Educational modules of skeletal muscle anatomy and function for middle and high school students with models and active data gathering

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INTRODUCTION

The driving principle behind our research is to build educational content to help with integration of the new national science standards (Achieve, Inc., 2013, USA) with biology, math and engineering topics. The educational products are to design various templates of biological models of skeletal muscle to present form and function by engineering design. The National Academy of Engineering (NAE) and the National Research Council (NRC) (Katehi, Pearson & Feder, 2009) claim several benefits to incorporating engineering in K-12 school curriculum. These are to provide starting blocks for teachers to use for their classrooms for students to then advance an inquiry-based investigation.

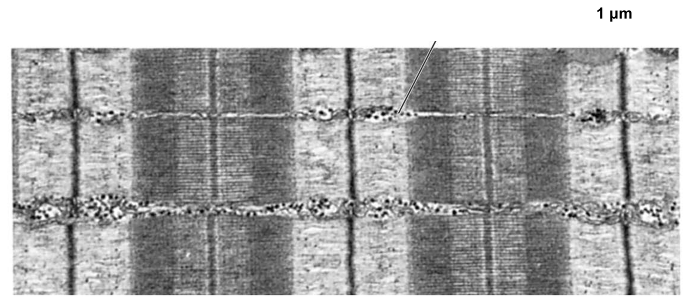
To engage students we have used a scenario to start off the various aspects of the lessons. This is designed to engage students in a potential real-life integrative problem. The conceptual problem used involves a classmate who is diagnosed with muscular dystrophy and asks his classmates for help in understanding his disease. The class is divided into groups to cover various topics and activities: (1) to model the disease with physical explanations of the cellular anatomy; (2) literature search the disease process and treatments; (3) develop a means of effectively presenting the topics to the classmates and a public awareness poster or display. The biology and medical terms will increase vocabulary and emphasize research in the primary scientific literature. Assessment of the learning could be a team-based project which is designed to be presented at an educational heath fair.

These educational modules were used in KY teacher workshops and presented at NSTA regional and national meetings to improve learning and understanding for teachers and students in issues in stereology and biological function of skeletal muscle. The participants working through these models have taken pre- and post-tests on knowledge of the topics. The preliminary assessments demonstrate the participants have learned ways to design/demonstrate the movements of skeletal muscle and the forces from various materials. The science in geometry and algebra, measures of force, building potential models to explain various disease states, and the comparative anatomy with various types of skeletal muscle in various animals are covered in these modules.

Some studies have implicated that engineering design alone helps students learn science (Diaz & Cox, 2013; Lachapelle and Cunningham, 2007; Mehalik, Doppelt & Schuun, 2008; Silk, Schunn, and Cary, 2009). We hope to develop some evaluation tools and investigate best practices for teaching and assessing science learning in the context of engineering and design of these skeletal muscle models.

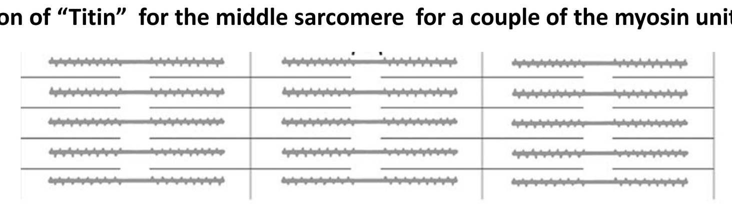
Pre Quiz (sample questions)

3. In the figure the scale bar is 1 μm. What is the sarcomere length in the figure ? (hint: estimate with marking your pencil. You can do the math with long hand.)
1 μm



A. About 5 to 6 μm.
B. About 1 to 2 μm.
C. About 2 to 3 μm
D. About 13 μm
E. About 3 to 4 μm

4. Draw in the location of "Titin" for the middle sarcomere for a couple of the myosin units.



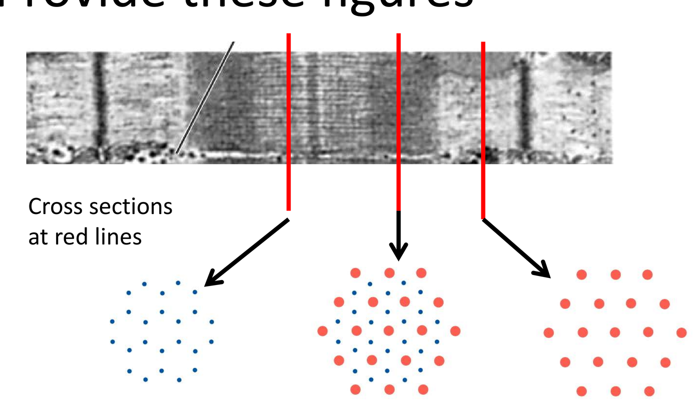
5. Where does the calcium come from that enters human skeletal muscle cells
A. ECF (extracellular fluid)
B. SR (sarcoplasmic reticulum)
C. mitochondria
D. A, B, and C
E. A and B

6. Which of the following best describes an isometric contraction?
a. tension (or force) increases, but length stays the same.
b. tension (or force) stays the same, but length increases.
c. tension (or force) stays the same, and length stays the same.
d. tension (or force) stays the same, but length decreases.
e. tension (or force) decreases, and length decreases.

Middle school level

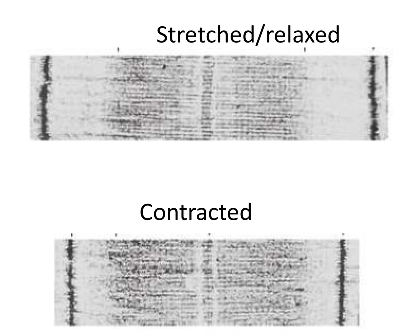
- Provide the history of the sarcomere and cross sections of different bands. (2 D figures)
- List or label the vocabulary for a sarcomere.
- How do the cross sections create a banding pattern? Have the students create their models (2 D-3 D models).
- Possible use of ppt. for modeling.
- Use tongue depressors and Velcro strips to illustrate force. Use of different numbers of patches to mimic number of myosin heads. Probes or weights used to measure force.

Provide these figures



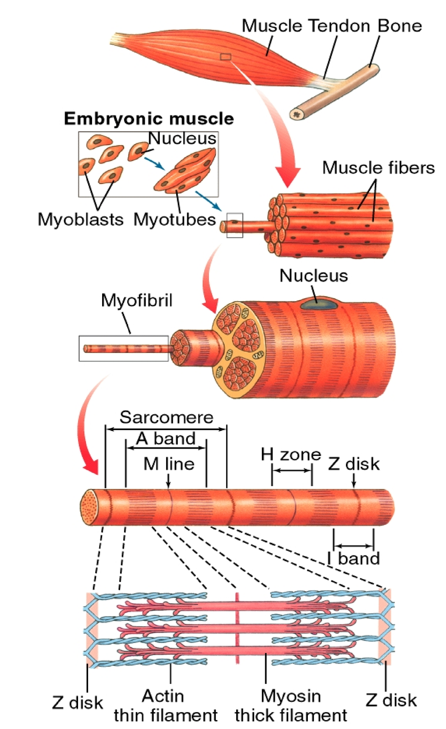
Students try to determine 3D structures from cross sections

Show stretched and contracted states of sarcomere



Students learn anatomy and names of structures

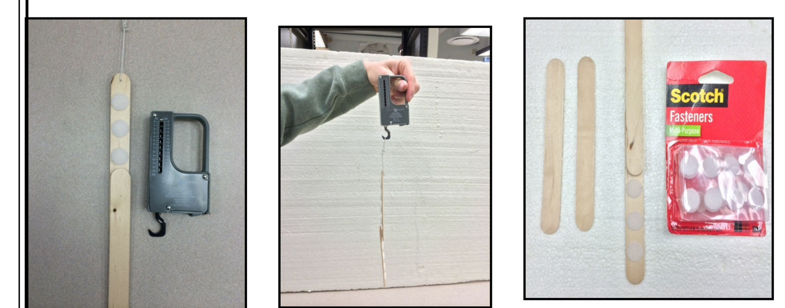
Provide list of names and students label on drawing (sample below).



Students determine force in relation to known anatomy of myosin heads attached to actin

See movies (1 myosin head or 2 myosin heads) Pay attention to the scale measure. You might have to download and then open to see the full screen for the scale.

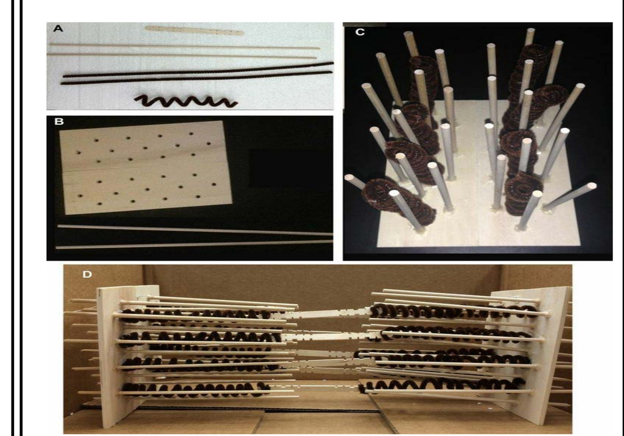
Vernier force probes or a spring scale (fishing scale) will work will for this activity.



1 myosin head 2 myosin heads < See movies

Building a diorama of some aspect of skeletal muscle.

Here is an example of "titin" attached to the myosin ends and to the Z-Disks. Also, "actin" is shown for relationship to the "myosin". Variations in the theme can readily be made such as adding myosin heads.

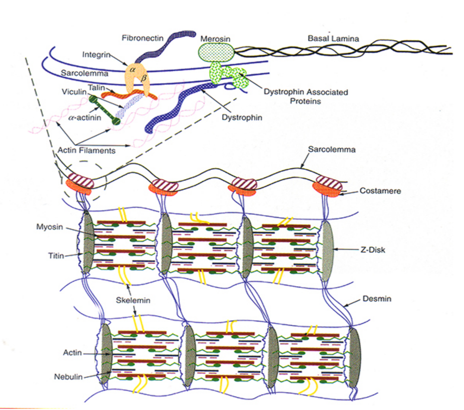


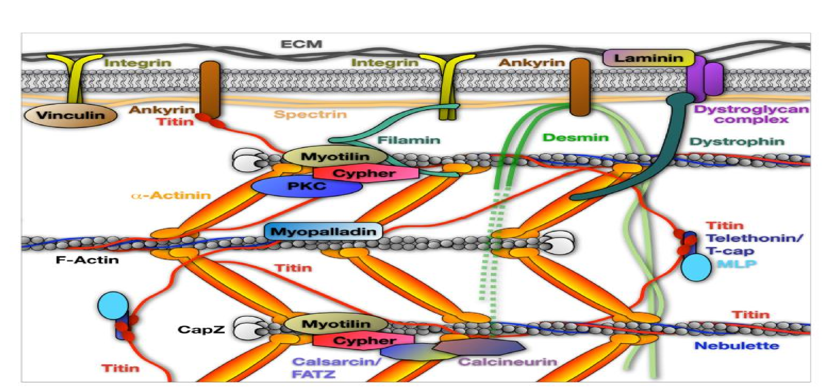
High school level

- Discussion of muscle cells and disease.
- Discussion of muscular dystrophy.
- Create muscular dystrophy models to give example as to how the disease works. (build up from Middle school models)
- Descriptive explanation of the disease and treatments prognosis
- 3D modeling with SketchUp or ppt

The class problem:
A fellow student in your class is asking for the whole class to help him understand his disease. He has been informed that he has the beginning stages of muscular dystrophy, but when he asked the doctor about it, he said that he would refer him to a help group about dealing with the disease, and the details of the disease seemed confusing to him. After talking with the parents, the teacher is allowing the class to help the student learn more about the disease. The teacher wants to know what level of knowledge the class has about the disease, so she made a short quiz for the class for you to take. She is dividing the class up in groups to work on various aspects of this project. One group is to conduct a literature search about the disease and then they are to compile information in the form of a presentation. A second group is to understand the basic anatomy and physiology of the disease and then explain it to the class. A third group is to build a physical model to explain the physical and mechanistic issues with this disease.

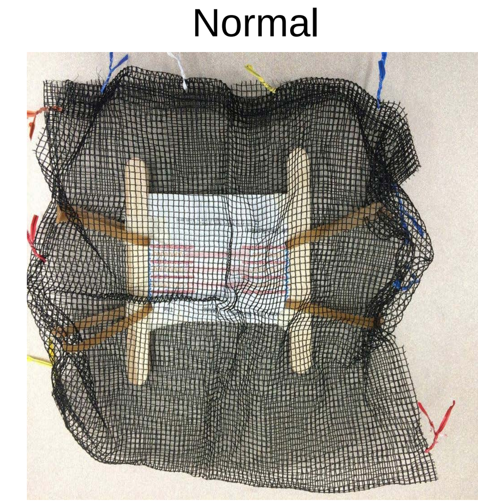
Diagram the details of the skeletal muscle and explain mechanistically the problems in this disease related to muscle function. Use scientific resources for information gathering. Sample figures below from primary articles.



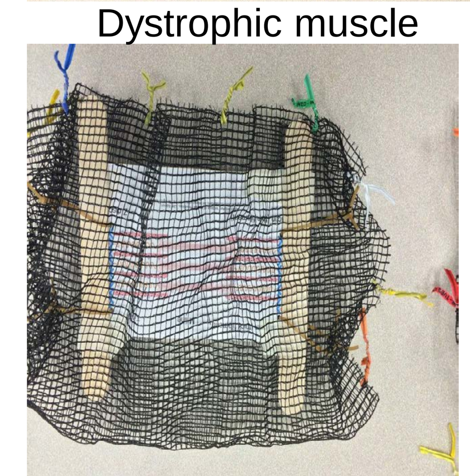


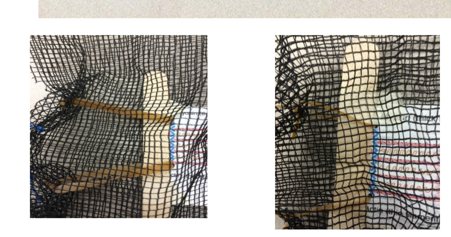
Build a physical model to help understand the problem with Duchenne's muscular dystrophy.

Normal



Dystrophic muscle

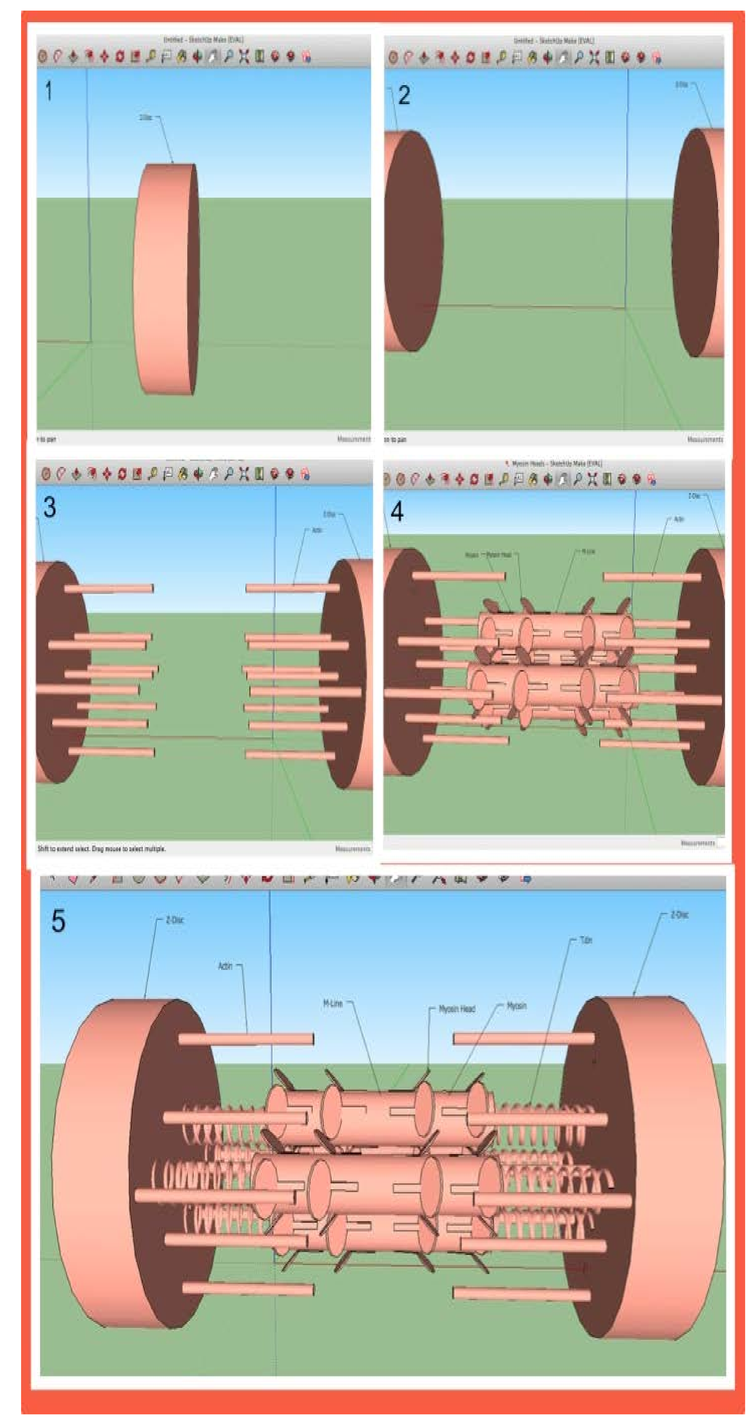




See movies

Normal Dystrophic muscle

Use the free version of SketchUp (http://www.sketchup.com/learn), and model in 3D some aspect of skeletal muscle anatomy.



Other activities:

1.Talk or communicate with physicians and/or researchers about skeletal muscle disorders.
Ask about their research (basic or applied).

Types of muscle diseases the person might have seen recently.

What do they foresee in the future for research related to skeletal muscle ?

2. Investigate the comparative differences in skeletal muscle from different animals. Compile a report on the differences with diagrams and/or tables from the literature research.

CONCLUSIONS

The topic of stereology (3D objects viewed in 2D) is a thread through these different disciplines.

These integrative engineering design-based curriculum module will cut across various disciplines which embrace the goals of the Next Generations Science Standards (NGSS) in cross-cutting concepts.

The depth of the modules allows high and middle school students to understand the concepts with substantive learning objectives and physical activities in addition to addressing scientific literacy.

FUTURE DIRECTIONS

The results of this project will be to develop assessment tools of the teachers and students that will serve as beta testers of the modules.

Continue to develop evaluation tools with pre- and post- tests with treatment and control groups .

This will help to determine if this training is useful for the goals.

We hope these modules and the evaluation tools will be utilized in the future by educators when they are disseminated.

References

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