

Ready, Cell, Go! Guided Movement Exercises in an Introductory Cell Biology Course[†]

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Cells and dance are each dynamic manifestations of energy, shape, time, and space. Here we present a novel application of movement learning in cell biology education. “Ready, Cell, Go!” is a set of movement exercises for introductory cell biology students designed to teach concepts of fluidity, crowding, and chaos. These aspects of cells are difficult to glean from two-dimensional illustrations in textbooks or animations where necessary simplification abstracts processes from their full cellular context. Forty-four undergraduate biology students were guided to move using three sets of cues in a dance studio setting where each exercise aimed to experientially highlight and deepen understanding of a different aspect of cellular structure and function. Students described their experiences and personal learning outcomes in written reflections. The movement-based exercises we describe provided a means of discovery, inquiry, and interest for introductory cell biology students and serve as a template to teach other central concepts in cell biology.

INTRODUCTION

Introductory undergraduate cell biology curricula rely on simplified, two-dimensional drawings and animations to supplement lectures. Important biological complexity is lost in translation; active, co-occurring cellular processes are shown as discrete sequences and a crowded cell interior is depicted as flat and static, leaving students with fundamental misconceptions about cellular physiology (1, 2). We devised immersive movement exercises that invite students to experience some of the actions and reactions of a crowded, busy cell interior using their own bodies. “Ready, Cell, Go!” encourages students to think about cells in novel ways, improving students’ understanding of biology and catalyzing new forms of trust between classmates.

BACKGROUND

Many educators have developed movement-based tools for scientific instruction. Susan Gerofsky integrated movement, narrative, and direct instruction to teach primary algebra students (3). Lucy Irving and Carl Senior created a series of dance films to demonstrate statistical

concepts (4). Mathematician Erik Stern and dancer Karl Schaffer argue that dancing allows an embodiment of math problems that is “memorable, creative, and social” (5). Science educators from Wesleyan University collaborated with the Liz Lerman Dance Exchange to develop “science-based choreography,” a movement technique used to encourage creative engagement with science, advocating for the empowerment of students through active meaning-production (6). In a similar vein, Ready, Cell, Go! brings together aspects of guided movement and play to create empowering and memorable learning experiences, where students collectively derive biological knowledge through ensemble movement.

THE COURSE AND MOVEMENT EXERCISES

Movement exercises were conducted in two separate hour-long sessions in an introductory cell biology course (Table 1). All students were invited to either move or observe their peers if they did not feel safe or comfortable participating. While the topics explored through movement were taught in lectures and tests *before* each session, we did not explicitly title the sessions for students or indicate the foundational principles that would be embodied by the movement activities. Instead, after each session, students reflected through group conversation and individual writing, discovering connections between the movement exercises and aspects of cellular physiology they had previously learned in lectures. Macalester’s Institutional Review Board approved the in-class activity and subsequent sharing of de-identified student reflections.

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TABLE 1.
Schedule of topics and movement exercises* in cell biology course.

Week of the Semester	Topic
1–2	Abiogenesis, macromolecules, cellular organization
3–4	Protein structures and folding, enzymes *Shape, function, and stability
5–6	Energy and metabolism
7–9	Membranes and transport across membranes
10	Vesicle traffic
11	Cytoskeleton
12	Cell signaling *Crowding, chaos, and fluidity *Cascade, sequence, and consequence
13–14	Cell cycle and apoptosis

These exercises serve as templates for adaptation and broader use. Appendices 1 to 3 provide detailed scripts that can be used as is or adapted to the learning goals of any instructor. Co-author Fricke, a dance pedagogy expert, provided valuable input in the initial design of these exercises and the scripting of the movements for broader use. In addition, movement exercises were tested by members of a campus dance group. We encourage collaboration with theater and dance faculty and with students versed in movement for the implementation of these exercises.

Shape, function, and stability

The first exercises used body connectivity to derive foundational principles of molecular shape, stability, and function (Appendix 1). In pairs, students created shapes with their connected bodies. We then asked students to do this in larger groups to create more complex structures. Students explored what would happen if one partner lost shape or shifted dramatically into non-weight-bearing shapes. This activity highlighted the interdependence of shape and energy (Table 2).

Crowding, chaos, and fluidity

We asked students to move inside a large, sturdy rope held in a circular shape (Appendix 2). Individuals were assigned particular intracellular roles (e.g., vesicles) in simulated cellular interactions. A facilitator called out different speeds of movement for each cellular component. We encouraged students to not be afraid to run into each other and to make necessary adjustments, mimicking the types of obstacles cellular processes overcome in a crowded, heterogeneous interior. The facilitators gradually reduced the cell size interior, making it increasingly challenging for students to complete their movement tasks. Students then reflected on discovering the

sequestrations and constraints on molecular and organelle movements within a cell (Table 2).

Cascade, sequence, and consequence

Our final activity modeled the constraints on signal-transduction cascades (Appendix 3). We asked groups of eight students to stand in a line and perform a repeated gesture of their choosing. The completion of one person's gesture triggered the adjacent student's movement. When the final student was "signaled," they moved a yoga block from an existing stack to a new pile, allowing the cycle to restart from the first student. Once the objects in the initial pile ran out, the movement cascade concluded. We then asked one eight-person "cascade" to perform this activity while the rest of the class simultaneously moved about the room at varied speeds, randomly disrupting the cascade's function. Concurrently dancing chaos and cascades highlighted the cell's interior complexity (Table 2).

CONCLUSIONS, PITFALLS, AND ADVICE

While any abstraction of an intricate phenomenon necessarily loses complexity, our model provides embodied access to the physicality of the cell. Students solved spatio-temporal and energetic problems with their own bodies in constrained spaces—a reality of cell biology they would not otherwise experience through traditional learning models. In its essence, discovery is a matter of rearranging evidence to create new ways of understanding (7); these exercises rearranged concepts learned in the classroom, facilitating that sense of discovery.

Howard Gardner defines "bodily-kinesthetic" intelligence as the "ability to solve problems using one's body" (8). Physical involvement in the learning process allowed our students to make precisely this sort of intellectual connection. According to practitioners of science-based choreography, kinesthetic learning empowers students to become active in knowledge production (6). Ready, Cell, Go! supported a wide range of students to bring their unique strengths and individual contributions into a collaborative learning context. In *Pedagogy of the Oppressed*, Paulo Freire champions personal discovery as a force of education and asks that students become free from teachers "depositing" knowledge into passive recipients (9). This echoes John Dewey's argument that knowledge cannot be "delivered," but must be created by students through exploring, reasoning, and living (10). Ready, Cell, Go! sets the stage for active student participation through physical engagement, that gives them tools to derive some of the foundational concepts of cellular physiology that are not readily accessed through traditional pedagogy. Students were also excited about learning cell biology in a way that made room for self-discovery in the process.

Ready, Cell, Go! asks both students and educators to take risks. Because risk-taking does not always come naturally in

TABLE 2.
Quotes from written student reflections.

Exercise	Student Reflection
Shape, function, and stability	“It was astonishing how we were unconsciously maximizing the stability of the structure by occupying spots of highest personal tranquility, just like the thermodynamically favorable folding of polypeptides into their lowest energy configurations.”
Crowding, chaos, and fluidity	“The movement exercise allowed me to better visualize the chaotic reality of a cell’s internal environment arising from a complex array of vibrant interactions between high-energy molecules and organelles, which is often neglected by YouTube videos that unrealistically display the cell as an oasis of serenity.”
Cascade, sequence, and consequence	“I reflected on how interdependent proteins are ... if one thing isn’t functioning correctly, the whole cascade wouldn’t be able to achieve its function ... Although we learn about one process at one time, when we were running around and the group in the middle did their cascade, it made me realize how multifaceted the cell is.”

academic settings, we offer takeaways to implement in future classrooms (Table 3). By encouraging collective risk-taking, these exercises have the potential to catalyze community in a classroom. Moving our students into a dance studio encouraged them to interact in different ways—sitting on the floor, moving, creating together. The success of team-based, active-learning pedagogies depends on this type of broad engagement and community building through new modes of learning.

SUPPLEMENTAL MATERIALS

- Appendix 1: Script for “Shape, function, and stability”
- Appendix 2: Script for “Crowding, chaos, and fluidity”
- Appendix 3: Script for “Cascade, sequence, and consequence”

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REFERENCES

1. Stith BJ. 2004. Use of animation in teaching cell biology. *Cell Biol Educ* 3(3):181–188. <http://doi.org/10.1187/cbe.03-10-0018>.
2. Saunders C, Taylor A. 2014. Close the textbook & open “The cell: an image library.” *Am Biol Teach* 76(3):201–207. <https://doi.org/10.1525/abt.2014.76.3.9>
3. Jao L, Radakovic N. 2017. Transdisciplinarity in mathematics education: blurring disciplinary boundaries. Springer International Publishing.
4. Irving LT. 2015. Teaching statistics using dance and movement. *Frontiers Psychol* 6:50. <http://doi.org/10.3389/fpsyg.2015.00050>.
5. Schaffer K, Director CA. 2012, July. Math and dance—windmills and tilings and things, p 619–622. In 2011 Bridges

TABLE 3.

Recommendations for future Ready, Cell, Go! instructors.

Involving performance artists and educators in the process allowed us to effectively communicate movement exercises to non-dancers. Even so, this vocabulary can be difficult to establish for first-time collaborators, so we recommend trying out the exercises with a handful of volunteers beforehand.

Don’t worry about nailing the choreography—students are more likely to actively participate when they are encouraged to make mistakes.

Provide time for students to iterate and come up with deviations of each exercise on their own. This experimentation allows for spontaneous connections to form.

Some students will likely resist embracing these activities due to preconceived notions about dance or other insecurities connected to performance. While understanding that full participation is not always possible, encourage students to think of these exercises as an extension of the laboratory which, like lab work, is dependent on every person’s contribution.

Finland Conference. <https://archive.bridgesmathart.org/2012/bridges2012-619.pdf>

6. Grabel L, Weir M, Appel LF, Johnson E, McCarthy R, Lerman L. 2013. Science choreography: a movement-based approach to biology teaching. *CBE Life Sci Educ* 12(4):582–583.
7. Bruner JS. 1961. The act of discovery. *Harvard Educ Rev* 31:21–32. <http://psycnet.apa.org/psycinfo/1962-00777-001>
8. Gardner H. 1983. *Frames of mind: the theory of multiple intelligences*. Basic Books, New York, NY.
9. Freire P. 1996. *Pedagogy of the oppressed* (revised). Continuum, New York, NY.
10. Savery JR, Duffy TM. 1996. Problem based learning: An instructional model and its constructivist framework, p 135–148. In Wilson BG (ed), *Constructivist learning environments: case studies in instructional design*. Educational Technology Publications, Englewood Cliffs, NJ.