



A Cases for Evolution Education Question Guide

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The Case of Citrate Metabolism Evolution in *E. coli* Bacteria

This Evo-Ed case consists of five modules that support the teaching and learning of biology in the framework of evolution in the model prokaryotic organism, *E. coli*. Together, the modules present evidence that evolution occurs because of:

- 1) competition for resources and differential reproductive success in populations
- 2) heritable genetic variation and resulting differences in gene expression.

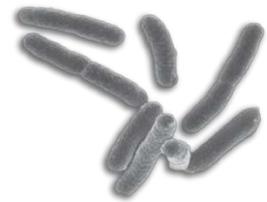
The following activities are designed to guide students' learning as they engage in the modules of this case. They can also be used as learning objectives. That is, "students will be able to" accomplish each of these as objectives.

The modules and activities are presented in the order in which they appear in the case and can be used as in-class activities, homework and/or formative assessments.

The background information on this case, and accompanying slides can be found at:
 → www.evo-ed.org/Pages/Ecoli

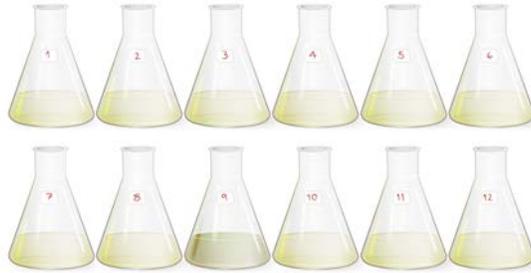
Background: Citrate Metabolism in *E. coli* Bacteria

- 1) Draw a model of the cellular structures (inside and outside), including their function, of the model prokaryote, *E. coli*.
- 2) Debate, based on evidence, whether or not *E. coli* is a "good" or "bad" bacterium.
- 3) Describe the attributes that allow *E. coli* to be a good organism for doing studies on evolution.



The Long-Term Evolution Experiment on E. coli

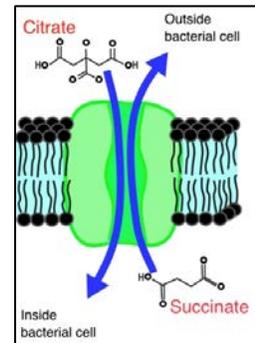
- 1) Explain the premise and design of Rich Lenski's LTEE study.
- 2) Describe how each individual flask of E. coli cells in this study is a tiny ecosystem.
- 3) Explain why and how E. coli cells can quickly "use up" glucose in the broth. [This requires explaining what "use up" means].



- 4) Explain the evidence that showed there were more E. coli in Flask #9 than in the other flasks.
- 5) Explain why both mutation and natural selection must act to lead to greater growth in Flask #9 compared to other flasks.

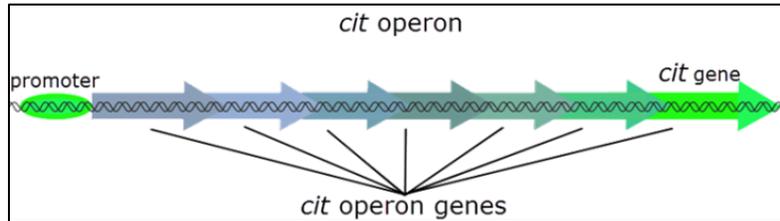
Cell Biology of Citrate Metabolism in E. coli Bacteria

- 1) Explain the differences in E. coli sugar metabolism under conditions with and without oxygen. [The answer requires going beyond the case to investigate fermentation in addition to both aerobic and anaerobic respiration].
- 2) Evaluate the phrase: "Organisms extract energy from food". To do so, define each term: organism, extract energy, food.
- 3) Explain the advantages to an E coli cell of being able to exchange citrate for succinate both with and without oxygen present.
- 4) Explain how the CitT transporter functions in E. coli.
- 5) Compare and contrast CitT to another membrane-bound molecule. For information consult Evo-Ed cases: clam toxin, mouse fur color, monkey color vision.



The Molecular Genetics of Citrate Metabolism in *E. coli* Bacteria

- 1) Summarize the normal function of the *cit* operon in both the presence and absence of oxygen in the environment.
- 2) Diagram the series of events in the *cit* operon that resulted in Flask #9 organisms being able to take in citrate when oxygen is present.
- 3) Describe the kind of mutation that allowed *E. coli* to transport citrate when oxygen is present and explain how that resulted in a change in protein synthesis.



- 4) Explain how the change in protein synthesis allowed *E. coli* to take up citrate from the medium when oxygen is present.
- 5) Compare and contrast the regulation of gene expression between eukaryotes and prokaryotes [see lactase persistence case].

The Ecology and Phylogenetics of Citrate Metabolism in *E. coli* Bacteria

- 1) Describe the conditions that allow Cit⁺ and Cit⁻ populations to coexist.
- 2) Predict what would happen to Cit⁺ and Cit⁻ populations if a researcher could remove succinate from the environment as soon as it was produced.
- 3) Predict the outcome of moving a mixture of Cit⁺ and Cit⁻ populations to an environment where oxygen was not present.
- 4) Apply the information in slide 73 to populations of a hypothetical mouse species living in the woods.
- 5) Bonus: Explain why DNA sequencing is a powerful tool in determining the relatedness of groups of organisms.

