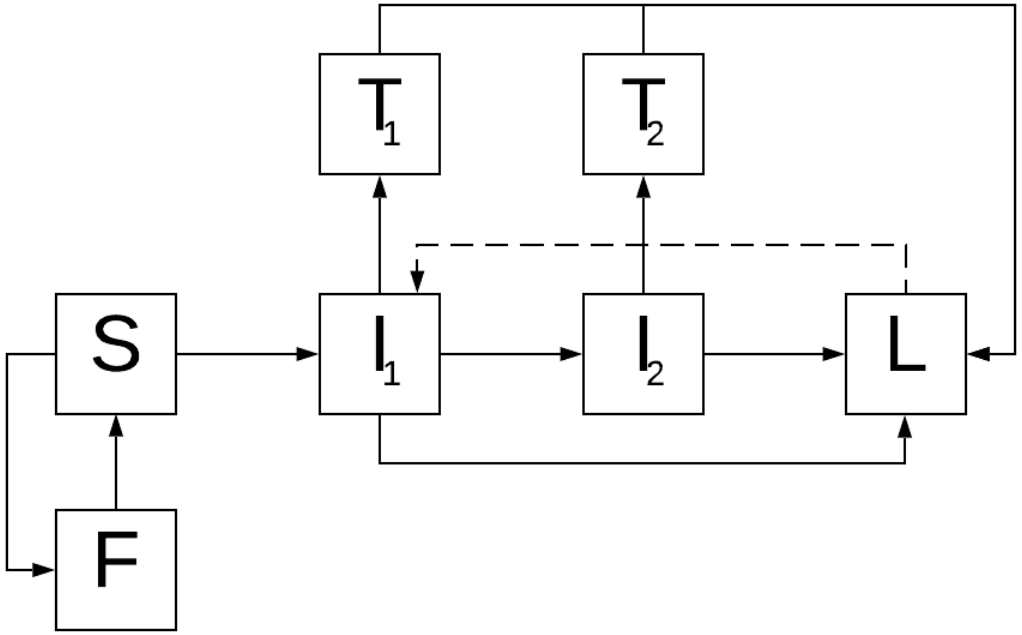
- *Student*: The current test that we have now, there is no way to test if you have [the] disease. There's absolutely no way. The only way you test it if you go here [I_2] and you have a lesion here to take samples
- *Mentor*: The cost of this testing, and the patient, the I_1. The same test?
- *Student*: There's no testing for I_1 in that.
- …
- *Mentor*: Why do you treat F if they're not sick?

The Fourth Model (Mentor Suggested)



- So then you screen that [S] and once you screen that you put it here [I_1], [you] do not go here [T]

The Final Model



DISCUSSION

Consistent problems with vocabulary and communication

- Students used standard terms in non-standard ways.
  - Cell competition vs super-competition
- Students used terms without idea of underlying mechanisms
  - “fitness”
- Students struggled with the complexity of their ideas and emphasizing what was important to them
  - Eating disorder vs. leptin vs. menstrual cycle
  - Competition induced apoptosis through MYC sensing
- Mentors felt that students didn’t understand their topics and took more control
  - “Remember you have three weeks”
- Students ended with projects that were only related to what they initially wanted to do
- Mentors invested in student-led projects need to work hard to draw out students’ goals, ideas, and explanations in a welcoming environment

Conclusions

- Mentoring student led projects requires careful listening to students
  - What question are the students interested in and why?
  - What are the constraints on the problem?
- Student-led projects require active listening
  - Students don't communicate ideas with vocabulary and styles that faculty are used to
  - Mentors must actively inquire to identify students' values and create space for students to explain their meanings
  - Mentors must sometimes fill in the gaps and help direct students to the important ideas in the literature that students have already read
  - When mentors don't give this time and grace, students lose some control over the project's direction.

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Thank you,

QUESTIONS?