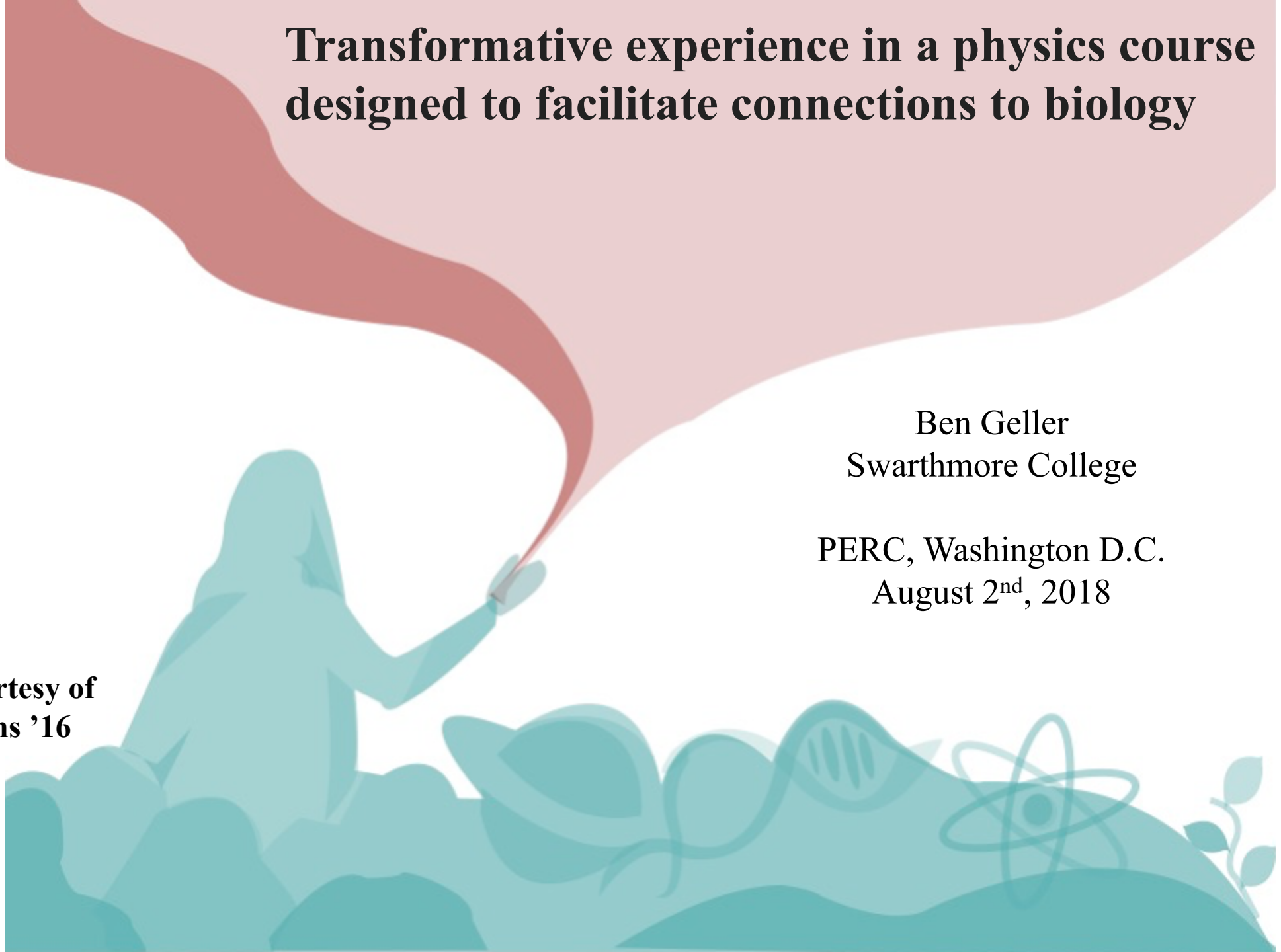


# Transformative experience in a physics course designed to facilitate connections to biology

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PERC, Washington D.C.  
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Artwork courtesy of  
Tessa Williams '16





## Transformative Experience

*“those experiences in which students actively use science concepts to see and experience their **everyday world** in meaningful, new ways”*

(Pugh et al., 2010)

The punchline:

We argue that Bryn, a life science student taking introductory physics, has a transformative experience, but one that is not precisely captured by Pugh’s definition.

In particular, Bryn’s transformation is inherently connected to her **evolving relationship with the disciplines of biology and physics**, and not just to how she experiences physics in the “everyday world.”

# Outline

- Context for studying Bryn's experience: Introductory Physics for Life Science (IPLS) at Swarthmore
- Bryn's evolving relationships with biology and physics: Disciplinary identity, affect, and epistemology
- Characterizing Bryn's transformative experience

# IPLS at Swarthmore:

## A unique methodological opportunity

First Semester:  
(Mechanics)

TRADITIONAL

Second Semester:  
(E&M)

IPLS

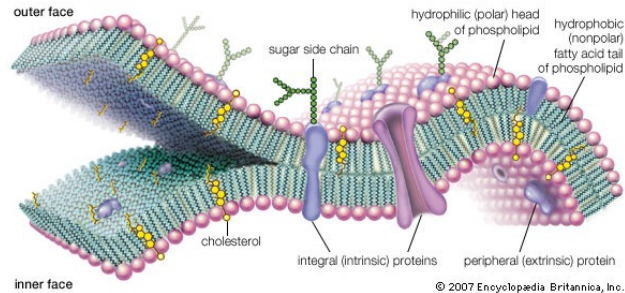
Students in the course are pre-med or life science majors, mostly sophomores and juniors; no formal biology or chemistry prerequisites, but most have taken courses in both areas.

# IPLS course design: Content

Organize each topic and unit around one or two  
*central biological contexts*

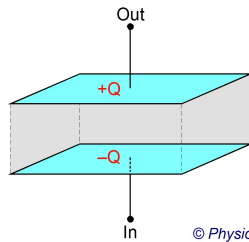
- Electricity/circuits: *cell membrane, nerve signaling*
- Magnetism and induction: *magnetic sensing, NMR*
- Optics: *animal vision and microscopy*
- Waves: *echolocation*

# IPLS course design: Skills

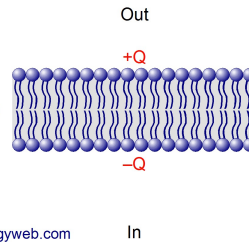


BIOLOGICAL SYSTEM (Cell Membrane)

A. Parallel-Plate Capacitor

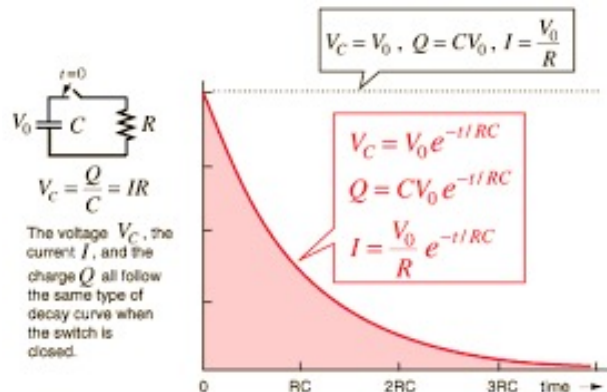


B. Lipid Membrane



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SIMPLE PHYSICAL MODEL (Electric Capacitor)



GRAPHS & EQUATIONS  
(associated with charging/discharging  
a capacitor)

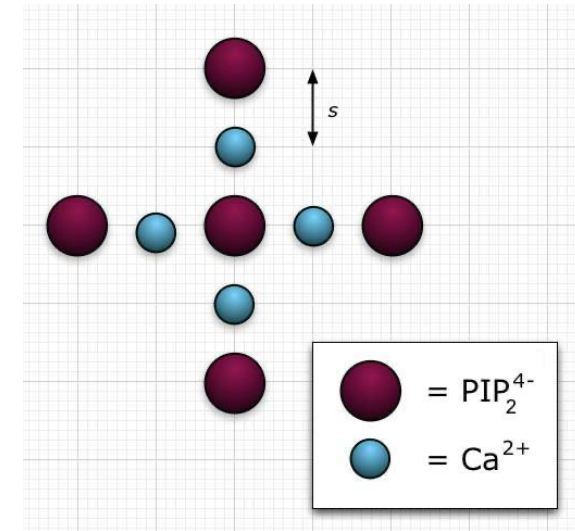
# IPLS task design: “Authenticity” and “Expansive Framing”

Watkins et al. (2011)

Engle et al. (2011)

## EXAMPLE:

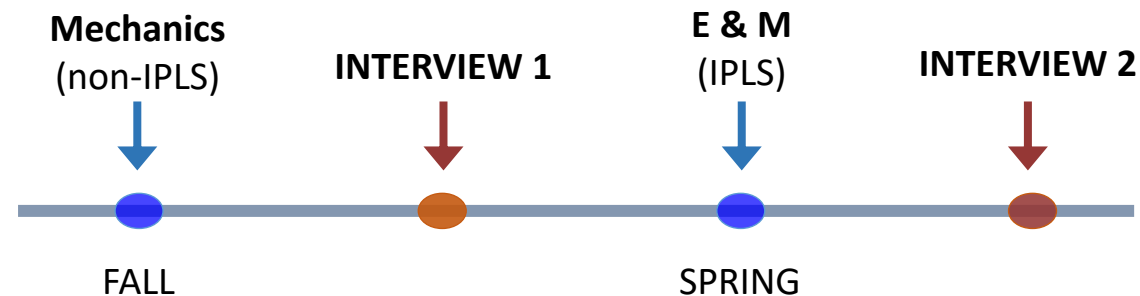
Rare, highly negatively charged lipids form clusters on the cell membrane surface for certain cellular processes. These clusters include small positive ions. For the simple model of a cluster shown, show that with doubly charged  $\text{Ca}^{2+}$  ions, electric forces hold the cluster together — but not with singly charged  $\text{Na}^+$  ions.



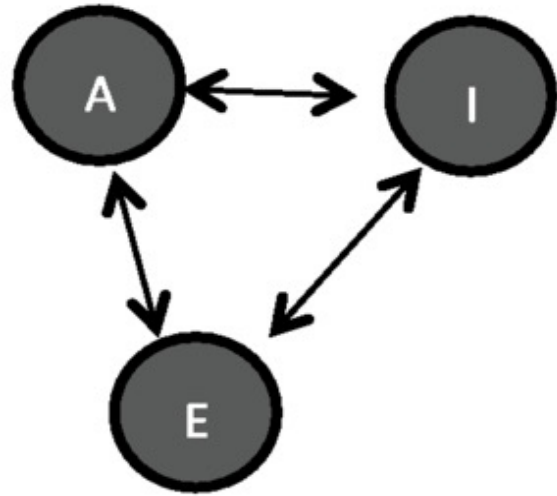
# Who is Bryn?

- Junior at Swarthmore College (small liberal arts college ~1600 students)
- Biology major, pre-med who would like to pursue pediatric medicine
- Enrolled in a two-sequence physics sequence to satisfy pre-med requirements, at the same time as a two-semester cell biology sequence:

Fall Semester	Spring Semester
Standard mechanics	IPLS E&M
Cell biology	Advanced cell biology







**Relationship with the discipline**

- **Disciplinary Identity:** (context-dependent) characterization of oneself in relation to a discipline
- **Disciplinary Affect:** (context-dependent) interest, motivation, and emotion related to a discipline
- **Disciplinary Epistemology:** (context-dependent) beliefs about the kinds of knowing and learning that “count” in a discipline.

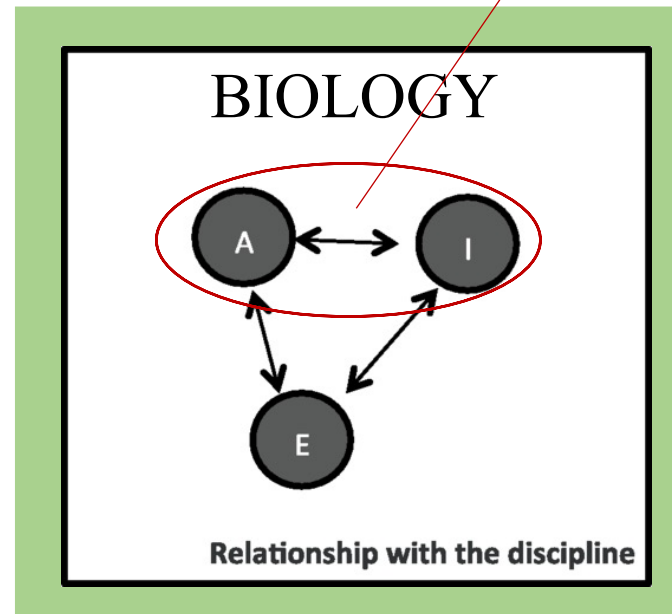
Sawtelle and Turpen (2016): *Leveraging a relationship with biology to expand a relationship with physics.*

# Research Questions

- How do Bryn's descriptions of her relationships with biology and physics evolve as she moves from the traditional physics to IPLS physics environment?
- How does this evolution map onto Pugh's notion of transformative experience?

## Bryn's relationship with biology BEFORE IPLS

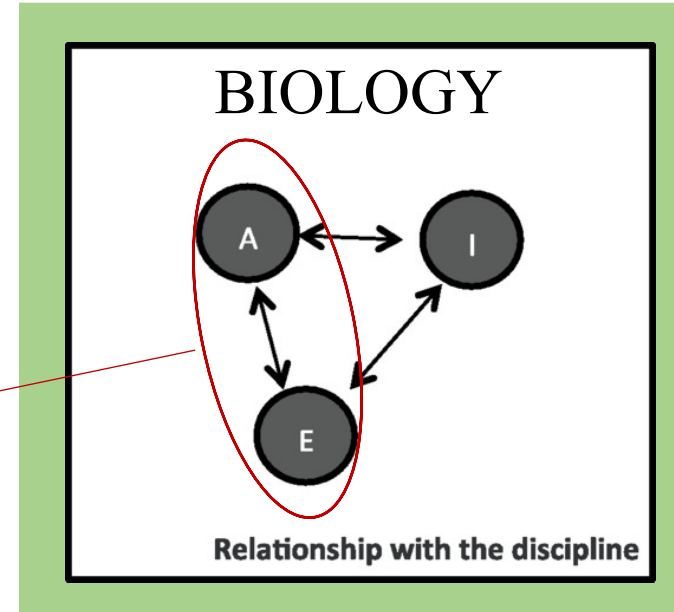
*I'm very obviously a bio person, so it's so hard for me to think in any other way... I am most confident in biology... Biology seems to be the one thing that I'm just like, this is it, **this is what I want to know.***



- Strong self-identification as a “biology person”

## Bryn's relationship with biology BEFORE IPLS

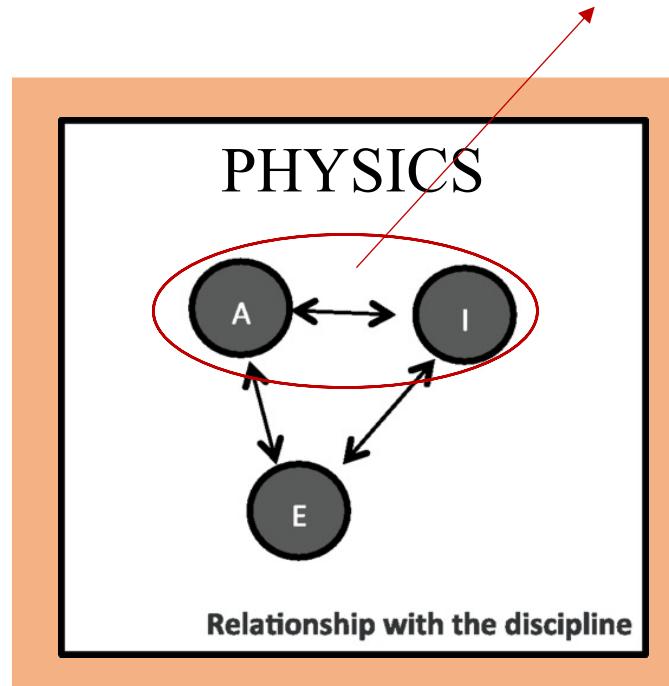
*There are people who study why it is that a frog bends its leg at a certain angle and therefore can achieve this sort of bouncing height. Like that is not something that I find automatically like 'Oh that's so cool, I'm gonna study that and catch a bunch of frogs and look at, like, the angle of frog leg bending and how high it jumps.' Like, the question I would be asking is probably like, so what is the gene that made its leg look like that? ... I wonder how it evolved to be like that.*



- Affinity for evolutionary questions (which she sees as biology) as opposed to mechanical ones (which she does not see as biology)

## Bryn's relationship with physics BEFORE IPLS

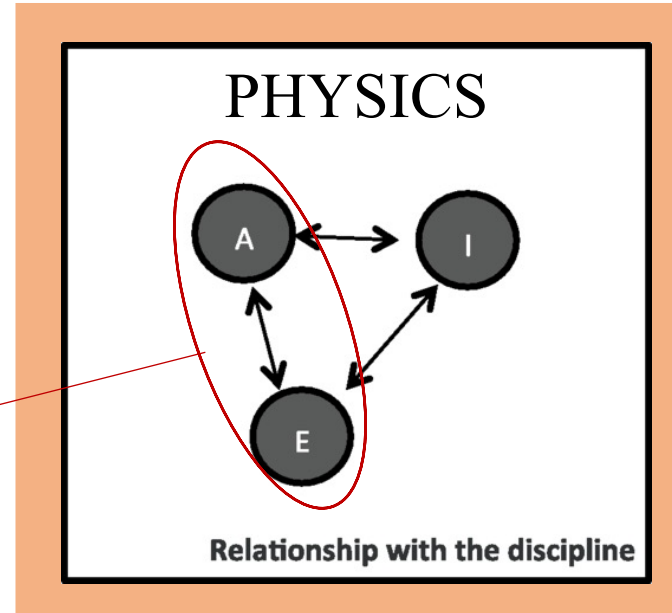
*Physics doesn't come intuitively to me... It has always been very foreign to me; it's always been very... like, I always say **'it's not my subject'**.*



- Self-identification as not a “physics person”

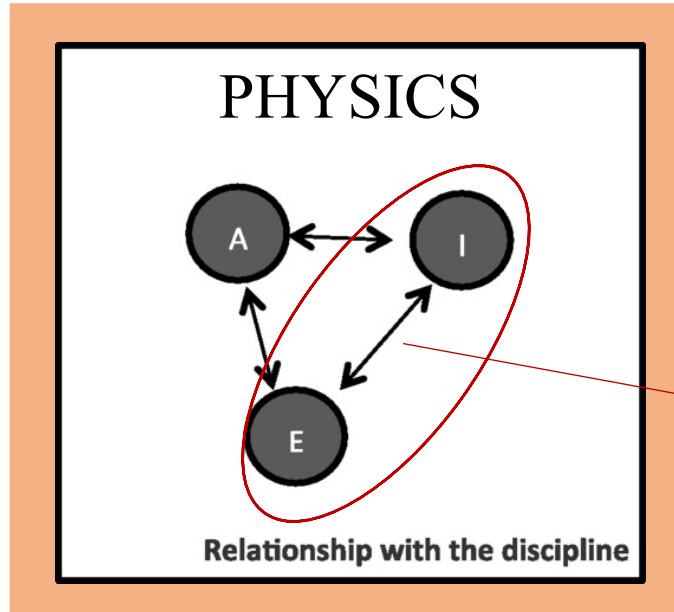
## Bryn's relationship with physics BEFORE IPLS

*I don't know why it's so hard for me to see a crossover [between physics and biology], but I wonder if it's because mechanics is so... that it's so... it's the ability of it to be simplified to the point that it becomes assumed... **When I think about mechanics, it's all like dropping apples and stuff.***



- Physics applies to phenomena that are “obvious” or not in need of explanation; not exciting

# Bryn's relationship with physics BEFORE IPLS



*[During traditional mechanics] I started being obsessed with everything that had friction, like when I moved my chair, or when I went home and I had to drive on an angled ramp, that is what I was like thinking about. **The integration with biology is not as obvious, but... [physics is] definitely applicable in life, and I just haven't found the crossover [between physics and biology].***

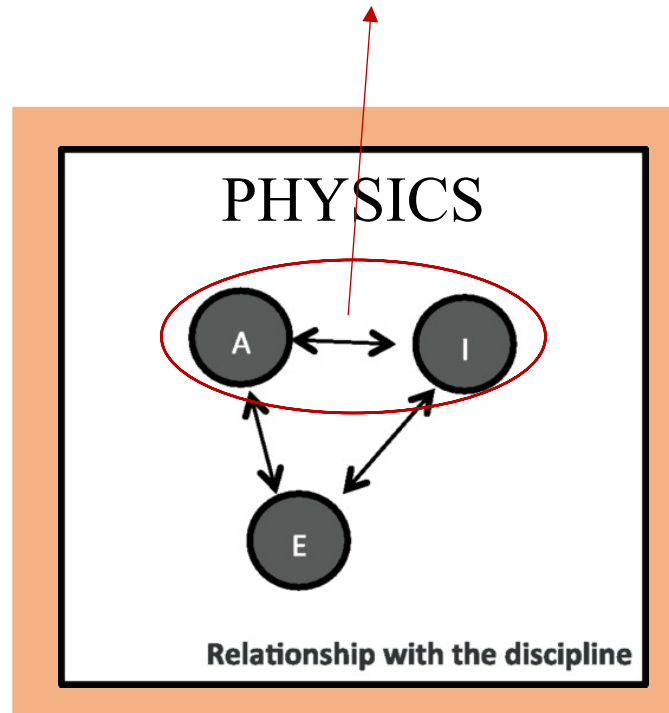
- Physics shows up in the everyday world, but not meaningfully in biology.





## Bryn's relationship with physics AFTER IPLS

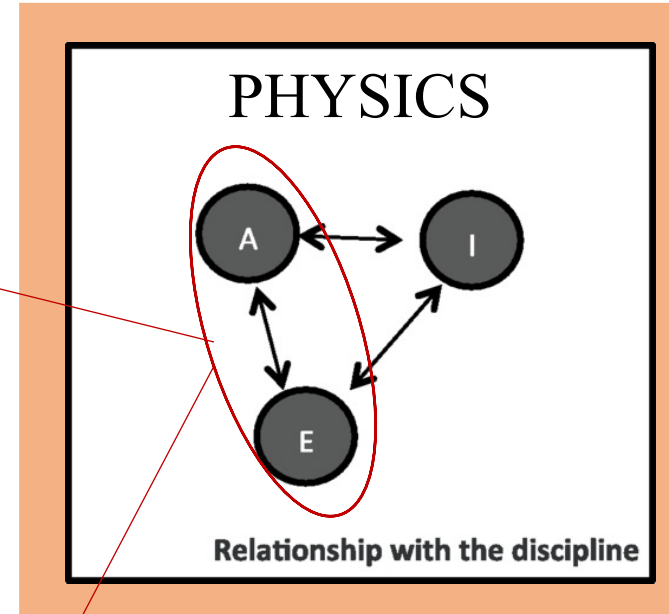
*Because for the first time something that I've always been like, 'eh, not my thing,' or 'that makes no sense,' or 'I don't speak physics,' now... I can re-think those statements. **I think for the first time, it has become something that I can, with basic understanding –I now have enough knowledge to apply toward something I'm really interested in. And I think that's exciting.***



- Greater self efficacy around physics

## Bryn's relationship with physics AFTER IPLS

*So, I thought that was just really cool... to think about the same thing that I had previously been like, this is a fact, and I know this just because, and... here there's actually like, **there's a more, like another way of explaining it, if not a deeper way... this is an actually really useful way of thinking about biology.***



- Physics provides explanatory coherence

Geller et al. (2018)

*I find it most satisfying when I can look at one thing that I previously saw through one angle, and look at it through a slightly different angle but still connect... like they intersect... **they're different perspectives of looking at the same thing.***


But what is *most* salient in the post-IPLS Bryn interview is her sense of:  
**AGENCY** and **OWNERSHIP**

*But then now, with taking a seminar and taking this like, um, this like physics applications, I found I didn't just apply physics concepts from that course but also just physics in general, what I had previously learned... and brought it to class, brought it to my (cell biology) professor and said like, This is something interesting I learned today, and I'm just going to tell you about it.*

*It's a very exciting feeling... when I took my cell bio seminar, I was asking [the cell bio professor] about like 'there has to be some underlying reason this looks this way'... the physics side of the processes that we studied became more apparent, and I was like, starting to ask more of those questions. And I think that was also really exciting... because I was able to...because I had internalized that physics can be applied, and then started to think in those... Not to say that necessarily that I'm more versed in physics, that I can explain everything, but I have now the tools and a bit of the foundational knowledge to explain things. So that, I think, makes it very exciting.*

But what is *most* salient in the post-IPLS Bryn interview is her sense of:  
**AGENCY** and **OWNERSHIP**

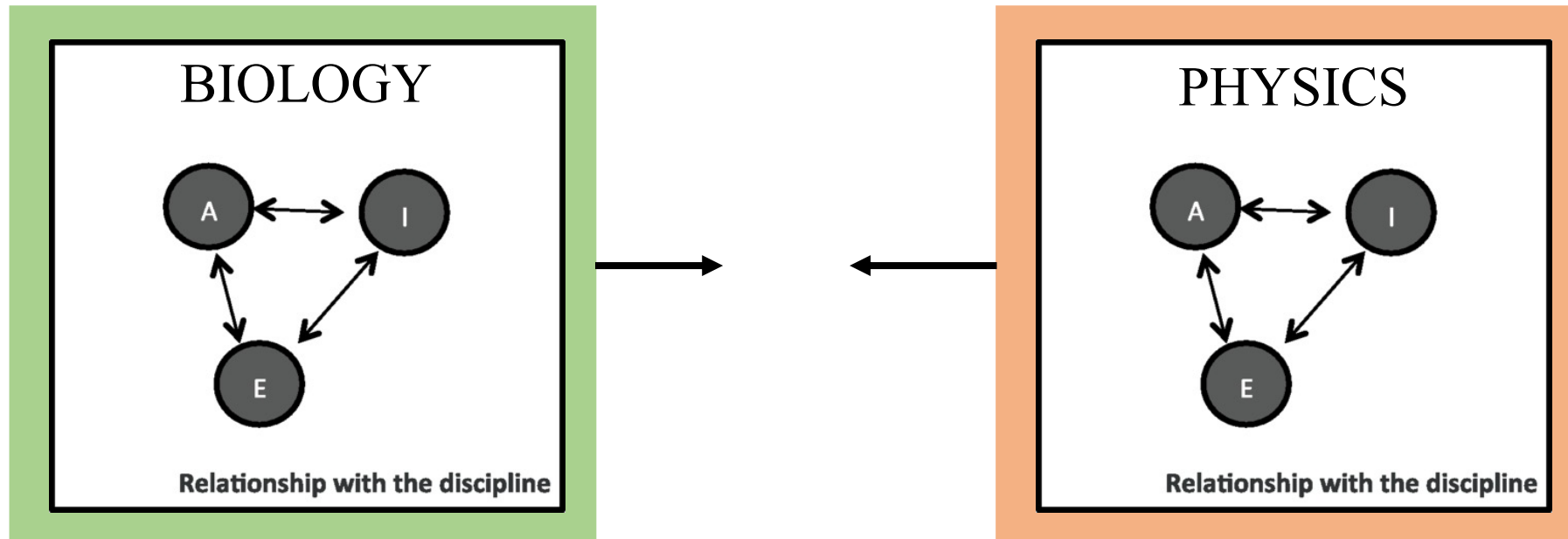
*So [in my cell biology seminar] we studied how organs essentially [do this thing called looping]... And my question was more of like, looping in itself like has to have a certain momentum, a certain velocity for it to reach a correct position at a correct time. So I was like, 'whoa, instead of asking like, asking genetic or molecular [questions], or instead of being vague and saying like how does the loop know to go certain places, I'm starting to ask: Okay, there must be an underlying momentum, or attractive force, and the force draws it, like pulls it towards a certain direction, and that's why our heart works a certain way... None of these terms are like really inherently biological, and I was like ... I didn't even realize I was thinking that way until I walked out of class the other day, I was like... 'Wow. There's like a lot more physics involved in these processes that we say are cellular and developmental.. there's quite a bit of physics in what we don't know.*



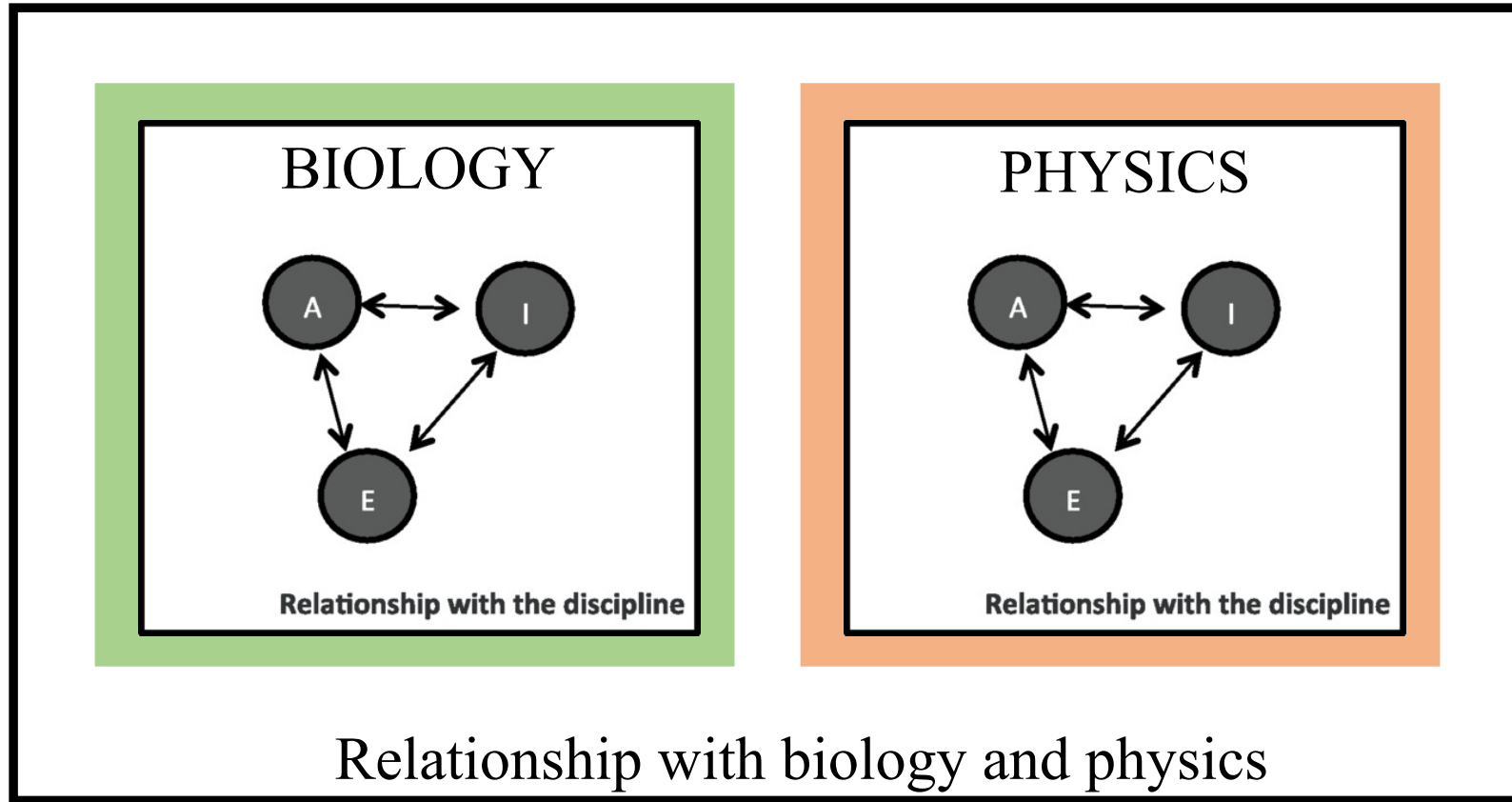
*The wonderful ideas I refer to need not look wonderful to the outside world. I see no difference in kind between wonderful ideas that many other people have already had, and wonderful ideas that nobody has yet happened upon... **In each case, new connections are being made among things already mastered.***

- Duckworth

Bryn's wonderful idea is about explanatory coherence, the idea that physics can in fact contribute to a more coherent picture of the biological world she cares so much about.



As the gap between Bryn's disciplinary relationships narrowed, Bryn's disciplinary identities, epistemologies, and affects became less siloed as well.



It became possible for Bryn to begin to articulate a relationship with both disciplines.



Did Bryn have a transformative experience?



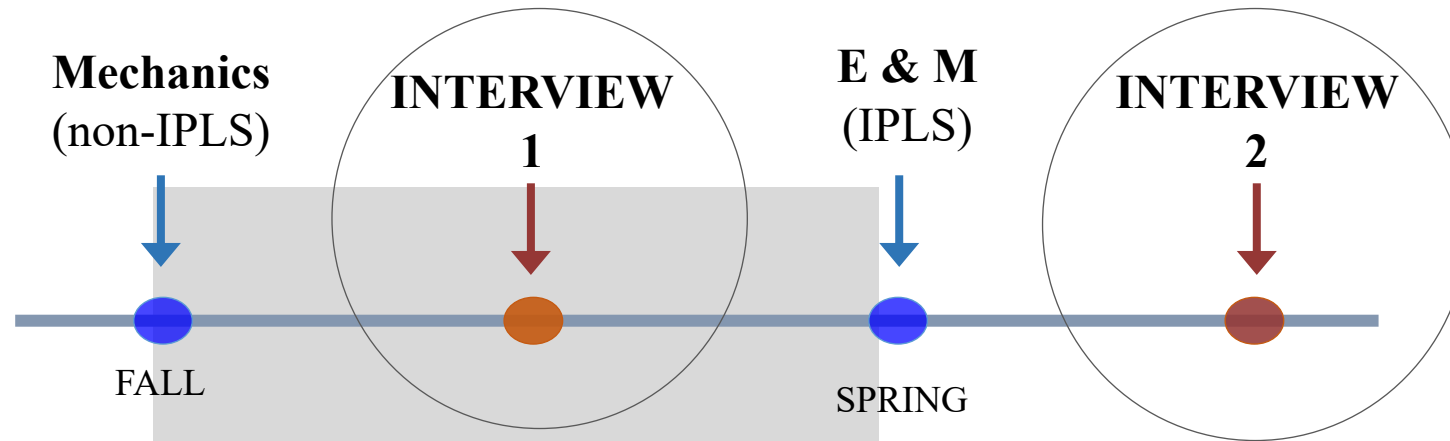
# Characteristics of Transformative Experience (Pugh 2010, 2017)

- **Motivated use:** students apply science content in their everyday experience without compulsion (BEHAVIORAL)
- **Expansion of perception:** students come to “re-see” the world through the lens of science content (COGNITIVE)
- **Experiential value:** students gain appreciation for parts of the world that are re-seen and value science content for its affordances in terms of such re-seeing (AFFECTIVE).

*The construct of transformative experience is unique in that it places particular emphasis on engagement that extends beyond the classroom.*

## Motivated use (behavioral):

### Bryn's Experience



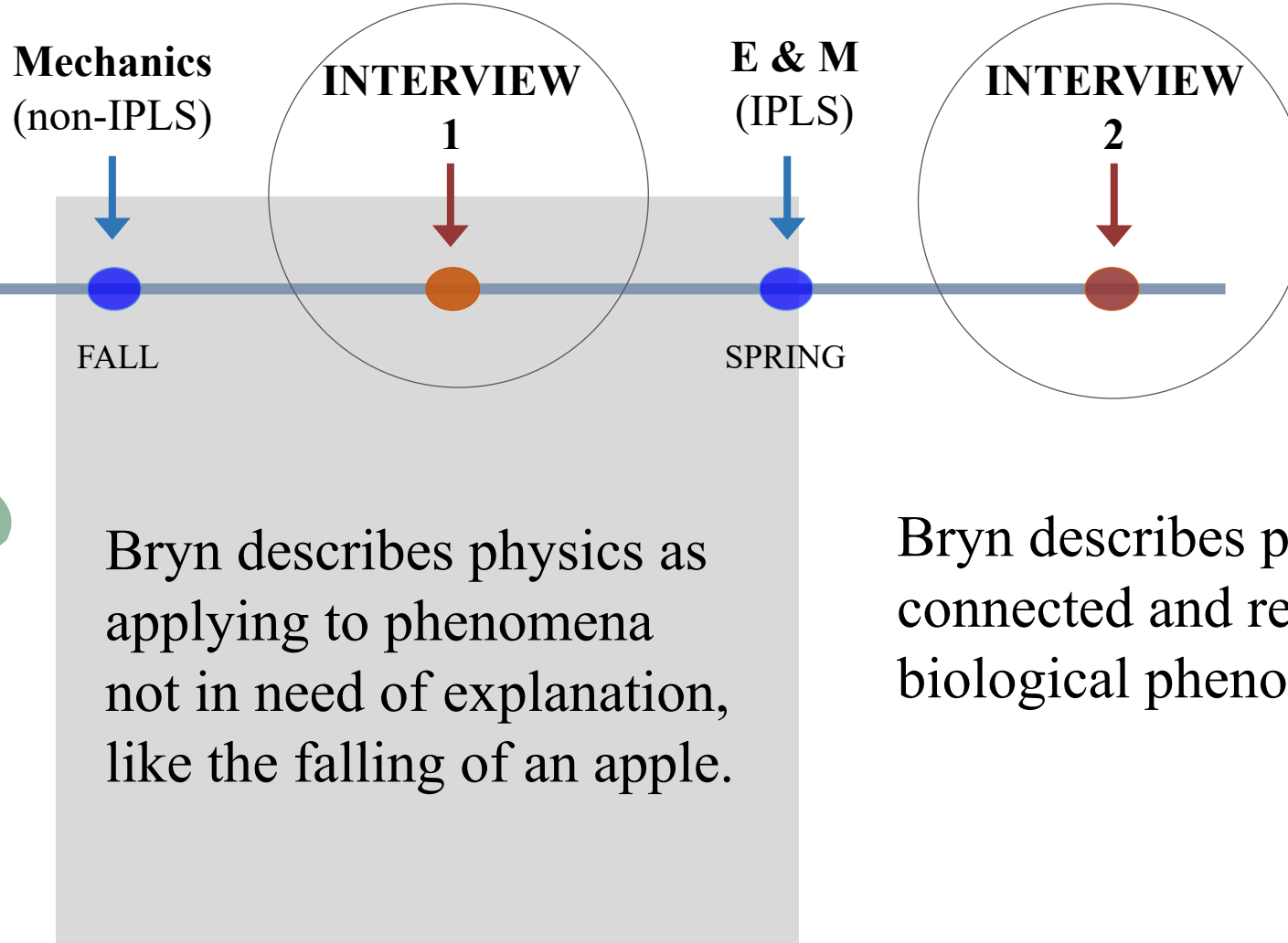
Although enrolled in cell biology (as she would be in the spring as well), Bryn is not motivated to bring up physics with her instructor.

Bryn repeatedly goes to her cell biology instructor (the same one as she had in the fall) and talks about physics. She finds herself motivated to look for mechanisms underlying biological phenomena, including mechanisms from mechanics.

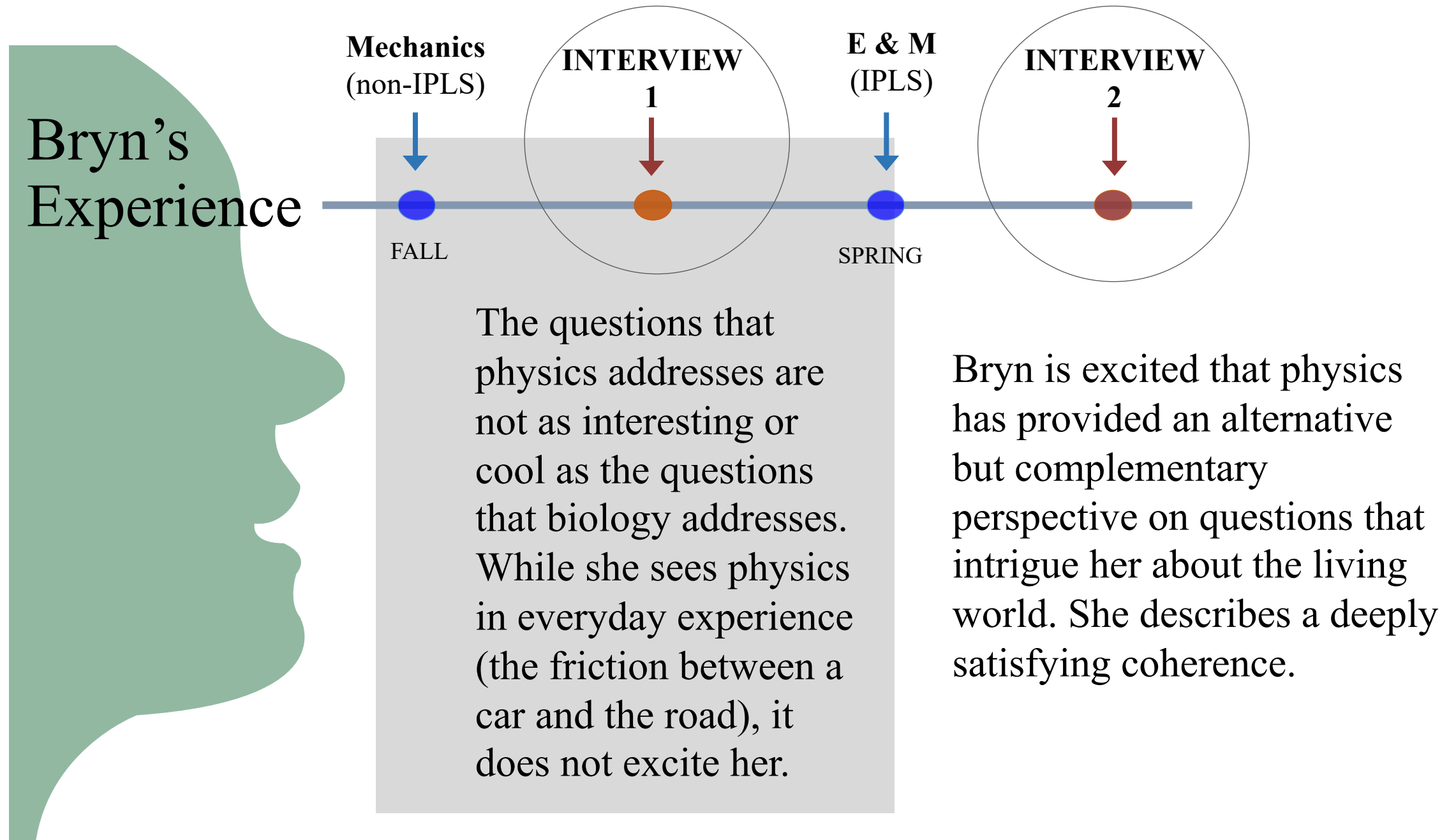
# Expansion of perception (cognitive):



Bryn's  
Experience



## Experiential value (affective):





# Did Bryn have a transformative experience?

Yes, via the evolution of her relationship with biology and physics.

This evolution was supported by:

- Authentic biological contexts at the heart of the IPLS curriculum
- Repeated coordination between biological phenomena, simple physical models, and the equations and graphs used to represent those simple models
- Explicit messaging about disciplinary coherence
- Bryn's maturity as a student and ownership of her studies

## Implications and Conclusions:

**Pugh's Transformative Experience Expanded:** Bryn meet's Pugh's criteria, provided that we expand the “everyday world” to also include students' experiences in areas of their *academic life* that have personal meaning to them.

- Most of our students make connections between the specific physics examples discussed in class and the manifestation of those specific examples in the “real world,” but few describe having a Bryn-like transformation.
- The importance of the “everyday world” makes sense in light of the Dewey/Pugh focus on younger children and the idea of liberal education, but for our IPLS population there seems to be another accessible type of transformation.

## Implications and Conclusions:

**Disciplinary Affect is Central to Bryn's Transformative Experience:** We distinguish “seeing the connections to everyday life or other disciplines” from “caring about these connections” (do these explanations or lenses add value/enhance the student's experiences in the world?)

- Prior to IPLS: Bryn sees connections between physics and everyday life, but there is not a sense that the physics enhances those everyday experiences.
- After IPLS: Bryn sees connections between physics and the biological world and values the lens that physics brings to the biological world.
- The *seeing* of connections between different disciplines is not itself transformative in the spirit of Pugh and Dewey. But, the excitement with which Bryn describes her newfound appreciation for physics suggests agency and comfort with the domain.

## Implications and Conclusions:

**Agency and Ownership:** The most salient feature of Bryn's post-IPLS interview, in comparison to other interviews we've conducted, is her sense of agency and ownership.

- Prior to IPLS: Bryn does not go to her cell biology instructor to discuss the role of physics in her field. In general, she feels less agency to use physics independently.
- After IPLS: Bryn excitedly, on her own initiative, goes to her cell biology instructor to describe how physics is relevant and important.
- Most significantly, Bryn recognizes the potential relevance of *mechanics* in a way that she did not during the traditional mechanics course. Although IPLS was in the context of E&M, she now sees connections between mechanics and biology that she did not appreciate before. She is moving beyond the particular examples from the course. She is connecting forward and backward.



Coherence is central to Dewey's conception of experiential learning.

*... To 'learn from experience' is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence...*

*... the measure of the value of an experience lies in the perception of relationships or continuities to which it leads up."*

John Dewey "Democracy and Education" (2004 Ed.; p. 133-134)

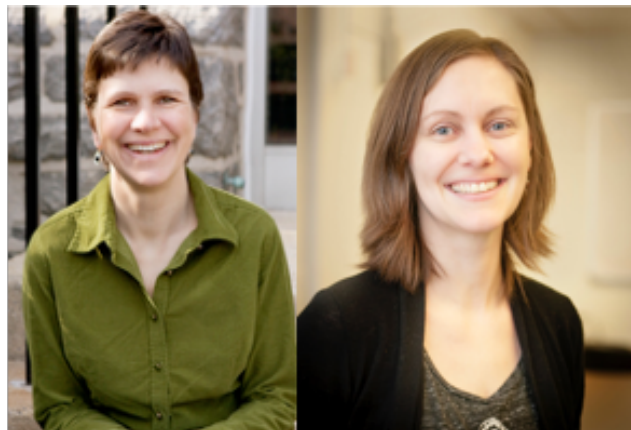
Thank you!



Katherine  
Lima '20



Tessa  
Williams '16



Catherine  
Crouch

Chandra  
Turpen

