Course design for an introductory course for Plant Biology

Aligning with Vision and Change

A. **Core Concepts**

1. EVOLUTION
2. STRUCTURE AND FUNCTION
3. INFORMATION FLOW, EXCHANGE, AND STORAGE
4. PATHWAYS AND TRANSFORMATIONS OF ENERGY AND MATTER
5. SYSTEMS

B. **Core competencies and disciplinary practices**

1. ABILITY TO APPLY THE PROCESS OF SCIENCE: Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.
2. ABILITY TO USE QUANTITATIVE REASONING: Biology relies on applications of quantitative analysis and mathematical reasoning.
3. ABILITY TO USE MODELING AND SIMULATION: Biology focuses on the study of complex systems.
4. ABILITY TO TAP INTO THE INTERDISCIPLINARY NATURE OF SCIENCE: Biology is an interdisciplinary science.
5. ABILITY TO COMMUNICATE AND COLLABORATE WITH OTHER DISCIPLINES: Biology is a collaborative scientific discipline.
6. ABILITY TO UNDERSTAND THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY: Biology is conducted in a societal context.

C. **Scientific skills**

1. Modeling
2. Data Analysis
3. Argumentation

Basic principles

- Unifying context – EVOLUTION - *integrating physiology within sections*
- Place based learning - KBS - pond scum - wintergreen lake -plant succession trail
- Inquiry based and outdoor learning- helps improve system learning skills

(1) Origin of plants - Wintergreen lake

- Construct a model to explain the role of endosymbiosis in the origin of plants
- Discuss the evolution of photosynthesis.
- Formulate a cost/benefit argument for physiological and behavioral traits in phytoplankton with respect to fitness and evaluate the consequences of 'decent with modification' of said physiological characteristics in extant organisms **– lesson based on this**
- Generate hypotheses to explain why the dominant form of photosynthetic pigment is green - using available literature formulate an argument to support your hypothesis.
- Identify and discuss evolutionary trade-offs for multicellularity and sexual reproduction

    - Endosymbiosis
    - Photosynthesis
    - Why is chlorophyll green
    - Multicellularity
    - Sex

(2) Emergence of land plants - Crooked lake and Lux arbor

- Construct an evolutionary cladogram that shows the extant plant groups and the gain/loss in synapomorphic physiological structures
- Evaluate the evolutionary tradeoffs in the water-land migration of plants with respect to Earth/Air /Fire Water and using examples explain the traits that would have increased fitness in the face of said challenges
- Construct a model that explains the flow of carbon and inorganic nutrients in a plant - your model should depict the major sources/sinks of carbon and the nutrients

    - Larger cells - gas vacuole - cellulose - give up motility - coastal algae
    - Challenges and benefits of moving to land - Deal with Earth (anchoring, nutrients) Air (lots of CO_2. drying out of cells) Fire (sunlight - lots of energy - bleaching of red and brown photosynthetic pigments) Water (lack of)
    - Adaptive features - cuticle (bryophytes), vascular system (ferns), seeds (gymnosperms), animal interactions (angiosperms)

(3) Plant ecology - Plant succession trail and Tomomi's plants in the greenhouse

- Compare different plant-plant interactions
- Analyse the changes in functional traits during community succession
- Evaluate how mutualisms benefit both plants and the organisms they interact with, and the trade-offs associated with said interaction.
- Compare and contrast different plant/animal interactions in the light of potential of speciation
- Using a pair of organisms that show coevolution - predict what the effect of changes in phenotype/population size of one could have on the other

Assessment and the end of this module

(4) Plants and society - Farms and dairy

- Document the dependence of society on plants and evaluate the role of artificial selection due to said dependence
- Select a crop plant (e.g., corn, rice, potato) and trace the evolutionary changes that occurred through human domestication of the wild relative.
- Assess ways that plants can mediate/exacerbate the challenges that global climate change will have for humans.
- Synthesise information about one ethical issue that has plants at its crux, develop an opinion and present an argument to support your opinion.

One day in class

Learning Objective: "Formulate a cost/benefit argument for physiological and behavioral traits in phytoplankton with respect to fitness and evaluate the consequences of 'decent with modification' of said physiological characteristics in extant organisms"

Using principles of problem based learning

1. **Introduction - Figuring out the problem(s)**

Imagine you are a phytoplankton, you are in the ocean - all you have to do is you have to get food, survive and reproduce. But even for you - life is not without challenges. Considering what you need in order to achieve your life goals - what are some of the challenges that you will have to overcome.

Work with your group to identify at least three

2. **Reporting problems**

Using the google form - submit the top three challenges that your group identified
List them and add others:

Food - light and nutrients
Buoyancy
Avoiding predation
Motility
Reproduction

3. **How can we fix that? - Identifying solutions**

Develop hypothesis in your groups to propose physiological or behavioral traits that might help address the challenges

   a. *Buoyancy*
      i. *Size - smaller is better*
      ii. *Shape - non spherical*
      iii. *oil/gas filled vacuoles*
      iv. *Protrusions*
      v. *Forming colonies*
   b. *Motility*
      i. *Ability to sink/rise*
      ii. *Structures that enable motility - flagella*
      iii. *Knowing when to move - sensory features*

c. *Avoiding predation*
    i. *Ornamentation*
    ii. *Multicellularity*
d. *Food - light and nutrients*
    i. *Light sensitivity*
    ii. *Motility - move lower to nutrient rich waters at night and higher to get the light during the day*
e. *Reproduction*
    i. *Ocean is homogeneous so mostly asexual*
    ii. *Sexual - survive foul environment or overcome functional limitations as in diatoms.*

4. **How does it actually work - class discussion**

Discuss actual adaptations that phytoplankton have that help them deal with these challenges using examples

5. **Construct an explanatory model**

Construct a consensus model in your group whose function is to explain the challenges phytoplankton face and the mechanisms they have evolved in order to face said challenges.

6. **Use model to make predictions about fitness - homework**

Remember that a trait that solves one problem could in fact worsen another - there are always tradeoffs. Evaluate the tradeoffs - consider the circumstances in which it might be beneficial to have a trait despite its cost.

- Generate two predictions to illustrate how adaptations that are beneficial in one sense can be costly in terms of fitness
- Construct a hypothesis based on one of your predictions.
- Design an experiment that could help you test your hypothesis.

Animals have toilets too!

Modified from : Chin, L., Moran, J. A. and Clarke, C. (2010), Trap geometry in three giant montane pitcher plant species from Borneo is a function of tree shrew body size. New Phytologist, 186: 461–470. doi:10.1111/j.1469-8137.2009.03166.x

Watch the video: https://www.youtube.com/watch?v=TwL7K_loRjM

Most pitcher plants (*Nepenthes*) are carnivorous, they attract insects and ants into the pitcher, where they are then digested by the juices present there.

In Borneo, it was recently discovered that some pitcher plants might be getting their nutrition from a novel source – shrew poop! The pitcher services both the ends of the GI tract – the shrews lick off nectar from the lid while the pitcher itself receives the feces (Figure 1).

Researchers have tried to characterize what differentiates the plants that get this unique ‘gift’ as compared to those that do not. They measured several physical attributes of 8 different pitcher species. They found feces of the shrew *Tupaia montana* in 3 of these species (*lowii, macrophylla and rajah*) but not in the other 5 (*burbidgeae, reinwardtiana, stenophylla, tentaculata* and *villosa*). Table 1 gives the values for the characteristics that they measured and figure 2 shows the location of these on the pitcher along with images of ‘the action’.

Figure 1: Mountain tree shrews (Tupaia montana), like this one, feed on the nectar coating the undersides of pitcher plant leaves. Conveniently, they can also defecate into the pitcher, leaving nitrogen-rich feces for the plant to consume

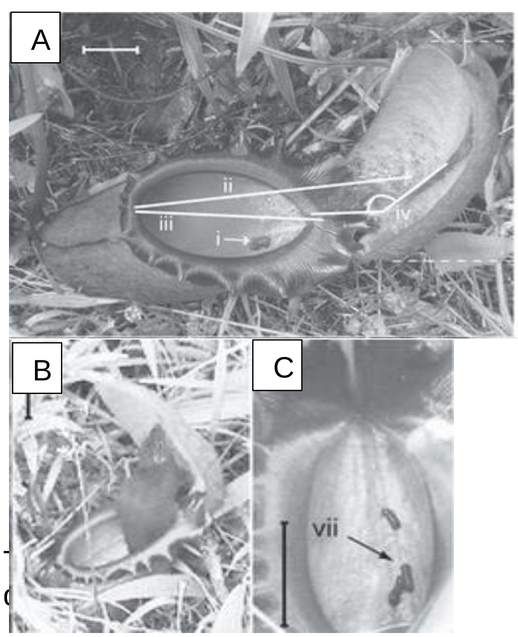
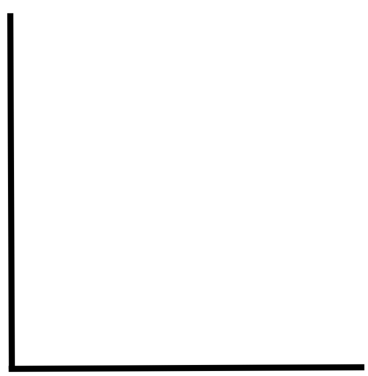
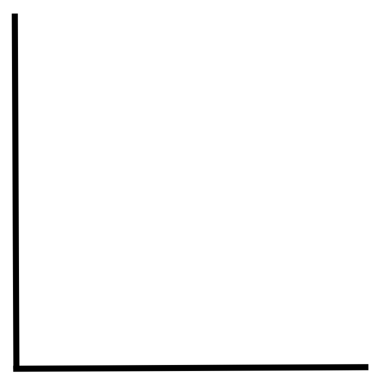


Figure 2: (A) *Nepenthes rajah* pitcher showing (i) *Tupaia montana* faeces on the inner surface, (ii) fmfs (front of the mouth to the food source), (iii) orifice depth, (iv) lid angle; (B) still image taken from a video recording, showing *T. montana* sitting astride the orifice of an *N. rajah* pitcher whilst it feeds on the secretions of the lid glands; note the position of the animal’s hindquarters and tail (inside the pitcher); (C) still image taken from a video recording, showing three *T. montana* faecal pellets on the inner surface of an *N. rajah* pitcher. The pellet labelled ‘vii’ was deposited by *T. montana* during a visit to this pitcher that occurred whilst this recording was being made. Scale bar on all images, 5 cm.

Pitcher characteristic	*Nepenthes* species							
	Tupaia montana **faeces-trapping species**			**'Typical' species**				
	lowii	*macrophylla*	*rajah*	*burbidgeae*	*reinwardtiana*	*stenophylla*	*tentaculata*	*villosa*
fmfs (mm)	176.9	196.3	177.3	75.4	57.8	64.8	42.5	74.6
Lid angle (deg)	107.1	103.5	83.3	56.6	56.6	57.9	78.7	50.7
fmfs – distance from front of the mouth to the food source.								

1. [6 points] In the space below construct 2 graphs that show the average measurements of 'fmfs' and lid angle for the 2 groups of Nepenthes species: faeces trapping vs typical. Write one concise legend for both the figures.





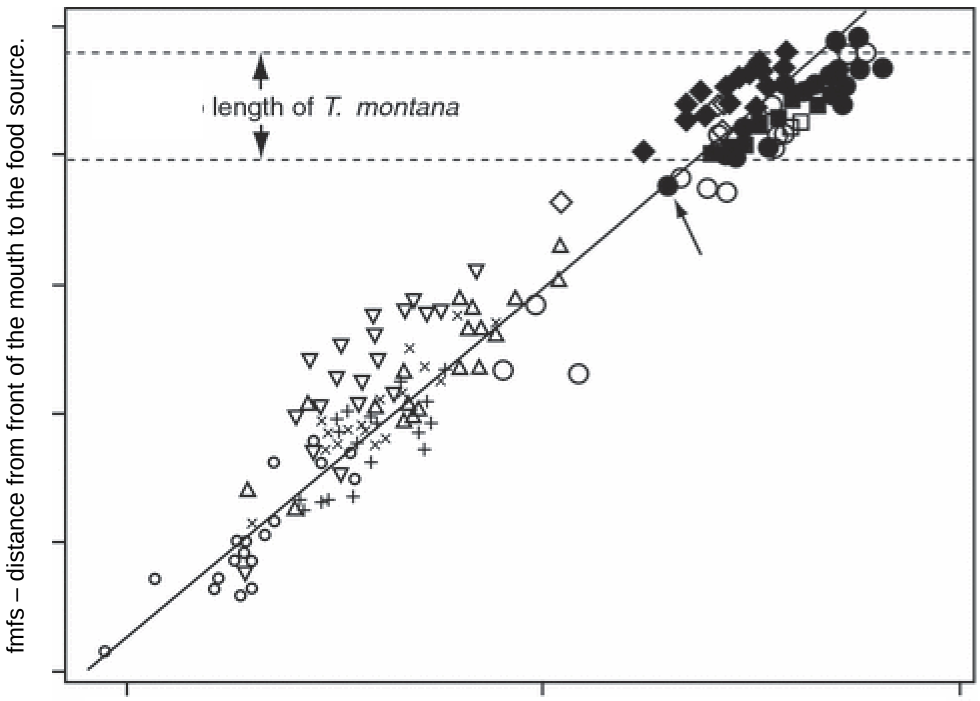


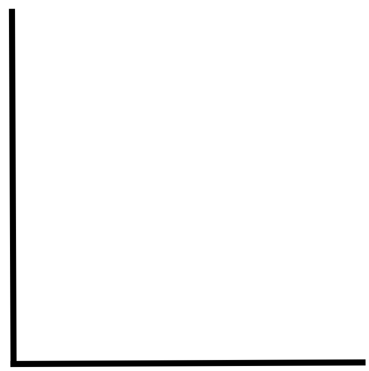
Figure 3: Regression of fmfs (front of the mouth to the food source) vs orifice depth and lid angle for the eight *Nepenthes* species studied. Closed symbols *for N. lowii, N. rajah* and *N. macrophylla* denote pitchers that trapped faeces

2. [4 points] Using figure 3, provide a coherent explanation to show why certain species of the pitcher plants are likely to be 'shrew toilets'. Your explanation has to refer to the evidence that links physical characteristics of both the plant and the shrew

3.[2 points]. List 2 more physical characteristics of the pitcher plant that you think would influence the probability of a 'visitation' followed by a 'deposit'

4.[2 points] Based on one characteristic that you chose, formulate a hypothesis that will explain the effect of variation in that characteristic on the probability of ‘getting a donation’.

5.[2 points] Sketch a simple graph to illustrate your hypothesis.



6. [4 points] With respect to the trait that you chose, discuss the evolutionary trade-offs that could influence the optimum measurement.

Assessment at the end of Plant Ecology Module

Question Number ⇒	1	2	3	4	5	6
Competency and skill ⇓						
ABILITY TO APPLY THE PROCESS OF SCIENCE		x	x	x		
ABILITY TO USE QUANTITATIVE REASONING	x					
ABILITY TO USE MODELING AND SIMULATION					x	
ABILITY TO TAP INTO THE INTERDISCIPLINARY NATURE OF SCIENCE						x
Modeling					x	
Data Analysis	x					
Argumentation		x	x	x		x