FEATURE ARTICLE

# Cystic Fibrosis as a Theme to Incorporate Team-Based Learning in Cell Biology Courses

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## Abstract

*Team-based learning (TBL) is structured, cooperative learning teaching strategy used in a variety of disciplines. TBL uses a three-step approach for delivering content to students: out-of-class preparation, readiness assurance, and application. In this article, a method for incorporating TBL into an undergraduate cell biology course using cystic fibrosis (CF) as a theme is described. Class content is divided into modules. Each module consists of (1) out-of-class video viewing and reading assignments; (2) individual and team assessments, mini-lectures, and think-pair-share activities to assess understanding of the material; and (3) in-class, group problem sets related to the molecular pathogenesis of CF. Although originally designed for an introductory undergraduate cell biology course, this curriculum can be easily adapted for upper-level undergraduate and high school students.*


**Key Words:** *cell biology; team-based learning; TBL; cystic fibrosis; cooperative learning.*

## ○ Introduction

Team-based learning (TBL) is a cooperative pedogeological approach, wherein course content is presented in structured modules (Michaelsen & Sweet, 2011). TBL has been show to improve student learning across many fields of study (Carmichael, 2009; Fatmi et al., 2013; Neider et al., 2005; Touchet & Coon, 2005). A TBL module is divided into three components. First, students complete out-of-class preparation activities by reading assigned portions of the textbook, watching videos, completing online tutorials, etc. Second, students demonstrate readiness assurance of the content associated with the out-of-class preparation assignments. Typically, this is done using individual quizzes, followed by group quizzes taken as student teams. Lastly, student teams complete application activities to reinforce and deepen the understanding of class concepts. These application assignments can range from problem sets to case studies to concept mapping. Upon completion of the assignments, students report out their answers to the instructor and/or class and, if needed, misconceptions are addressed as a class.

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The following outlines a method for incorporating TBL into my sophomore-level cell biology class. An overview of the course modules and materials for a single module are provided in Tables 1 and 2, respectively (complete teaching materials can be found in Supplementary Materials). This course meets twice a week for 75 minutes for lecture and once a week for 2 hours and 45 minutes for lab. The class comprises both Biology and Exercise Science majors and a combination of traditional and non-traditional students. The genetic disease Cystic fibrosis (CF) was chosen as a theme in the course because many aspects of the molecular pathogenesis of CF align well with the course learning objectives. Each module consists of a pre-class video viewing or reading assignments, in class activities to assess student understanding, and CF-related problem sets.

## ○ Getting Started

Before using TBL in your classroom, you will need a plan for establishing groups and for conducting peer evaluations. Michaelsen, Knight, and Fink outline a number methods for this in their book, "Team-Based Learning: A Transformative Use of Small Groups in College Teaching." (2002). In my course, a survey (see Supplementary Materials) is administered on the first day of class on learning styles, preferred modes of communication, and time management practices, and group students in teams of four accordingly. Since many of my application problem sets involve accessing Internet resources, I ensure that at least one group member regularly brings an Internet-enabled device to class. To measure individual student participation, group

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**Table 1. Overview of CF-themed TBL modules.**

| Module Topic | Out-of-Class Preparation | Readiness Assurance | Application |
|---|---|---|---|
| ***Transcription and Translation*** | • *Assigned videos:* "The Central Dogma: Transcription and Translation" (Bozeman Science); self-produced video on ribosome function<br>• *Assigned readings:* selections from Chapter 7, *Essential Cell Biology* | • Individual and group quizzes with IFAT cards<br>• Diagramming transcription and translation as groups<br>• *Think-pair-share question:* What are at least three differences and similarities between transcription and translation? | *CF problem sets:* Diagram the CFTR gene, most common mRNA transcript, and protein domains; calculate the % exons in the CFTR gene; calculate the sizes of the coding region, 5'UTR, and 3'UTR in a CFTR mRNA transcript; determine the CFTR expression pattern in humans using the *Human Protein Atlas* |
| ***Membrane Function*** | • *Assigned videos:* "In Da Club—Membranes and Transport" (Crash Course Biology); self-produced video on membrane structure<br>• *Assigned readings:* selections from Chapters 11 and 12, *Essential Cell Biology* | • Individual and group quizzes with IFAT cards<br>• *Think-pair-share questions:* What molecules can readily cross a membrane without the aid of a transport protein? Define and give examples of active and passive transport. | *CF problem sets:* Diagram the how CFTR moves ions across plasma membranes in cells; diagram the electrochemical gradient and extracellular fluid levels in normal and CF-afflicted lung epithelial cells |
| ***Protein Post-Translational Modification and Transport*** | • *Assigned video:* self-produced video on vesicular budding and docking<br>• *Assigned readings:* selections from Chapter 15, *Essential Cell Biology* | • Individual and group quizzes with IFAT cards<br>• Diagramming synthesis of a transmembrane protein in groups | *CF problem sets:* Analyze the impact of specific mutations that alter protein folding and/or glycosylation on CFTR function; propose a therapy, based on your knowledge the molecular pathogenesis of CF |

**Table 2. Protein Post-Translational Modification and Transport TBL Module.**

| | |
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| ***Out-of-Class Preparation*** | *Pre-class video:* Self-produced Kaltura video on vesicle docking and budding (*Essential Cell Biology*, pp. 503–506 [Alberts et al., 2013]) |
| **Readiness Assurance and Classroom Activities** | *Individual and group "scratch off" card quizzes (15 minutes)*<br>Quiz Questions:<br>1. Which of the following are the GTPases that facilitate the "budding off" of vesicles?<br>a. Rabs b. dynamins<br>c. SNAREs d. Rans<br>2. Which of the following are the GTPases involved in vesicle docking?<br>a. Rabs b. dynamins<br>c. SNAREs d. Rans<br>3. Which of the following are proteins that twist together during vesicle docking?<br>a. Rabs b. dynamins<br>c. SNAREs d. Rans<br>4. What is the purpose of coat proteins, such as clathrin?<br>A. They give vesicles their shape.<br>B. They cause vesicles to be degraded by the proteasome.<br>C. They cause vesicles to be ubiquitinated.<br>D. They cause vesicles to be phosphorylated. |

(continued)

**Table 2. Continued**

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|---|---|
| | 5. What is the name of the proteins that "grab" Rab proteins during vesicle docking?<br>A. latching proteins<br>B. tethering proteins<br>C. docking proteins<br>D. acceptor proteins<br>*Mini-lecture on synthesis of secretory and transmembrane protein (20 minutes)*<br>Topics: Synthesis of proteins at the endoplasmic reticulum, protein folding, and protein glycosylation<br>*Group board work (20 minutes)*<br>Students work in their groups to diagram synthesis of a transmembrane protein. After 5 minutes, groups rotate to another board and annotate the diagram created by the group that was there. We conclude by compiling a "key points" list on the board as a class. |
| ***Application Problems*** | *Cystic fibrosis application problem set (20 minutes. Unfinished problems are completed during the following class period or as homework.)*<br>1. CFTR is a plasma membrane protein. What kind of signal sequence must CFTR have?<br>2. Where is the CFTR protein made in the cell? How is it transported to the plasma membrane?<br>3. Many disease-linked mutations cause the CFTR protein to be folded incorrectly, causing CFTR to be sequestered in a particular organelle in the cell—what is this organelle?<br>4. How would a mutation that causes the CFTR protein to fold incorrectly affect CFTR function in lung epithelial cells? Specifically, mention how these types of mutations would impact the cellular ion gradients, extracellular fluid levels, and cilia function in these cells.<br>5. Many disease-linked mutations cause the CFTR protein to be glycosylated incorrectly. Where in the cell are proteins glycosylated?<br>6. How would a mutation that causes the CFTR protein to be glycosylated incorrectly affect CFTR function in lung epithelial cells? Specifically, mention how these types of mutations would impact the cellular ion gradients, extracellular fluid levels, and cilia function in these cells.<br>7. Based on what you have learned about cystic fibrosis this semester, propose a therapy to treat cystic fibrosis. Be sure to explain how your therapy would work on a cellular level. |

members complete peer evaluations at the end of module. Each group member has 30 points to distribute among their group members and must show some differentiation in their scoring. For example, a student can assign group member A 10 points, group member B 8 points, and group member C 12 points, averaging 10 points per group member.

## ○ Out of Class Preparation

Each TBL module in my class typically lasts 1–2 weeks. Before each class period, students must watch an assigned video or read sections from their textbook. A combination of published videos and self-produced videos are used for pre-class video assignments. For my undergraduate, sophomore-level class, many videos produced by Bozeman Science and the DNA Learning Center are at the appropriate level. Additionally, Crash Course Biology provides excellent videos for reviewing core concepts from introductory biology courses, and the Journal of Visualized Experiments (JOVE) provides more advanced videos on laboratory techniques used to study cell biology. For self-produced videos, Kaltura is used to create voice-over PowerPoints lectures. Pre-class assigned readings are short sections (2–3 pages) of their textbook, *Essential Cell Biology* (Alberts et al., 2013).

## ○ Readiness Assurance

To determine readiness assurance, class begins with each student taking a 5- to 10-question multiple choice quiz on the assigned video and readings. Students have approximately 5 minutes to complete the individual quiz. Afterward, individual quizzes are collected and students retake the same quiz with their teams. For the team quizzes, I use "scratch off" cards, similar to lottery tickets. If students scratch off the box for the correct answer, a star is revealed, giving them the instant feedback that they are correct. If they do not select the correct answer, teams can scratch off a second answer for partial credit. This process takes 5–10 minutes of class time. Many students are initially apprehensive about the team quizzes, fearing that underprepared teammates will hurt their grades. To alleviate these fears, quizzes are graded in this manner: a student's quiz is either their individual quiz score *or* the average of their individual and team quiz scores, whichever score is higher. As such, team quiz scores cannot lower the grade of student who does well on the individual quiz.

In addition to quizzes, students diagram concepts on classroom whiteboards and complete think-pair-share questions. Misconceptions that are identified during these activities are addressed through class discussion and short lectures. Collectively, these activities take 30–60 minutes, the majority of the 75-minute class period.

## ○ Application

Each week, student teams are responsible for completing an application problem set related to the cystic fibrosis transmembrane conductance regulator (CFTR) gene and the pathogenesis of CF. The first application problem set of the semester is a literature search activity (see Supplementary Materials). Groups are instructed to find four unique review articles on CF. These review articles will be used during other problem sets throughout the course. Additionally, links are provided to online CF tutorials, including CFTR.info and Learn Genetics—Gene Therapy Case Study: Cystic Fibrosis.

CFTR is a transmembrane protein that regulates the transport of chloride ions across cell membranes (Cutting, 2015). Problem sets investigating the function of CFTR provide an opportunity to address the course goal, "Explain and classify various methods of membrane transport." In the CF disease state, CFTR function is altered by mutations that disrupt protein folding, post-translation modification, and/or protein trafficking. As such, different CF-linked mutations in the CFTR gene can be studied in relation to the course learning objectives, "Describe and apply the processes of gene expression and protein trafficking" and "Apply cell biological concepts and techniques to scientific research and real world problems." CF problem sets include higher Bloom's level (apply, analyze, and evaluate tiers) questions related to that module's topic. Additionally, some problem sets have embedded lessons on using databases such as PubMed, Google Scholar, and the Human Protein Atlas.

Once a week, students are given 20–30 minutes of class time to work on the group problem sets. During this time, I rotate among groups to check on their progress and answer questions. If student groups are struggling with a problem, they are encouraged to merge with other groups to form "super groups," and/or to send group members as "ambassadors" to other groups to compare responses. Any application problems that are not completed in class can be completed during the next class period or lab or as homework.

## ○ Student Feedback

In general, student feedback was very positive. An end-of-semester attitudinal survey was administered during the Spring 2017 semester ($n = 16$). The majority of students agreed or strongly agreed that the pre-class videos, group quizzes, and application problem sets helped them understand class concepts. Furthermore, most reported that they used the TBL materials to prepare for exams and felt that learning about CF was relevant to their coursework. Students told me they particularly enjoyed the pre-class video assignments and group quizzing with the "scratch off" cards. Among other student feedback are these: "I really liked the video quizzes. Sometimes I get confused by the way questions are asked, so even though I watched and understood the material, I still get the question wrong, but that is something I need to work on. I also LOVED group quizzes averaging with individ. ones." "The group quizzes helped me better prepare for the class. I knew what to expect going into class. The online videos were a simplified version of what we were going to learn."

## ○ How to Adapt this Curriculum for Your Course

This TBL curriculum can be adapted to teach cell biology concepts—as well as other biology concepts—in high school and in upper-level undergraduate courses. This can be accomplished by adjusting the "depth" of the content in the out-of-class preparation assignments to meet your specific course's learning objectives. Crash Course Biology and Amoeba Sisters videos are recommended for high school audiences, in addition to a course level-appropriate textbook and Nature Education's Scitables. For an advanced, upper-level cell biology course, I recommend videos from JOVE and iBiology seminars, as well as review papers. Additionally, problem sets related to the pathogenesis of other diseases, such as some forms of cancer and diabetes mellitus, may be used.

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