

Chirality

Structure-Function-Properties Series

Instructor's Guide

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INTRO

SOPH 304

RESOURCES

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Introduction

When to Use this Video

- In Soph 304, in class or in recitation, after Lecture 3: Proteins.
- Prior knowledge: Molecular geometry, the structure of the 20 naturally occurring amino acids, an understanding of what a protein is and its three-dimensional structure

Learning Objectives

After watching this video students will be able to:

- Identify chiral objects and molecules.
- Understand how chirality plays a role in the function of biological compounds.

Motivation

Perhaps due to the 3D visualization skills needed, many students have a hard time understanding that a chiral molecule and its mirror image compound are not the same molecule. Students will gain an understanding of how chirality plays a crucial role in biological function and properties.

Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Think of everyday objects that are chiral.
- Identify objects that are not chiral and try to determine what property of the object makes it achiral.
- Determine whether a molecule is chiral based on rules presented in the video.
- Examine the primary and secondary structure of the anti-freeze protein, the symmetry of its binding partner, water, and how these two molecules bind.

Key Information

Duration: 13:48

Narrator: Prof. Brad Pentelute

Materials Needed:

- molecular modeling set (optional)

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Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
1:25	Students are shown examples of chiral objects from everyday life.	The property of chirality is introduced. This may be a new concept for your students.
4:07	Students are asked to think of objects that have a plane of symmetry and how this relates to objects that are not chiral.	The concept of a plane of symmetry is introduced to show why some objects are chiral while others are not.
5:35	Chiral molecules are introduced. Examples include biological compounds such as amino acids, drugs, and other organic molecules found in nature.	
8:33	Mirror-image proteins (D-proteins) are introduced.	In nature, proteins are synthesized from L-amino acids only. Scientists can now chemically synthesize proteins made entirely of D-amino acids. These proteins, which are called mirror image proteins, fold into the mirror image of their naturally occurring L-protein counter-part.
10:07	The anti-freeze protein is introduced. The anti-freeze protein stops ice growth in organisms that live in sub-freezing temperatures by binding to water.	The anti-freeze protein is one of the first proteins to be chemically synthesized from all D-amino acids.

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Video Summary

In this video, students are introduced to the concept of chiral molecules and the relationship between molecular structure and function. Students first analyze some everyday objects and determine if they are chiral or achiral. Students then extend this idea to small molecules and proteins. Mirror image proteins are discussed, specifically antifreeze proteins.

Soph 304 Materials

Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.



1. Work with a partner to predict the geometry about the central atom(s) of each of the following molecules or ions. A molecular modeling kit may be useful.

- (a) CH_3^+
- (b) CO_2
- (c) H_2O
- (d) H_2CO
- (e) CH_4
- (f) H_2O_2
- (g) NH_2CH_3



2. What features are common to all 20 amino acids? What functional groups are present in the 20 amino acids? Identify which amino acid sidechains have non-polar groups, polar neutral groups, acidic groups and basic groups.



3. Have your students look at the structure of the snow flea anti-freeze protein, a protein that will be discussed in the video. The protein can be downloaded from the Protein Data Bank (<http://www.rcsb.org/pdb/home/home.do>), pdb ID: 3BOI. Students can view the protein structure using free visualization tools, such as StarBiochem (<http://star.mit.edu/biochem/>). Have students examine the four levels of protein structure.

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Post-Video Materials



1. Bring spearmint leaves and caraway seeds to class and pass these around the class in small plastic bags. This will give the students the chance to smell two different odors coming from the enantiomers of carvone. Have your students discuss why these seemingly similar molecules smell so differently.



2. The mirror image protein of the snow flea antifreeze protein binds water in the same way as the natural protein. Discuss the possible implications of being able to synthesize mirror image proteins that bind with the same binding partner as their natural protein counterpart.

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Going Further

This video provided an introduction to the concept of chirality. You may wish to examine this area further, for example, by delving into the related topics of optical activity of molecules and diastereomers.

References

Chirality is generally covered by most organic chemistry textbooks.

- Straumanis, A. (2009). *Organic Chemistry*. Boston: Houghton Mifflin Harcourt.
- Bruice, P. (2007). *Organic Chemistry*. Upper Saddle River: Prentice Hall.

The following journal articles were resources in the development of this video:

- Collins, M. J. and Easdon, J. (2001). Demonstrating Chirality: Using a Mirror with Physical Models to Show Non-superimposability of Chiral Molecules with Their Mirror Images. *Journal of Chemical Education*, 78(11), 1484-1485.
- Kraft, P. and Mannschreck, A. (2010). The Enantioselectivity of Odor Sensation: Some Examples for Undergraduate Chemistry Courses. *Journal of Chemical Education*, 87(6), 598-603.

The following article contains information about the snow flea antifreeze protein:

- Pentelute, B. L., Gates, Z. P., Tereshko, V., Dashnau, J. L., Vanderkrooi, J. M., Kosiakoff, A. A., and Kent, Stephen B. H. (2008). X-ray Structure of Snow Flea Antifreeze Protein Determined by Racemic Crystallization of Synthetic Protein Enantiomers. *Journal of the American Chemical Society*, 130(30), 9695-9701.

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