

Supplemental Material

CBE—Life Sciences Education

Russell *et al.*

Appendix 1. Content knowledge and skills assessment questions forPOB (BIOL 1108K, Principles of Biology II). Content knowledge and skills were assessed with pre-exposure (beginning of semester) and post-exposure (end of semester) tests.* indicates correct answer.

Content area	Question
Taxonomy	<p><i>Which definition best describes a species?</i></p> <p>a. A group of similar looking organisms that live in the same habitat</p> <p>b. A group of organisms that breed together</p> <p>c. A group of organisms that consists of males and females</p> <p>*d. A group of organisms that produce fertile offspring</p> <p>e. None of the above</p>
	<p><i>In taxonomy, which taxonomic rank is most inclusive?</i></p> <p>a. Species</p> <p>*b. Domain</p> <p>c. Family</p> <p>d. Order</p> <p>e. None of the above</p>
	<p><i>In taxonomy, which taxonomic rank is more specific than family?</i></p> <p>a. Class</p> <p>*b. Genus</p> <p>c. Order</p>

	<p>d. Domain</p> <p>e. None of the above</p>
	<p><i>In taxonomy, which taxonomic rank is more inclusive than order?</i></p> <p>a. Family</p> <p>b. Genus</p> <p>*c. Phylum</p> <p>d. Species</p> <p>e. None of the above</p>
	<p><i>Organisms in the same genus would _____.</i></p> <p>a. be able to breed together</p> <p>b. have similar physical traits</p> <p>c. have similar DNA</p> <p>*d. all of the above</p>
Methods	<p><i>Which piece of field equipment would best collect organisms that live in the leaf litter?</i></p> <p>a. malaise trap</p> <p>b. sweep net</p> <p>*c. pit trap</p> <p>d. vane trap</p> <p>e. beating sheet</p>

	<p><i>Which piece of field equipment would best collect the widest range of organisms that move on the ground and fly?</i></p> <p>*a. malaise trap</p> <p>b. sweep net</p> <p>c. pit trap</p> <p>d. vane trap</p> <p>e. beating sheet</p>
	<p><i>Which piece of equipment would best collect organisms that live in tall grasses and/or the tops of bushes?</i></p> <p>a. malaise trap</p> <p>*b. sweep net</p> <p>c. pit trap</p> <p>d. vane trap</p> <p>e. beating sheet</p>
	<p><i>Which piece of field equipment would best collect organisms that are attracted to colored traps (e.g., blue and yellow)?</i></p> <p>a. malaise trap</p> <p>b. sweep net</p> <p>c. pit trap</p> <p>*d. vane trap</p>

	e. none of the above
	<p><i>Which piece of field equipment is most likely to have a biased collection?</i></p> <p>a. malaise trap</p> <p>b. sweep net</p> <p>c. pit trap</p> <p>*d. vane trap</p> <p>e. none of the above</p>
Classification	<p><i>Use the dichotomous key for the parrots of Costa Rica to answer the following questions.</i></p> <p>Dichotomous Key for the Parrot of Costa Rica</p> <p>1. a. The body is mostly green.....2</p> <p> b. The body is not mostly green.....7</p> <p>2. a. The wings do not have red patches.....3</p> <p> b. The wings have red patches.....4</p> <p>3. a. The head is white with some blue.....White-crowned parrot</p> <p> b. The head is totally blue.....Blue-headed parrot</p> <p>4. a. The head is white with some green.....White-fronted parrot</p> <p> b. The head has no white feathers.....5</p> <p>5. a. The head has some red feathers.....Red-lored parrot</p> <p> b. The head has no red feathers.....6</p> <p>6. a. The neck feathers are white.....Mealy parrot</p>

	<p>b. The neck feathers are yellow.....Yellow-naped parrot</p> <p>7. a. The head is mostly red.....Scarlet macaw</p> <p>b. The head is mostly green with some red and yellow.....Great green macaw</p>
	<p><i>Identify a bird with mostly green feathers. It has yellow tail feathers, wings with blue, red, and green feathers, a green head, and a white neck.</i></p> <p>a. White-crowned parrot</p> <p>b. Blue-headed parrot</p> <p>c. Red-lored parrot</p> <p>*d. Mealy parrot</p> <p>e. None of the above</p>
	<p><i>Identify a bird with mostly green feathers. It has green tail feathers, wings with blue and green feathers, and a white and blue head, and a green neck.</i></p> <p>*a. White-crowned parrot</p> <p>b. Blue-headed parrot</p> <p>c. Red-lored parrot</p> <p>d. Mealy parrot</p> <p>e. None of the above</p>
	<p><i>Identify a bird with blue and green feathers. It has red and blue tail feathers, wings with blue and green feathers, a green and red head, and a green neck.</i></p>

	<p>a. Yellow-naped parrot</p> <p>b. Great green macaw</p> <p>c. Red-lored parrot</p> <p>d. Mealy parrot</p> <p>*e. None of the above</p>
	<p><i>Identify a bird with mostly green feathers. It has yellow tail feathers, wings with blue, red, and green feathers, a green head, and a yellow neck.</i></p> <p>a. White-crowned parrot</p> <p>b. Blue-headed parrot</p> <p>c. Red-lored parrot</p> <p>d. Mealy parrot</p> <p>*e. None of the above</p>
	<p><i>Identify a bird with mostly green feathers. It has green tail feathers, wings with blue, red, and green feathers, a green and red head, and a green neck.</i></p> <p>a. Yellow-naped parrot</p> <p>b. Great green macaw</p> <p>*c. Red-lored parrot</p> <p>d. Mealy parrot</p> <p>e. None of the above</p>
Knowledge of	<i>Which order of insects includes the grasshoppers?</i>

<p>insect classification</p>	<p>a. Hymenoptera</p> <p>b. Diptera</p> <p>c. Coleoptera</p> <p>*d. Orthoptera</p> <p>e. None of the above</p>
	<p><i>Which order of insects includes the flies?</i></p> <p>a. Hymenoptera</p> <p>*b. Diptera</p> <p>c. Coleoptera</p> <p>d. Orthoptera</p> <p>e. None of the above</p>
	<p><i>Which order of insects includes the bees?</i></p> <p>*a. Hymenoptera</p> <p>b. Diptera</p> <p>c. Coleoptera</p> <p>d. Orthoptera</p> <p>e. None of the above</p>
	<p><i>Which order of insects includes the beetles?</i></p> <p>a. Hymenoptera</p> <p>b. Diptera</p>

	<p>*c. Coleoptera</p> <p>d. Orthoptera</p> <p>e. None of the above</p>
	<p><i>Which order of insects includes the butterflies?</i></p> <p>a. Hymenoptera</p> <p>b. Diptera</p> <p>c. Coleoptera</p> <p>d. Orthoptera</p> <p>*e. None of the above</p>
Field design and methods	<p><i>Given: You have 3 malaise traps. In order to collect the greatest diversity of insects in your study, you should set up your traps_____.</i></p> <p>a. Spread out in the same habitat</p> <p>b. Clustered together in the same habitat</p> <p>*c. Place one trap in 3 different habitats</p> <p>d. Move the 3 traps every other day in the same habitat</p> <p>e. None of the above</p>
	<p><i>Given: You have 3 malaise traps. In order to collect the most accurate diversity of insects in a given habitat, you should set up your traps_____.</i></p> <p>*a. Spread out in the same habitat</p> <p>b. Clustered together in the same habitat</p>

	<p>c. Place one trap in 3 different habitats</p> <p>d. Move the 3 traps every other day in the same habitat</p> <p>e. None of the above</p>
	<p><i>Given: Sweep-netting. In order to collect the most accurate diversity of insects in a given habitat, you should_____.</i></p> <p>a. Collect insects for a specific time (30 minutes per day)</p> <p>b. Collect insects along a given track (a transect)</p> <p>c. Collect insects along a given track (a transect) for a specific time</p> <p>*d. Collect insects while moving randomly through a plot for a specific time</p> <p>e. None of the above</p>
	<p><i>Which type of trap would be the least favorable for collection of nocturnal insects?</i></p> <p>a. malaise trap</p> <p>b. sweep net</p> <p>c. pit trap</p> <p>*d. vane trap</p> <p>e. none of the above</p>
	<p><i>Which type of trap would be the least biased collection?</i></p> <p>*a. malaise trap</p> <p>b. sweep net</p>

	<p>c. pit trap</p> <p>d. vane trap</p> <p>e. none of the above</p>
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Appendix 2. Content knowledge and skills assessment questions for Ecology (BIOL 3500K). Content knowledge and skills were assessed with pre-exposure (beginning of semester) and post-exposure (end of semester) tests. * indicates correct answer.

Content area	Question
Taxonomy	<p><i>Which definition best describes a species?</i></p> <p>a. A group of similar looking organisms that live in the same habitat</p> <p>b. A group of organisms that breed together</p> <p>c. A group of organisms that consists of males and females</p> <p>*d. A group of organisms that produce fertile offspring</p> <p>e. None of the above</p>
	<p><i>In taxonomy, which taxonomic rank is most inclusive?</i></p> <p>a. Species</p> <p>*b. Domain</p> <p>c. Family</p> <p>d. Order</p> <p>e. None of the above</p>
	<p><i>In taxonomy, which taxonomic rank is more specific than family?</i></p> <p>a. Class</p> <p>*b. Genus</p> <p>c. Order</p>

	<p>d. Domain</p> <p>e. None of the above</p>
Ecology	<p><i>Biodiversity plays an important role in which ecological service?</i></p> <p>a. Aquatic chemistry</p> <p>b. Atmospheric chemistry</p> <p>c. Nutrient recycling</p> <p>*d. All of the above</p> <p>e. None of the above</p>
	<p><i>Arthropods can be placed in which trophic level?</i></p> <p>a. Chemoautotrophs</p> <p>b. Primary producers</p> <p>*c. Secondary consumers</p> <p>d. All of the above</p> <p>e. None of the above</p>
	<p><i>All of the following are abiotic factors influencing the abundance and distribution of species except:</i></p> <p>a. Moisture</p> <p>*b. Predation</p> <p>c. Solar radiation</p> <p>d. Soil composition</p>

	<p>e. Topography</p> <p><i>Which of the following does not play a role in the regulation of populations?</i></p> <p>a. Competition</p> <p>b. Density dependent factors</p> <p>c. Density independent factors</p> <p>d. All of the above</p> <p>*e. None of the above</p>
	<p><i>Ecology could best be described as:</i></p> <p>*a. The abundance and distribution of organisms</p> <p>b. The change in allele frequencies in populations</p> <p>c. The physical forces that distribute water resources</p> <p>d. The naming of organisms according to observable features</p> <p>e. The spatial distribution of land and water</p>
	<p><i>Which order of insects includes the flies?</i></p> <p>a. Hymenoptera</p> <p>*b. Diptera</p> <p>c. Coleoptera</p> <p>d. Orthoptera</p> <p>e. None of the above</p>
	<p><i>Which order of insects includes the bees?</i></p>

	<p>*a. Hymenoptera</p> <p>b. Diptera</p> <p>c. Coleoptera</p> <p>d. Orthoptera</p> <p>e. None of the above</p>
Methodology	<p><i>Biodiversity is measured by:</i></p> <p>a. Population structure</p> <p>b. Species richness</p> <p>c. Species evenness</p> <p>d. a & b</p> <p>*e. b & c</p> <p>f. None of the above</p>
	<p><i>The bulk of biodiversity in terrestrial habitats is found in which group of organisms?</i></p> <p>*a. Arthropods</p> <p>b. Fungi</p> <p>c. Plants</p> <p>d. Vertebrates</p>
	<p><i>According to the Simpson index of biodiversity $D = \sum (n_i/N)^2$, $n_i =$</i></p> <p>*a. Number of individuals</p>

	<p>b. Number of a species</p> <p>c. Population size</p> <p>d. Species name</p>
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Appendix 3. Content knowledge and skills assessment questions for BIOL 3400K (Cell Biology). Content knowledge and skills were assessed with pre-exposure (beginning of semester) and post-exposure (end of semester) lab quizzes.* indicates correct answer.

Questions:

What does "PCR" stand for?

- a. Protein Chemical Reaction
- *b. Polymerase Chain Reaction
- c. Primer Copy Reagent
- d. Prepared Chromosomal Regeneration

What is the purpose of the PCR procedure?

- *a. to amplify a specific region of DNA
- b. to run a gel
- c. to convert DNA to protein
- d. to replicate an organism's entire genome
- e. all of the above

Which enzyme is used in the PCR procedure?

- a. ligase
- *b. Taq DNA polymerase
- c. helicase
- d. DNA polymerase III

e. all of the above

Which of the following are important components of PCR?

a. DNA

b. DNA primers

c. dNTPs (deoxyribonucleotides)

d. Mg^{2+}

*e. all of the above

Place in order the following steps involved in PCR:

(1) newly synthesized strands act as templates

(2) temperature lowered; DNA primers and polymerase added

(3) heat separates strands of parent DNA

(4) complementary base pairing between primers and template

(5) DNA nucleotide bases added; newly synthesized stands produced.

The correct order is:

a. 1 - 2 - 3 - 4 - 5 - 2

b. 3 - 5 - 4 - 2 - 3 - 1

*c. 3 - 2 - 4 - 5 - 1 - 3

d. 2 - 3 - 4 - 5 - 2 - 1

What is TRUE about primers used in PCR?

a. A single primer can be used to amplify a region of DNA

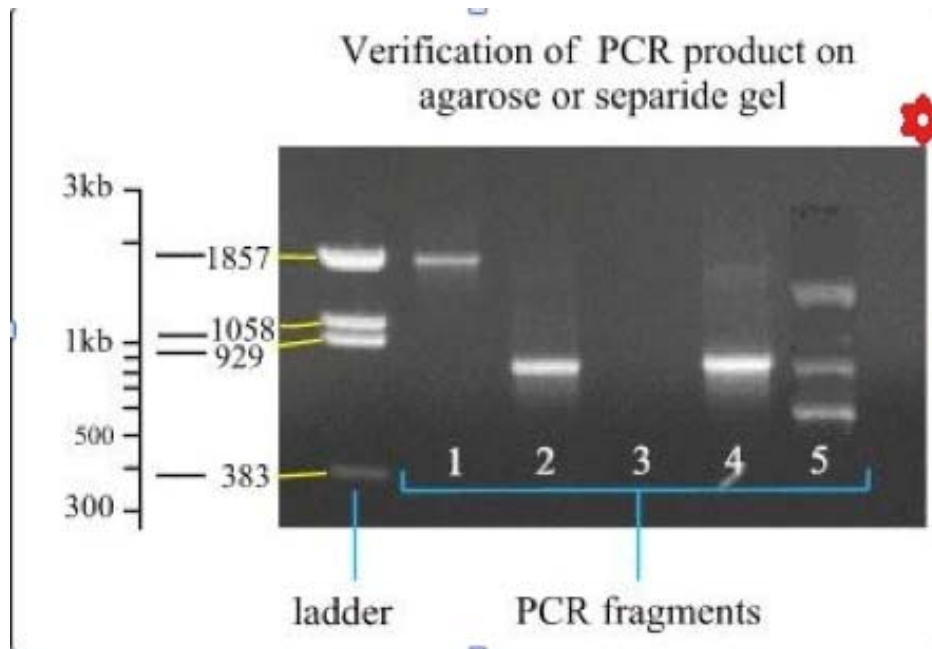
- b. They are usually around 100 base pairs long
- c. They are double-stranded
- *d. The primer sequence is always included within the amplified DNA
- e. none of the above

What is true about the following primer? 5'-AGCTGTGGCGCTGCGCGCGGTA-3'

- a. It is a great primer
- *b. It has a high GC content
- c. It is too short
- d. It has a melting temperature in the correct range
- e. all of the above

In agarose gel electrophoresis, DNA is _____ charged, and hence moves towards the _____ electrode. Smaller bands move _____ than larger bands.

- a. positively; positive; faster
- b. positively; negative; slower
- c. negatively; negative; slower
- *d. negatively; positive; faster



<http://users.ugent.be/~avierstr/principles/pcr.html>

Using the gel picture provided, the RED * represents the position of the _____ electrode.

a. positive

*b. negative

c. neutral

d. none of the above

Using the gel picture provided, the size of the band in lane 1 is _____ bps.

*a. 1857

b. 902

c. 1593

d. 557

e. 1058

What are primer dimers?

a. they have low level intensity

b. primers that are twice as long

c. dissociation product of primer tetramers

*d. a product forms due to primer complementarity

e. all of the above

The cytochrome oxidase subunit I (COI) gene is

a. nuclear

*b. mitochondrial

c. chloroplastic

d. lysosomal

e. none of the above

COI gene is involved in

*a. cellular respiration

b. transcription

c. fertilization

d. mitosis

e. all of the above

The purpose of the international DNA barcoding Project is

- *a. to obtain a unique identifier of each individual species on Earth
- b. to study migration of monarch butterflies
- c. to study the decrease in the honey-bee population
- d. to study emerging virus

Appendix 4. Survey questions for student attitudes toward science. Attitudes were assessed with pre-exposure (beginning of semester) and post-exposure (end of semester) surveys.

<i>I understand inquiry and the nature of scientific investigation.</i>
<i>I have become better at overcoming obstacles and solving problems.</i>
<i>I can design and carry out my own experiments or projects.</i>
<i>I understand how to conduct a research project.</i>
<i>As a result of my research experience I am more likely to choose a career in a STEM field (Science, Technology, Engineering, Math).</i>