Supplemental Material CBE—Life Sciences Education

Hill et al.

Appendix A. The rubric provided to all TAs. Grey-shaded lines refer to items in which TAs might attend to students' scientific thinking.

Section	Criteria	Information	pts
Title	dependent variable	hornworm growth	2
	independent variable	dietary components (can be more specific with	2
	independent variable	regard to the component the group used)	2
	organism/sci name	tobacco hornworm (Manduca sexta)	2
	concise and clear		2
Introduction	broad background	what is the big picture context for this study?	5
	study system	general information about <i>Manduca</i> and secondary chemicals	5
	hypothesis and predictions		3
	citations	include several, relevant citations	2
Methods	study system	<i>Manduca sexta</i> - stage of development at which they're used. Rationale for why chosen for the study	3
	test compound	what was it and its final concentration in diet	3
	prep of diet	how was it prepared, solidified, cut up, and distributed	3
	growth determination	measuring of weight and intervals at which weight is determined	3
	data analysis	# of replicates, determination of RGR or % weight gain, stat. tests used	4
	past tense	should be written in past tense	2
	concise and clear	not too detailed	2
Written results	General statement of trends	describe major trends in relation to treatments	3
	refers to figure	parenthetical	2
	stats	stat. values (p, df, t) in Pechenik form included to support statements	3
	data	averages, st. devs, percents - some numerical data included	2
	no interpretation	this comes later - in the discussion	2
Figures and tables	Figure 1 - RGR	The figure should show the means +/- the std. dev of the RGR	5
	legend/caption	study system and question asked, sample size, etc.	4
	labels	variables, units, graph clear and easy to read	4
Discussion	one sentence summary		3
	relate results to hypothesis	what was found; was or was not what expected	5
	discuss implications	interprets results in context of results from other lab groups and in context of literature	5
	alternative hypothesis	possible sources of error, etc (should focus on biology not on trivial issues like sample size)	3
	future directions	future direction is interesting new angle, not just repeating experiment with a small change	4
Acknowledgments			1
Literature cited		alphabetical order, indented, correct format. At least 6 sources, at least 3 primary	5
Overall	Clarity/concise		3
	Spelling/grammar/format		3

Appendix B. Excerpts from Micky's lab report, Abby's margin comments and interview comments. [Line numbers] refer to location of comment in the interview transcript and follow a chronological order.

Excerpt of marked report	Margin comments	Interview comments
1. Nitrogen is one of the most important elements for life because it is a derivative of amino acids, which build together to make proteins. Plants absorbanitrogen from the soil and thus contain a large amount of the element (Wagner, 2012). Insects consumer plants to source this essential element for their own needs.	Not a large amount much less than animals	Plants contain less nitrogen than animals [line 613-616] "She makes a factual mistake" "Plants actually contain considerably less nitrogen than animals do" Experiment has nothing to do with nitrogen [line 618-619] "Her whole experiment has nothing to do with nitrogen" Student is confused about nitrogen [line 622-623] "nitrogen is not the independent variable. But we had talked about nitrogen in the pre-lab, which is maybe people decided it was important to their experiment when it wasn't"
2. This predator-prey relationship has created a pattern of co-evolution between plants and herbivores for millions of years. Plants have evolutionary developed mechanisms to protect themselves from consumption such as secondary chemicals. These special chemicals include phenolics, such as phenolic glycoside (also known as salicin), and alkaloids, such as nicotine (Orians, 2013). Phenolics are the most diverse group of secondary metabolites. Specifically, salicin is present in woody plants and may be toxic to insects. Nicotine, an alkaloid, is a natural insecticide. The inducible aspect of this biochemical decreases the amount of secondary metabolites that a plant must synthesize, thus conserving energy efficiently and <u>also makes</u> <u>evolution of the herbivores more difficult</u> (Mckey, 1974).	I'm not entirely clear what you are saying here	Lack of logic between facts listed in introduction [line 624- 631] "there's no coherency or, um, point or, there's not even, like, an internal logic or flow between them" Introduction is a list of facts – some true, some not [line 624, 634] "this introduction is, like, a list of facts which are mostly true, some of them are not true," "like, I know these facts and I need to write a paper, and it has something to do with this topic, so I'm just going to list a bunch of facts that I know about this topic and that will be an introduction.

3. These defensive tactics have		Can't work out the meaning of this
seen offensive metabolism		call t work out the meaning of this
mechanisms on behalf of the		6261
insects. Some insects, for		"I don't know what that
example the tobacco hornworm		sentence means"
Manduca sexta, have gained		Points out more facts with a lack
resistance to secondary		of logical structure [line 638]
compounds but have also been		"So, more facts, also not
able to use the plant's defensive		presented in a very coherent
compounds for their own benefit		logical structure"
(WI01118,1983).		
4. The tobacco' hornworm Manduca sexta		Students approach to intro [line
and the tobacco plant are a classic		644-650]
example of a plant-insect co-evolution		I sometimes think that my
plants contain alkaloid nicotine a		introduction is like a grade
chemical toxic to some insects		school report "
Homworms have developed a mechanism	I like that you've taken	"so they just write everything
to digest nicotine and are even able to use	a wide angle view to	about penguins and there's not
in for their own defensive function such	your experiment, and	nurnose to it "
as preventing spider attacks (Kumar et al	trying to set up the	"any fact is equally good as
2014). Recent studies indicate that the	context. Remember that	any other fact in that
physiology in the digestive and nervous	everything in your intro	assignment"
system allow the caterpillars to reduce	should be pointing	"But they don't realize that the
their susceptibility of the nicotine, but the	toward your hypothesis.	introduction for a lab report is
exact mechanism is yet to be identified		different in that facts that
(Kumar, Pandit, Steppuhn and Baldwin,		you're giving me should be in
2014). It is important to note that the		service of the hypothesis and
phenolic chemical, salicin, is not part of		of the experiment that you're
the tobacco hornworm's natural diet.		going to be doing."
5. An experiment was designed and		Attempts to follow style by
performed in order to demonstrate the use		starting broad [line 658]
of secondary chemicals, specifically		"she did try to start with the
nicotine (inducible) and salicin, and		broader context and then get to
observe the resulting effects on the	higger then what? then	ner experiment
growth of tobacco hornworth Manduca	orternillers fod plain	Line 661 6711
be highly correlated with reproductive	food? Keen in mind	"It's not grammatically
fitness thus it has been determined that	that there is no plain	incorrect but it's not correct
anything that limits growth also limits	food treatment group in	Like she's not using language
fitness (Reynolds 1986). Since nicotine is	vour experiment so	in a precise way"
a source high in nitrogen and many	you're not going to be	Confusion [line 669]
insects have evolved to acquire	able to make that	"I just feel confused the whole
mechanisms to metabolize alkaloids	comparison. Also, are	time that I'm reading the paper
biochemicals, it could be predicted that	you saying that you	when a person writes like this"
not only will the caterpillars be able to	think caterpillars fed	*Interviewer cue* [line 672]
consume nicotine, but also they might	the nicotine diet will do	"What do you think she's
become significantly bigger due to the	better than control	trying to say?"
high nitrogen content of the metabolite	caterpillars?	Attempts to decipher [line 673]
(wagner, 2012).		"I think she's trying to say that
		the experiment was designed in
		different secondary chamical
		on the esternillers "
		on the caterphilars.

	Figures out why Micky focuses on nitrogen [line 695] "(<i>reading</i>) 'due to the high nitrogen content' Okay, this is why she was talking about nitrogen"
6. Salicin is included in the group of biochemicals with more variety and can be toxic to insects. This variety <u>would</u> <u>cause a barrier to evolution of insects to</u> <u>be able to survive the toxicity</u> . It could be postulated that the salicin would cause the caterpillars to not grow as large as the caterpillars on a nicotine diet. In conclusion, it is predicted that less growth will occur with the newly introduced chemical salicin, when compared with that of the natural diet, nicotine (inducible).	Not sure about meaning of sentence (underlined) [line 699] "I'm really still not really sure what that sentence means"Attempt to make sense of the sentence [lines 701-705] "If I had to guess what she was saying,"Reasonable hypothesis [line 706] "So that is a reasonable hypothesis"Hypothesis "Interaction of the sentence [line 709] "The part that I found to be not reasonable [line 709] "The part that I found to be not reasonable was when she said it could be predicted that not only will the caterpillars be able to consume nicotine, but they might also become significantly bigger due to the high nitrogen content of the metabolite"Maybe confusing ability to metabolize with preference for given diet [line 718-724] "she's confusing the ability to be okay with a chemically as actually liking it and choosing nicotine or preferring a nicotine diet over just a control diet."Consider prediction made [lines 728-732] "She's predicting [she's] not going to be able to make that comparison."

Appendix C. Excerpts from Nora's lab report, Ed's margin comments and interview comments. Line numbers refer to location of comment in the interview transcript and follow a chronological order.

Excerpt of marked report Margin comments Interview comments 1. The effects of nutrients inefficiency caused by the existence of cellulose in diet on the growth of herbivores, Manduca sexta. Idiosyncratic phrasing [line 484-486] ************************************	_			- ·
 1. The effects of nutrients inefficiency caused by the existence of cellulose in dict on the growth of herbivores, <i>Manduca sexta</i>. 2. In this lab, we used <i>Manduca sexta</i>, commonly known as tobacco hornworms, used to be the object of the study. The larvae feed on the foliage of tobacco and related plants as the main resource of nutrients intake. <i>Manduca sexta</i> has relatively short life cycle, which can make the lab efficient and convenient. Also, the caterpillars' size and fitness are highly depended on the dict for <i>Manduca sexta</i>, which can make the results physically easy to observe. 3. Controlled and experimental diets were prepared from two pre-weighed beakers with different treatments in the hot bath: one contained mainly wheat germ without cellulose was the control dict, and one contained high concontation of cellulose: The transmet and tabeled streit pert dish separately, smoothed by the statual as daide uncovered 3. Controlled and experimental diets were maintained to be the same. Each treatment was pourced into a labeled streit pert dish separately, smoothed by the statual tab disk ducar with a statual and a tabeled streit pert dish separately, smoothed by the statual and a tabeled streit perti dish separately, smoothed by the statual and at a disk our or distingt the statual and at a disk our or distingt the statual and tabeled streit perti dish separately, smoothed by the statual and at a disk our or distingt the statual and at a disk our or distingt the statual and a statual and tabeled streit perticition a labeled streament at advise uncovered streament at a side uncovered streament and tabeled streament without cellulose mate a disk our or distingt the statual and at a statual work of the statual and at a statual work of the statual statue and the statual and statue and the statue statue the statue statue the statue statue the statue statue and the statue statue the statue statue the statue statue statue thabed statue and the statue statue the statue statue s	Ex	cerpt of marked report	Margin comments	Interview comments
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sterile petri dish separately, smoothed by the spatula, and set aside uncovered		treatment was poured into a labeled	were the caternillars	instead of wheat germ
by the spatula, and set aside uncovered know the concentration you		sterile petri dish separately smoothed	at?	Others I point out need to
		by the spatula and set aside uncovered		know the concentration you
for an hour to cool down into solid		for an hour to cool down into solid		used if they're going to test or
Meanwhile 10 caternillars of Manduca		Meanwhile 10 caternillars of Manduca		replicate your results"

	sexta were separately weighed and put		Missing information about growth
	into 10 plastic cups with labels of their		instar [line 576]
	treatment and number. After the diets		"She didn't mention second
	in petri dishes cooled into solid, diets		instar of growth, so I pointed
	were cut into few pieces and put into		that out"
	the cups with the caterpillar in it		
	depending on different treatments.		
4.	the cups with the caterpillar in it depending on different treatments. The results of the lab above indicates that the hypothesis, the growth of herbivores decreases as the amount of cellulose increases in the plant, is accepted. Caterpillars fed by diet with less cellulose had both means of Relative Growth Rate and % weight gain higher than the caterpillars fed by high cellulose diet did, which means that caterpillars with less cellulose intake grew better in terms of fitness and size than caterpillars with more cellulose intake. The performance of t- test of two means after 1 week reduced the possibility that the difference was caused by chance. Since the only difference between the controlled and experimental treatments was the absence or the existence of the cellulose in the diet, it can be said that the existence of cellulose in the diet affects herbivores' growth and performance significantly. In other words, increasing the concentration of cellulose in plant itself can avoid much damage from the herbivores as one of the efficient plant defenses.	Possible sources of error?	Null hypothesis identified [line 616-617] "Your hypothesis, not the null hypothesis, but you made clear which hypothesis you were talking about, so fine" Size correlates with fitness [line 620-621] "In terms of size which correlates with fitness, but she mentioned that in her methods section when she was talking about why you use <i>Manduca</i> <i>sexta</i> " Misunderstanding of t-test or poor phrasing [623-628] "That, again, is something where I don't know if she misunderstands the purpose of the t-test or just phrased it poorly. Because performing the t-test doesn't reduce the possibility your results were caused by chance, it quantifies the possibility that your results were caused by chance. That's an important distinction, but, you know I don't generally make line edits on [this student's] paper because there would just be so many of them that I don't think it would be useful" Understanding the meaning of what is written: either phrased poorly or poor understanding [line 629-636] "as long as I can understand what she's saying, I generally just let it go. I think this would have been a good time to, actually, bring it to her attention, being, like, 'make sure you know what you're saying here, because what
			you re saying is not correct
			and it may have not been what

		you meant – you may have
		meant the thing that is correct
		or you may not have, but I
		can't tell. So I should have
		called attention to that, I
		think, but I didn't because I'm
		not in the habit of making line
		edits on her papers. So I think
		maybe I'm not making like
		edits when they could really
		be useful on her papers."
		Thinks caterpillars may eat more
		to compensate for low nutritional
		value [line 638-640]
		"I'm not so sure about that
		because it's also possible
		they'll eat more to
		compensate for the low
		nutritional value, as I think I
		mention in her summary"
5. As one of the defense mechanisms of		Knows Nora understands
the plant, cellulose is also a necessary		difference between secondary
structure of the plant: it exists in the		compounds and cellulose [642-
plant even there isn't any external		645]
invasion. This indicates that like many		"Good. I'm glad it was
other secondary chemicals, cellulose is		clear before that she knew it
also inducible. Further experiment can		wasn't like any other
focus on different situations that might		secondary compounds in here.
induce the increase or decrease of		She is, in fact, saving that its
cellulose in the plant, and how does the		primary purpose in here is
plant "know" that it's under attack by		structural so I'm glad that she
external environment.		understands that"
		Misunderstanding of 'inducible'
	Really? Do plants	[line 648-650]
	produce more	"Because I could tell here.
	cellulose when	that inducible did not mean
	attacked?	what she thinks it meant.
		Because otherwise, she
	Interesting ideas –	exactly contradicted her last
	give some more	sentence"
	detail!	Disagrees with idea that plants can
		regulate cellulose levels [654-659]
		"maybe she thinks plants can
		regulate their cellulose
		content, which I am pretty
		sure is not true. Um. but.
		doing this future direction
		would illustrate the fact that
		no, they don't dynamically
		alter their cellulose content
		and I don't know for sure that
		they don't but I don't think
		that they do so I did not make
		a big deal out of this. And
		a org ucar out or uns. Anu

I'm sure that somewhere in nature there's a plant that can
alter its cellulose
concentration of its tissues
and, like, does so regularly,"