Using BioInteractive.org Resources to Teach:

Gene Expression
(From Gene to Protein)

Prepared by:

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**Using BioInteractive.org Resources to Teach:**

**GENE EXPRESSION (From Gene to Protein)**

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From the Author

With the pace of current research, the biological sciences change incredibly fast, particularly in the fields of molecular genetics, specifically gene expression. Therefore, as a veteran biology teacher, I am constantly looking for resources that include up-to-date research, prompt students to process material, help reinforce textbook material, and stimulate discussions and explorations of current biological topics. For these reasons, I routinely use HHMI’s BioInteractive website and Holiday Lectures on Science DVDs in my classroom to highlight and strengthen my day-to-day coverage of material.

These resources are accurate, user friendly, free, and easily accessible—all key elements for successful classroom implementation. They have greatly enhanced my teaching methods, my students’ ability to understand the material, and our shared knowledge about current findings in biology. The video clips, animations, and lecture chapters enhance formal classroom lecture material, increasing student understanding and assisting student visualization of the subject matter, particularly at the molecular level, where many students struggle. Furthermore, the interactive Click and Learn activities, virtual museum, and classroom activities are used to introduce or complement curricular objectives. Finally, the virtual lab series is an excellent set of computer laboratory simulations.

This curriculum guide assists in filtering and organizing the vast resources available according to topics related to the central dogma of biology, gene expression. Please do not hesitate to contact me with any questions or suggestions.

Most sincerely,

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Introduction

The amount of resources accessible to teachers from various organizations and the Internet can be overwhelming. Furthermore, finding the time to process these resources and develop them into solid, classroom-ready activities and lessons is difficult. This guide provides teacher-ready curriculum ideas using Howard Hughes Medical Institute (HHMI) resources, including the BioInteractive website features and the Holiday Lectures on Science DVDs, to enhance classroom instruction of molecular genetics, specifically instruction related to gene expression.

This curriculum guide organizes HHMI resources into the following categories: gene expression, RNA, transcription, translation, and post-translational events. The resources include animations, video clips, interactive Click and Learn activities, virtual labs, and lectures specific to the topic. The following is a brief overview of the material covered in each section.

“Gene Expression” includes a vast array of information on the central dogma of biology: gene expression. It covers human disease; the use of fruit flies as genetic models; visualizing gene expression in the lab; the role of gene expression in circadian rhythm, AIDS, and the development of the human brain; and the Human Genome Project.

“RNA Structure and Function” reviews the diversity of structure and function of various types of RNA during the gene expression process. Also included is information about RNA serving as a catalyst for cellular processes and its role in interfering with the gene expression process. (More information on RNA interference can be found in the Gene Regulation curriculum guide.)

“Transcription” helps students visualize the process of transcription as well as understand the use of RNA expression–level analysis to complete genetic research.

“RNA Processing (Post-transcription)” helps explain how, once transcription is complete, eukaryotic cells undergo a process called RNA splicing in order to prepare the RNA to leave the nucleus.

“Translation” includes animations showing the process of translation. In addition, other resources explain the role of translation in human disease and the circadian rhythm of some organisms.

“Proteasome (Post-translation)” explores what happens to proteins once they are used by the cell. The proteasome is a large molecular machine that plays an important role in recycling and regulating cellular proteins. In this section, students learn about the structure and function of this fascinating cellular machine and its role in neurodegenerative diseases.
Gene Expression

All of these resources can be accessed via [www.BioInteractive.org](http://www.BioInteractive.org) and/or the Holiday Lectures on Science DVDs.

If you have downloaded this document from BioInteractive.org, simply click on the resource name to open the resource.

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<tr>
<td>Click &amp; Learn</td>
<td>Visualizing Gene-Expression Patterns</td>
<td>Learn about the different ways scientists are able to detect when genes are being expressed in various tissues. (19 slides)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-2 (LS4.B, LS4.C)</td>
<td>3.A.1.e; 3.B.1.a,b,c,d; 3.B.2.a,b; 3.C.1.d</td>
<td>1.5, 2.7, 3.5, 5.2, 7.2, 7.3, 8.4</td>
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<tr>
<td>Lecture</td>
<td>Lecture 2: Unwinding Clock Genetics, Ch. 4</td>
<td>How much of what we are is inherited? Genetics as a tool to search for disease mechanisms. (5:26–7:58)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS3.A)</td>
<td>3.A.1.a; 3.A.3.a,c</td>
<td>2.7, 3.1, 10.2</td>
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<tr>
<td>Lecture</td>
<td>Lecture 2: Unwinding Clock Genetics, Chs. 5–6</td>
<td>Pioneering the use of the fruit fly Drosophila as a genetic tool. (7:58–10:41) This section also includes a discussion of mutant fly examples.</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS3.B)</td>
<td>3.A.4.a,b; 3.C.1.a,b,c</td>
<td>1.1, 3.1, 7.2</td>
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<tr>
<td>Video Clip</td>
<td>Rett Syndrome</td>
<td>Dr. Zoghbi introduces the topic of Rett syndrome by showing how development usually progresses in a young girl. She then shows an excerpt from Silent Angels, introduced by Julia Roberts, which shows how Rett syndrome affects development. (2 min. 52 sec.)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A)</td>
<td>2.E.1.b; 3.B.1.a,c,d; 3.B.1.c,d; 3.C.1.a; 4.B.1a</td>
<td>2.1, 3.1, 3.5, 5.2, 7.2, A1</td>
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<tr>
<td>Video Clip</td>
<td>Rett Syndrome Mouse</td>
<td>Dr. Zoghbi shows how a mouse that has been given the gene responsible for Rett syndrome exhibits some of the same neurological symptoms as human Rett patients. (1 min. 14 sec.)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A)</td>
<td>2.E.1.a; 3.B.1,c,d; 3.C.1.a; 4.B.1a</td>
<td>1.1, 2.1, 3.1, 3.5, 7.2, A1</td>
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<td>Lecture</td>
<td>Video Clip</td>
<td>Question &amp; Answer</td>
<td>Lecture Type</td>
<td>Lecture Title</td>
<td>Lecture Description</td>
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<td>Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 19</td>
<td>Interview with Dr. Eric Lander</td>
<td>Q&amp;A: How do the nerve cells express specific genes? (31:11–32:18)</td>
<td>Lecture</td>
<td></td>
<td>How do neurons differentiate during development? (13:06–22:55) This lecture reviews human development and then discusses specific genes controlling brain development. It includes two animations to help students visualize the process.</td>
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<td>Lecture 2: Unwinding Clock Genetics, Chs. 25–29</td>
<td></td>
<td>Q&amp;A: What affects biological clocks more: location, organization, and role.</td>
<td>Lecture</td>
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Using BioInteractive.org Resources to Teach: Gene Expression 6
| Lecture | Lecture 3: PERfect TIMing, Chs. 4–6 | Summary of the fruit fly’s circadian clock. (6:11–11:31) This segment includes information on genes associated with biological clocks. | HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A), HS-LS2-8 (LS2.D), HS-LS4-6 (LS4.C) | 2.C.1.a; 2.C.2.a; 2.E.2.b; 2.E.3.b | 2.7, 6.6, 7.2 |
| Lecture | Lecture 4: The Mammalian Timekeeper, Ch. 17 | Q&A: Have you done overexpression experiments with Clock? (26:24–27:06) | HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A) | 3.A.1.d.e.f | 1.4, 3.5, 5.1, 8.1, B.1, B.2, B.4 |
| Lecture | Lecture 4: The Mammalian Timekeeper, Ch. 18 | Q&A: What experiments do you use to see the difference between mutant and wild-type genes? (27:06–28:09) | HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A) | 3.A.1.d.e.f | 1.4, 3.5, 5.1, 8.1, B.1, B.2, B.4 |
### RNA Structure and Function

Most of these resources can be accessed via [www.BioInteractive.org](http://www.BioInteractive.org) and/or the Holiday Lectures on Science DVDs.

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<td>Lecture</td>
<td>Lecture 1: Catalysis: Chemical and Biochemical, Chs. 9–12</td>
<td>RNA as an information carrier and an enzyme. (20:00–28:14) This segment reviews the roles of DNA, RNA, and proteins in the gene expression pathway.</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 1.D.1.a; 2.C.1.a; 2.E.1.a; 3.A.1.a,b,c,d; 3.B.1.a,b,c; 3.C.1.a,b,d; 3.C.2.a; 4.A.1.a,b; 4.A.2.a; 4.A.3.a,b,c</td>
<td>1.1, 2.1, 2.3, 2.4, 2.6, 3.1, 3.5, 5.2, 7.1, 7.2, 7.3</td>
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<tr>
<td>Lecture</td>
<td>Lecture 1: Catalysis: Chemical and Biochemical, Ch. 27</td>
<td>Q&amp;A: What allows RNA to form different structures? (55:09–56:47)</td>
<td>HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b</td>
<td>1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<td>Lecture</td>
<td>Lecture 3: PERfect TIMing, Ch. 16</td>
<td>Q&amp;A: How many different RNAs do we know of? (25:29–26:53)</td>
<td>HS-LS1-1 (LS1.A)</td>
<td>3.A.1,c,e</td>
<td>2.7, 3.5</td>
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<td>Video Clip</td>
<td>Enzymes That Are Not Proteins: The Discovery of Ribozymes</td>
<td>Listen to former HHMI President Dr. Thomas Cech discussing his Nobel Prize–winning discovery of RNA’s catalytic properties. (19 min.)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A)</td>
<td>1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b</td>
<td>1.5, 2.1, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Lecture</td>
<td>Lecture 1: Catalysis: Chemical and Biochemical, Ch. 22</td>
<td>Q&amp;A: What are examples of RNA as a catalyst? (45:49–47:39)</td>
<td>HS-LS1-1 (LS1.A)</td>
<td>3.A.1.c; 4.A.2.a</td>
<td>2.7, 7.3</td>
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<td>Lecture</td>
<td>Lecture 2: RNA as an Enzyme: Discovery, Origins of Life, and Medical Possibilities, Chs. 3–5</td>
<td>Review of RNA’s dual nature. (2:47–10:20) This material reviews the roles of RNA in gene expression.</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1(LS4.A)</td>
<td>1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b</td>
<td>1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 3.1, 5.2, 6.6, 7.1, 7.2, 7.3</td>
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<tr>
<td>Animation</td>
<td>RNA Diversity</td>
<td>RNA is an information molecule that can also function as an enzyme. Learn about the many different forms that RNA can take and their roles. (11 slides)</td>
<td>HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Animation</td>
<td>RNA Folding</td>
<td>Since RNA is single stranded, it can fold upon itself and form structures that are protein-like in both appearance and functionality. (33 sec.)</td>
<td>HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Animation</td>
<td>Triplet Code</td>
<td>Once the structure of DNA was discovered, the next challenge was determining how the sequence of letters coded for the 20 amino acids. In theory, one or two letters can only code for 4 or 16 amino acids, respectively. A scheme using three letters, a triplet code, is the minimum necessary to encode all the amino acids. (1 min. 8 sec.)</td>
<td>HS-L51-1 (L51.A), HS-L51-3 (L51.A), HS-L53-1 (L53.A), HS-L54-1 (L54.A)</td>
<td>1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b</td>
<td>1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 3.1, 5.2, 6.6, 7.1, 7.2, 7.3, D.5</td>
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<td>Animation</td>
<td>DNA Transcription (basic detail)</td>
<td>The first phase of the process of reading DNA information to make proteins starts with a molecule unzipping the DNA. The molecule then copies one of the strands of DNA into a strand of RNA, a close cousin of DNA. This process is called transcription. (1 min. 55 sec.)</td>
<td>HS-L51-1 (L51.A), HS-L54-1 (L54.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Animation</td>
<td>DNA Transcription (advanced detail)</td>
<td>The process of copying DNA into messenger RNA (mRNA) is called transcription. Transcription factors assemble at the promoter region of a gene, bringing an RNA polymerase enzyme to form the transcription initiation complex. Activator proteins at the enhancer region of DNA then activate the transcription initiation complex. RNA polymerase unzips a small portion of the DNA and copies one strand into an mRNA molecule. (1 min. 55 sec.)</td>
<td>HS-L51-1 (L51.A), HS-L54-1 (L54.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Lecture</td>
<td>Lecture 3: Human Genomics: A New Guide for Medicine, Ch. 20</td>
<td>Measuring variations in the levels of all RNA expressions. (32:39–33:57)</td>
<td>HS-L51-1 (L51.A)</td>
<td>3.A.1.b</td>
<td>2.6, 2.7, 7.1</td>
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<td>Lecture</td>
<td>Lecture 3: PERfect TIMing, Ch. 26</td>
<td>DBT mutant strain showing a long period. (43:17–45:06)</td>
<td></td>
<td>3.B.1.a,c,d</td>
<td>1.1, 3.1, 7.1, 7.2</td>
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RNA Processing (Post-transcription)

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<tr>
<td>Animation</td>
<td>mRNA Splicing</td>
<td>Once a gene has been transcribed into messenger RNA (mRNA), it is edited in a process called splicing. Noncoding regions called introns are removed, leaving protein-coding regions called exons. (39 sec.)</td>
<td>H5-LS1-1 (LS1.A), H5-LS1-4 (LS1.B), H5-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Lecture</td>
<td>Lecture 2: RNA as an Enzyme: Discovery, Origins of Life, and Medical Possibilities, Chs. 7–12</td>
<td>Why study the protozoan Tetrahymena and RNA splicing? (12:28–28:33) This lecture segment explains the details of RNA splicing following DNA transcription.</td>
<td>H5-LS1-1 (LS1.A), H5-LS1-4 (LS1.B), H5-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<td>Lecture</td>
<td>Lecture 3: How to Accelerate a Reaction 100,000,000,000 Times Using Only RNA, Chs. 4–8</td>
<td>Outline of the lecture and the biochemical mechanism of RNA splicing. (7:14–21:05) This segment discusses the biochemical mechanism of RNA splicing along with the catalytic nature of RNA.</td>
<td>H5-LS1-1 (LS1.A), H5-LS1-4 (LS1.B), H5-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b</td>
<td>2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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Translation

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<tr>
<td>Animation</td>
<td>Translation (basic detail)</td>
<td>The ribosome is a molecular factory that translates the genetic information in RNA into a string of amino acids that becomes a protein. Inside the ribosome, the genetic code of the RNA is read three letters at a time and compared with the corresponding code on a transfer molecule. When a match occurs between the codes, the amino acid carried by the transfer molecule is added to the growing protein chain. (2 min. 6 sec.)</td>
<td>H5-LS1-1 (LS1.A), H5-LS1-4 (LS1.B), H5-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b; 4.A.2.a</td>
<td>2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3</td>
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<tr>
<td>Animation</td>
<td>Translation (advanced detail)</td>
<td>Messenger RNA (mRNA) carries DNA’s genetic information to the ribosome, where it is translated into a sequence of amino acids. mRNA is fed into the ribosome, and it is positioned so that it can be read in groups of three letters, known as codons. Each mRNA codon is matched against the transfer RNA molecule’s anticodon. If there is a match, the amino acid carried by the transfer RNA is added to the growing protein chain. (3 min. 4 sec.)</td>
<td>H5-LS1-1 (LS1.A), H5-LS1-4 (LS1.B), H5-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b; 4.A.2.a</td>
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<td>Animation</td>
<td>Sickle Cell Anemia</td>
<td>Sickle cell anemia is a genetic disease that affects hemoglobin. A single nucleotide change in the hemoglobin gene causes an amino acid substitution in the hemoglobin protein from glutamic acid to valine. The resulting proteins stick together to form long fibers and distort the shape of the red blood cells. (1 min.)</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A)</td>
<td>1.B.1.a; 3.A.1.a;b; 3.C.1.a,b; 3.C.2.a; 4.A.1.a,b; 4.B.1.a</td>
<td>1.1, 2.3, 2.4, 2.6, 2.7, 3.2, 7.1, 7.2, 7.3, 10.1</td>
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<tr>
<td>Lecture</td>
<td>Lecture 1: Reading Genes and Genomes, Ch. 36</td>
<td>Q&amp;A: Is it possible to treat genetic diseases with proteins? (54:52–56:37)</td>
<td>HS-LS3-1 (LS3.A), HS-LS3-2 (LS3.B)</td>
<td>3.A.3.c</td>
<td>3.1, 3.4</td>
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<td>Lecture</td>
<td>Lecture 4: The Mammalian Timekeeper, Chs. 21–23</td>
<td>Nine different proteins related to circadian clock genes. (30:50–35:10) This segment discusses the clock genes and related proteins associated with these genes, and it includes an animation.</td>
<td>HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A)</td>
<td>2.E.2.b; 2.E.3.b; 3.A.1.c; 4.A.1.a</td>
<td>2.3, 4, 2.6, 2.7, 6.6, 7.1, 9.3</td>
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### Proteasome (Post-translation)

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<tr>
<td>Click &amp; Learn</td>
<td>The Proteasome and Protein Regulation Resource title on DVD: Structure of the Proteasome</td>
<td>The proteasome is a large molecular machine that plays an important role in recycling and regulating cellular proteins. It degrades proteins by chopping them up into small pieces. (4 slides)</td>
<td>HS-LS1-1 (LS1.A)</td>
<td>3.A.1.c; 3.B.1.c; 4.A.1.a</td>
<td>2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.6, 7.1, 7.2, 9.3, 10.1</td>
</tr>
<tr>
<td>Animation</td>
<td>The Proteasome</td>
<td>A 3-D animation showing how proteins in the cell are tagged for disposal and degraded by the proteasome. (1 min. 44 sec.)</td>
<td>HS-LS1-1 (LS1.A)</td>
<td>3.A.1.c; 3.B.1.c; 4.A.1.a</td>
<td>2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.6, 7.1, 7.2, 9.3, 10.1</td>
</tr>
<tr>
<td>Lecture</td>
<td>Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 30</td>
<td>Protein accumulation occurs in many neurodegenerative diseases. (44:21–46:31)</td>
<td>HS-L51-1 (LS1.A)</td>
<td>3.A.1.c; 3.B.1.c; 3.D.4.a; 4.A.1.a</td>
<td>1.6, 2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.5, 6.6, 7.1, 7.2, 9.3, 10.1</td>
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</tbody>
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