
Biological Motors Activity

Instructor Guide

Notes to Instructor

This activity provides the participants with the opportunity to further explore biomolecules by studying the action of biological motors and their ATP energy source. This activity can be completed prior to or after the primary knowledge unit for Biomolecular Applications for bioMEMS. The instructor may choose the order in which to use each of these units. One or more of the activities could be used as inquiry activities prior to the primary knowledge unit or to reinforce material during the primary knowledge unit.

This activity is part of *Mapping Biological Concepts* which contain the following learning modules:

- DNA Overview
- DNA to Protein Overview
- Cells – The Building Blocks of Life
- Biomolecular Applications in bioMEMS

This unit is one of three activities for the *Biomolecular Applications for bioMEMS Learning Module*:

- Biomolecular Applications for bioMEMS Primary Knowledge
- Biomolecular Functions - Activity
- The Scale of Biomolecules – Activities
- **Biological Motors – Activity**
- Biomolecular Applications for bioMEMS Assessment

This activity is presented as a hand-out (Participant Guide - PG).

This companion Instructor Guide (IG) contains all of the information in the PG as well as answers to the Post-Activity questions.

Description and Estimated Time to Complete

This activity provides you with the opportunity to further explore biomolecules by studying the action of biological motors and their ATP energy source. You may choose to complete this activity prior to or after reviewing the primary knowledge unit for *Biomolecular Applications for bioMEMS*.

Estimated Time to Complete

Allow at least 45 minutes to complete this activity.

Introduction

All cellular receptors and enzymes are molecular machines because they all have moving parts. There are molecular motors that have linear motion along cytoskeletal elements (microtubules or actin microfilaments) within the cell. There are also rotary motors that spin on an axis within a cell.

Just as macro-motors need fuel to operate, molecular motors also need fuel. Their fuel comes in the form of a high energy molecule called adenosine triphosphate (ATP). This molecule gives up its chemical energy when it is hydrolyzed into adenosine diphosphate (ADP) and phosphate molecules. The surrendered chemical energy is then transduced to the mechanical energy of the molecular motor.

In a bioMEMS device, molecular motors can act as actuators that are controlled by the availability of "fuel" or ATP.

Activity Objectives and Outcomes

Activity Objectives

- Demonstrate your understanding of molecule motors by watching three (3) on-line movies and correctly answering questions at the end of each movie.

Activity Outcomes

In this activity you will become familiar with how ATP is created and used for energy, and how molecular motors move.

Resources

Computer with high-speed Internet access.

Documentation

In this activity you will review three (3) on-line animated movies:

ATP Synthase Enzyme (<http://vcell.ndsu.nodak.edu/animations/atpgradient/movie.htm>)

Flagellum Motor Protein (http://www.arn.org/docs/mm/flag_dithani.gif)

Kinesin Motor Protein (<http://valelab.ucsf.edu/>)

For your documentation, answer the questions at the end of each procedure for each animation. Write a brief summary of the basic concepts presented in each animated movie.

Procedure 1: ATP Synthase Enzyme

1. View this video created by the Molecular and Cellular Biology Learning Center NDSU: Gradients (ATP Synthase) <https://youtu.be/3y1dO4nNaKY> (You may need to cut and paste the URL into your browser.)
2. Write a brief summary of the basic concepts introduced.
3. Answer the following questions.
 - a. What propels the rotation of the ATP synthase?
 - b. ATP is the product of this enzyme. What are the substrates for this reaction?
 - c. How many protons (hydrogen ions) must pass through the channel to synthesize each ATP molecule?
 - d. What would you have to do in order to assemble an ATP synthase molecule to power an ATP energy-requiring biomolecule on a bioMEMS device? How would you turn ATP synthase activity on? How could you turn ATP synthase activity off?

Procedure 1: ATP Synthase Enzymes - Answers

- a. What propels the rotation of the ATP synthase?
Answer: The diffusion of hydrogen ions through the ATP synthase channel across the membrane
- b. ATP is the product of this enzyme. What are the substrates for this reaction?
Answer: ADP and inorganic phosphate
- c. How many protons (hydrogen ions) must pass through the channel to synthesize each ATP molecule?
Answer: 3
- d. What would you have to do in order to assemble an ATP synthase molecule to power an ATP energy-requiring biomolecule on a bioMEMS device? How would you turn ATP synthase activity on? How could you turn ATP synthase activity off?
Answer: Surround the biomolecule (along with ADP and inorganic phosphate) with an ATP-synthase embedded membrane and lower the pH on the outside of the membrane (increasing the hydrogen ion concentration on the outside)

Procedure 2: Flagellum Motor Protein

1. Go to the following link (You may need to cut and paste into your browser):
http://www.arn.org/docs/mm/flag_dithani.gif
2. Watch the animation of the movement of a flagellum motor protein.
3. Write a brief summary of the basic concepts introduced.
4. Answer the following questions.
 - a. What type of motion does this motor protein make?
 - b. What is attached to the motor that provides the locomotion to a bacterium?
 - c. What fuels the motion of a flagellum motor protein?
 - d. What causes locomotion when a flagellum motor protein is moving?

Procedure 2: Flagellum Motor Protein - Answers

- a. What type of motion does this motor protein make?
Answer: Rotator
- b. What is attached to the motor that provides the locomotion to a bacterium?
Answer: A long spiral-shaped flagellum
- c. What fuels the motion of a flagellum motor protein?
Answer: ATP
- d. What causes locomotion when a flagellum motor protein is moving?
Answer: The whipping action of the flagellum propels the bacterium

Procedure 3: Kinesin Motor Protein

1. Watch the following animations.
 - a. Kinesin Walking (Narrated) <https://youtu.be/YAva4g3Pk6k>
 - b. Kinesin Protein Walking on MicroTubule <https://www.youtube.com/watch?v=y-uuk4Pr2i8>
2. Write a brief summary of the basic concepts introduced in these videos.
3. Answer the following questions.
 - a. What is the structure called that the kinesin molecule is "walking" along?
 - b. What is the direct effect of ATP binding and hydrolysis on the motion of the kinesin molecule?
 - c. What would stop, start, and speed up such a motor that is applied to a bioMEMS surface?
 - d. What controls the direction that the kinesin moves on a bioMEMS surface?
 - e. What would allow a kinesin motor protein to carry cargo, such as a membrane vesicle or nanoparticle?

Procedure 3: Kinesin Motor Protein - Answers

- a. What is the structure called that the kinesin molecule is "walking" along?
Answer: A microtubule
- b. What is the direct effect of ATP binding and hydrolysis on the motion of the kinesin molecule?
Answer: A "leg" of the kinesin is propelled forward to make a "step" along the microtubule
- c. What would stop, start, and speed up such a motor that is applied to a bioMEMS surface?
Answer: Since the motion is ATP dependent, it can be "throttled" by the availability of fuel (ATP)
- d. What controls the direction that the kinesin moves on a bioMEMS surface?
Answer: The deposition of the microtubules will determine where the kinesin can go.
- e. What would allow a kinesin motor protein to carry cargo, such as a membrane vesicle or nanoparticle?
Answer: Chemically coupling the cargo to the "carrying end" of the kinesin will saddle the kinesin with the cargo.

Summary

The range of movement in molecular motors is generally very small and subtle, on the order of nanometers. Some molecular motors transport "cargo". Others are responsible for providing locomotion for the cell itself, or for transporting particles within the cell. They are all controlled by the availability of ATP fuel.

Resources – SCME Learning Modules

- Biomolecular Applications for bioMEMS
- DNA Overview
- DNA to Protein Overview
- Cells: The Building Blocks of Life

Disclaimer

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Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program through Grants. For more learning modules related to microtechnology, visit the SCME website (<http://scme-nm.org>).

This Learning Module was developed in conjunction with Bio-Link, a National Science Foundation Advanced Technological Education (ATE) Center for Biotechnology @ www.bio-link.org.