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PCB 4673 Answering Essay Questions

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General Points

In my courses I emphasize essay answers to examination questions. Some questions are designed for very short answers and others for longer, more complex answers. The questions range in scope and complexity, which is why different questions require answers of different length. Regardless of this variation in length, all of the questions are really "short-answer essay questions" because no single question requires you to write for 2-3 hours.

Writing an effective short answer is a learned skill. By "effective" I mean an answer that is correct and that is succinct. The "succinct" attribute is important for two reasons. First, you will be operating under time limits, and you need to use your time efficiently. Second, succinct answers are easier to understand and interpret, and you are more likely to get the credit you deserve with a succinct answer. Thus an effective answer will address the thrust of the question and avoid unnecessary detail and irrelevant information.

An effective answer will not do the following:

- restate the question (which wastes time)
- list everything that could conceivably be relevant to the question (which not only wastes time but suggests to the grader that you can't distinguish relevant from irrelevant information)
- place potentially useful statements of fact in random order (which forces the grader to attempt to discern your logic, usually to your detriment)
- use vague or very general sentences (which forces the grader to guess what you really meant to write)

An effective answer will do the following:

- state the major point as the first sentence (which declares an immediate focus for your answer and inspires confidence in the grader that you know what you are doing as you answer the question)
- organize supportive or explanatory material to follow the major point (which helps the grader understand your logic and the intent of your answer)
- use specific terms and careful language (which helps minimize ambiguity so that the grader does not misinterpret the meaning of the answer)

Effective answers need not be long; indeed, long answers are often bad answers. A common flaw in essay answers is the writer's inability to communicate the crucial point or, stated differently, separate the facts from their significance. Science is not a collection of dusty facts (or acetone-smeared facts or adjectival

facts of any sort) but a process of critical reasoning, careful experimentation, and insightful integration of apparently unrelated information into a synthetic hypothesis to explain natural phenomena. The essay questions require you to perform the first and third of these elements on this small scale.

On the following pages, I offer four examples of different types of essay questions. Each example uses an actual question that I've employed in one of my courses and includes a short analysis of the question so that you can appreciate it drawn, as they are here, out of context from the course. For three of the four examples I present genuine answers of varying quality; by "genuine" I mean answers that were actually written by students on a quiz or examination that used that question. For each answer I offer some diagnostic analysis of its quality.

Example 1: A straightforward regurgitation question

Let's look first at a straightforward question that I use in PCB 4673 (Evolution) and analyze why some of the answers are good ones and others not.

Question. Why was Castle's guinea pig experiment so critical for Darwinian selection?

Note. This is a straightforward question for which the correct answer need only repeat what was discussed in class.

Good answer. Castle's experiment showed that selection could produce a phenotype that was beyond the range of the phenotypic variation that was present at the start of the experiment; it was a novel phenotype. Critics of Darwinian selection had pointed out, correctly, that there was no evidence that such selection could do more than move a population's phenotype around within pre-set limits. Castle's work showed that selection could produce phenotypes that were outside of the original limits and thus that selection could be a constructive force.

Analysis. The writer states first what Castle's experiment showed. She then points out why Darwinian selection was not being accepted as a useful mechanism for evolution, and follows this statement by reiterating the result of Castle's work in those terms. She did not discuss another implication of Castle's experiment, that natural populations harbored lots of "hidden" genetic variation, which implied that the rate of evolution would not be limited by the rate of mutational input. Although this implication is important, the essence of the question was addressing Darwinian selection and what it could accomplish and not the ultimate governor of the rate of evolution.

Bad answer. Castle's experiment was critical for Darwinian selection. Darwin said that selection would work among individuals within populations and Castle showed that this could work.

Analysis. The writer first re-states the question; if doing so helps you focus, that's fine, but the writer appears to have mistaken restating the question for a good topic sentence or a good opening claim. The rest of the answer includes two true statements, that Darwin said . . . and that Castle showed . . . , but of course others had shown that selection could work within populations (indeed, Darwin himself

knew this from agronomic records) and that the process could work was not at issue. The contentious issue was its effectiveness. Now the writer might claim that this is what he meant of course, but the answer doesn't say that, and the graders shouldn't be expected to be mind readers.

Mediocre answer. Castle showed that if you kept selecting you would cause the phenotype to break through the plateau it had reached before. Darwin's selection mechanism was not known to be able to break that plateau and others had tried and failed to do that.

Analysis. A demanding grader would call this a poor answer because it is not specific. There is no clear description of what "the plateau" is and no clear, unambiguous interpretation of the phrase "it had reached before." Before what? Before when? Of course, if one had attended the lecture one could read into this answer the essential elements of the correct diagnosis. We know that the "plateau" refers to the point at which no further phenotypic change was obtained and that the location of that "plateau" was usually at the extreme of the original phenotypic range. But without that knowledge the answer is vague; the student is asking for the grader's indulgence and a bit of "reading between the lines" in order to get full credit. A grader in a good mood, early in the semester, might let this vagueness be acceptable, but do you really want your grade to depend on my mood?

Example 2: A question that allows you to choose what to regurgitate

Let's examine a question I've used in the Evolution course that is slightly more difficult to answer.

Question. Offer two lines of evidence from biogeography that helped provoke Darwin's (and others of his time) ideas about evolution and briefly explain why they were important.

Note. In the lecture I discuss several biogeographic patterns that provoked Darwin and many of his contemporaries to wonder about the idea that the earth's features (physiography, flora, and fauna) were static. This question asks the student to recall two out of those several patterns; any two of them will suffice if the student can also recall correctly the significance of each pattern. The answer is a regurgitation of lecture material, but in this case there are some options about what to regurgitate.

Good answer. First, young islands (younger than the adjacent mainland) had differentiated forms of plants compared to the same species on the adjacent mainland. The differential ages of the two locations would rule out a single creation event so there would have to be either multiple creations, a serious flaw in understanding ages of land masses, or some type of evolution. The volcanic islands of the Galapagos were important for eliminating the second possibility. Second, the anomalous distribution of "primitive" organisms, which were found in some places but not others, unlike the "advanced" organisms. These were awfully odd and idiosyncratic patterns of placement for a single creation and there were not traces of differential extinction that would explain it.

Analysis. The student set out two clear lines of evidence, using "first" and

"second" so that there was no doubt as to where one idea ended and the next began. The student then stated why each line of evidence was important. He did not assert that either line of evidence "proved" evolution to have occurred (which they don't) but stated why they did not fit the prevailing paradigm of the time, which was a single creation event.

Bad answer. Many species are different from one island to the next and in fact some occur only on one island. When an island is younger than another one and many animals are different then they must have evolved on one or more of them. Skunk cabbage is found only in two very different places and this means it had to have evolved twice and not once in any single creation.

Analysis. This answer has a lot of problems. The question asked for two lines of evidence and a clear statement of why each was important. I count four lines of evidence (two in the first sentence) and there is no clear demarcation of where one line ends and another begins. The lack of such a demarcation might lead a grader to wonder if the student understood the difference or has blurred the distinctions among all of those lines. Let's move on to another part of the answer: in no case can one unequivocally conclude that ". . . this means it had to have evolved . . ." because these patterns alone are not proof of anything. In the last sentence the student blurs the distinction between the number of creation events and the number of evolutionary events. Finally, there is no mention of the fact that skunk cabbage is a "primitive" plant, which is vital to the argument. Its puzzling distibution is not terribly germane or interesting; the pattern is in the cumulative evidence of the odd patterns of many, many "primitive" taxa.

Example 3: A question whose answer is regurgitation but that requires some thought about what, precisely, is to be regurgitated

This example is drawn from the Evolution course (PCB 4673); as in the preceding questions, the answers I've reproduced here are real ones offered by students in the past.

Question. Explain the meaning of the statement "natural selection is not evolution."

Note. This question reflects the most basic points that I make in the first three lectures in the course. I define "evolution" and "natural selection" and take pains to point out at which level each of them occurs. Many students enter the course with the idea that "natural selection" and "evolution" are synonymous, which they are not, and I consider it vitally important to disabuse them of this idea at the start of the course. The dilemma many students encounter in answering this question is that they are not entirely sure why natural selection is not evolution. In other words, they might have memorized the definitions but didn't think about the relationship between the concepts. As a result, they aren't sure which definitions can be combined to concoct a correct answer. The key to a correct answer is to appreciate the definitions and the relationships among the concepts that they describe.

Good answer. Evolution is a process of descent with modification at the level of the biological population; selection is one of several mechanisms that produce

evolution.

Good answer. Evolution is a genetic phenomenon and selection is a phenotypic one that occurs within a single generation and is only a mechanism of evolution.

Analysis. In the first case the student began with the definition of evolution; as the second answer reveals, this wasn't really necessary to get full credit, although both writers obviously knew the definition of evolution. The first student emphasized the definition of evolution and the second, the definition of selection, but the essence of each good answer was to distinguish evolution from one of its driving mechanisms.

Bad answer. Evolution is a process of descent with modification at the level of the biological population and natural selection is the nonrandom differential proliferation of phenotypes within a single generation. Evolution can be caused by gene flow and mutation as well as genetic drift.

Analysis. Here the student repeats the definitions of evolution and natural selection, correctly. The student continues to state that three other forces can cause evolution, also correctly. Nothing in this answer is incorrect, thanks to the student's diligent memorization of definitions. Unfortunately he did not answer the question except in an implicit fashion, presuming (I suppose) that if the grader read the definitions enough times he/she would realize that "evolution" and "selection" were quite different concepts. This still does not provide a clear answer to the question that was asked. The problem with this answer is that the grader must decide whether the student really understands the material or is simply regurgitating definitions in the hope that these will be sufficient. Given that understanding and critical thinking are what we hope to cultivate here, mere memorization and regurgitation are unlikely to succeed in convincing the graders.

Worse answer. Natural selection is part of evolution.

Analysis. In some sense this statement is true, but of course it is so vague that it could mean almost anything (even something mystical, which is NOT the province of this course). The statement is trivially true and no credit would be given for it.

Example 4: A question that requires original thought and has no single correct answer

Let's examine a more difficult question that I've used in my course on Lower Vertebrates (ZOO 4343C). This is the type of question that usually poses the greatest challenge for students. One reason is that there is no single correct answer to parts of the question; therefore anyone who relies solely on memorization of lecture and textual material is likely to be lost immediately. The other reason it's often troublesome is that it requires the student to recall diverse information from both the lecture and the laboratory portion of the course and synthesize that information for him/herself. I will present the question and instead of offering analyses of "good" and "bad" answers, describe what is needed to answer the question.

Question. Consider four local frogs and their larval habitats. In temporary ponds we can find *Hyla femoralis* and *Rana areolata,* whereas in permanent rivers we can find *Hyla avivoca* and *Rana heckscheri*. The two *Hyla* species are palatable to fish and salamanders, but the two species of *Rana* are unpalatable to both fish and salamanders. Salamander larvae are never found in the presence of fish and are quite palatable to fish.

- (a) Design an experiment that would reveal whether the larvae of each frog species can detect and respond to the presence of a predator.

- (b) Speculate on the results of such an experiment for each species if you used the following animals (one at a time) as potential predator stimulants:
  - *Fundulus lineolatus*
  - *Lepomis* spp.
  - *Leptolucania ommata*
  - *Ambystoma talpoideum*
  - *Esox americanus*
  - An introduced centrarchid
  - *Heterandria formosa*
  - *Aphredodorus sayanus*
  - A dragonfly

- (c) Frog larvae are herbivorous, and salamander larvae are carnivorous. Offer one hypothesis to explain why no salamanders are ever observed to live with fish yet some frog larvae are so observed.

- (d) Parts (a)-(c) addressed the responses of larval frogs or salamanders. Given the facts in hand, should you expect adult female *Hyla femoralis* to recognize and respond to the presence of fish in a body of water? Justify your answer.

- (e) Several species of frogs have larvae that "school," that is that actively associate and move as a roughly coordinated unit in the water. Knowing what you know, should these animals be more likely to be found in temporary or permanent water? Justify your answer.

Note. In the lecture on predator-prey relationships, I describe experiments of the type requested in part (a), so in fact that portion of the question might be considered simple regurgitation. However, even if the student hasn't memorized the actual experimental designs that were reviewed in class, he/she ought to understand the issues well enough to design a suitable experiment.

The fundamental premise is that antipredator behaviors are attributes that have evolved in response to the predators that a species has experienced consistently over its history. Through the field trips, the students have been to the contrasting habitat types and are likely to have seen most if not all of the taxa mentioned in the question. Moreover, they should know which taxa occur in which type of habitat (which is required to answer part (b) correctly, or at least with some logical basis).

Armed with that knowledge, a student might expect that tadpoles of *H. femoralis,*

which live only in temporary ponds, would be able to recognize and respond to predators in temporary ponds like dragonflies or the salamander and not to the fish (which don't occur in temporary ponds). Tadpoles of the closely related *H. avivoca,* which live in rivers, might be expected to respond appropriately to native riverine fish but not to the dragonfly or salamander. Its unclear what one might expect those tadpoles to do in response to lacustrine fish or an introduced fish species; they might be using a cue that is provided by all fish, or they might use species-specific cues. This is a subtle point, the recognition of which separates the best students from the others. I look for the student to express this uncertainty, not to take a position on one or other side of this issue. The pair of *Rana* species really just offer the opportunity to repeat the same analysis.

Parts (c), (d), and (e) request a speculative answer. Thoughtful answers require the student to have paid attention to the lectures on ecological relationships and antipredator behaviors and assimilated some of the patterns of habitat associations that I would have pointed out on our field trips.

Conclusions

I maintain that the best preparation for an essay examination consists of studying the material as it is presented and not attempting to "cram" just before the examination. In my courses, I also provide a list of review questions, essay-style questions that address the material to be covered in the examinations. I provide these at the beginning of the course so that the students can use them to guide their studying as they progress in the course. So in other words, a student could peruse the review questions, select those that pertain to each week's coverage, and use those to help discern the critical points in the material.

But even an energetic student can encounter trouble in attempting to express his/her knowledge in writing. One way to try to improve one's communication skills is to discuss the review questions with other students and develop a consensus about how they are best answered. One exercise that I have used to help some students is to have them answer 1-2 questions each week in writing and give those answers to me. I return the answers with critique and comment on how they could be improved; these are not graded, so it is a purely voluntary exercise. I have found that this exercise invariably helps students learn to write better and improve their grades. The improvement in writing skills carries over to other venues as well.